1st Asia-Pacific Atomic Layer Deposition Conference （AP-ALD 2024）

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October 17 – 20
Sheraton Shanghai Waigaoqiao Hotel,
No. 28 Jilong Road,Pudongxin District,
Shanghai, China

Program

Contents

Message

Following the successes of the previous four international conferences on ALD applications and ten China ALD conferences since 2010. The 2024 1st Asia-Pacific Atomic Layer Deposition (AP-ALD) Conference will be a four-day meeting, dedicated to the fundamentals and applications of Atomic Layer Deposition (ALD) technology in various fields. It will be held in Shanghai, China, from October 17 to 20, 2024. This conference will feature plenary sessions, oral sessions, poster sessions and industrial exhibitions.

The ALD technique has been widely used and explored in numerous fields such as microelectronics, photoelectronics, optical coating, functional nanomaterials, MEMS/NEMS, energy storage, biotechnology, catalysis technology and etc. This is attributed to some unique advantages of ALD, including precise control of nano-scale thickness, superior uniformity across a large area, excellent conformity, relatively low deposition temperature and stoichiometric composition. Especially in the field of microelectronics, ALD has been involved deeply into advanced integrated circuits to prepare high-k/metal gate, spacer, and ultrathin diffusion barriers for Cu interconnects etc. Furthermore, ALD is also receiving great attention for its potential application in photovoltaics, flexible electronics, organic electronics, flat-panel display and other emerging areas.

This conference will cover the following aspects:

- ALD Fundamentals
  ALD Precursors and Precursor Design
  ALD Surface Chemistry
  Simulation, Modeling, and Theory of ALD Growth
- ALD Process and Instruments
  Plasma and Other Energy-Enhanced ALD Methods
  Molecular Layer Deposition and Atomic Layer Infiltration
- ALD for Microelectronics
- ALD for Photovatics/Display & other Optoelectronics
- ALD for Batteries/Supercapacitors/Catalysis/Fuel cell
- ALD for Sensors/Membranes/Emerging applications
- Area-selective ALD
- Atomic Layer Etching (ALE) and related topics such as atomic layer cleaning

Conference Committees

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Huazhong University of Science and Technology

Program Co-Chair

Prof. **Soo-Hyun Kim**
Ulsan National Institute of Science and Technology

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Prof. **Lin Chen**, Fudan University
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Prof. **Junjie Zhao**, Zhejiang University
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Mr. **Jun Yang**, Shanghai Sidijia Conference Service Co., Ltd.

Host by

Asia-Pacific Atomic Layer Deposition Association

Co-organized by

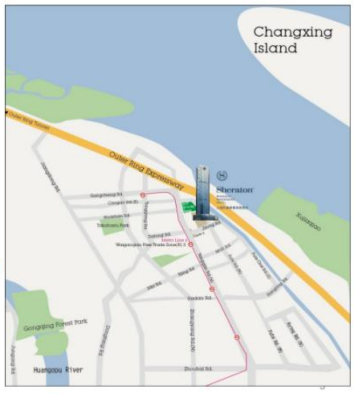
Huazhong University of Science and Technology
HUST-Wuxi Research Institute

General Information

Conference Venue

Sheraton Shanghai Waigaoqiao Hotel (No. 28 Jilong Road,Pudongxin District, Shanghai)

- **Lujiazui Financial District**
  20 km 45 minutes
- **Shanghai Railway Station**
  24 km 55 minutes
- **Shanghai Pudong International Airport**
  35 km 45 minutes
- **Shanghai Hongqiao International Airport**
  40 km 60 minutes



From Pudong Airport to the hotel: Take Metro Line 2 from Pudong Terminal 1 and Terminal 2, transfer to Line 6 at Century Avenue Station, and then get off at Waigaoqiao Free Trade Zone North Metro Station. Walk 448 meters from Exit 1 and it will take about 7 minutes to reach the hotel.

From Hongqiao Railway Station to the hotel: Take Line 10 from Hongqiao Railway Station to Keelung Road Station and get off the subway. Walk 278 meters from Exit 1 and it will take about 4 minutes to reach the hotel.

Conference Registration Hours

Thursday, Oct. 17th, 2024	14:00 – 21:00	First floor lobby
Friday, Oct. 18th, 2024	09:00 – 17:30	Third floor lobby
Saturday, Oct. 19th, 2024	09:00 – 17:30	Third floor lobby

Conference Schedule

Friday, Oct. 18th, 2024	09:00 – 18:30	Third floor conference hall
Saturday, Oct. 19th, 2024	09:00 – 17:25	Third floor conference hall
Sunday, Oct. 20th, 2024	09:00 – 11:00	Third floor conference hall

Poster Session Setup and Show Hours

The poster presenters will be provided with a blank board at **Third floor Shanghai Ballroom Anteroom** and push pins for mounting their posters. The poster with a size of 0.9m (width) × 1.2m (height) shall be presented in the order of the posters listed in the program.

Poster setup time: Friday, Oct. 18th, 13:00-17:00

Poster show time: Friday, Oct. 18th, 17:00-19:00

AP-ALD 2024 Best Poster Awards Time: Saturday, Oct. 19th, 17:30

Poster tear down: Please take your poster down immediately following the poster session-any remaining posters will be discarded.

During the poster show time, poster presenters are encouraged to have an author available near the poster for questions and discussions.

2024 AP-ALD Technical Sessions Overview

Sheraton Shanghai Waigaoqiao Hotel, Shanghai, China, Oct. 17 ~ Oct. 20, 2024

<table>
<tr><th>Date</th><th>Time</th><th>Meeting room A</th><th>Meeting room B</th><th>Meeting room C</th></tr>
<tr><td rowspan="6">Oct 18th</td><td>9:00-9:10</td><td colspan="3">Opening (Shanghai Ballroom)</td></tr>
<tr><td>9:10-10:40</td><td colspan="3">Plenary Session (Shanghai Ballroom)</td></tr>
<tr><td>11:00-12:10</td><td colspan="3">Special Keynote (Shanghai Ballroom)</td></tr>
<tr><td>14:00-15:25</td><td>Session A1
ALD Oxides I</td><td>Session B1
ALD Simulations I</td><td>Session C1
ALD Catalysis I</td></tr>
<tr><td>15:50-17:15</td><td>Session A2
ALD Oxides II</td><td>Session B2
ALD Simulations II</td><td>Session C2
ALD Catalysis II</td></tr>
<tr><td>17:15-18:30</td><td colspan="3">Poster Session I (Shanghai Ballroom Anteroom)</td></tr>
<tr><td rowspan="4">Oct 19th</td><td>9:00-10:25</td><td>Session A3
ALD Oxides III</td><td>Session B3
Area Selective ALD I</td><td>Session C3
ALD Energy I</td></tr>
<tr><td>10:50-12:15</td><td>Session A4
ALD 2D Materials</td><td>Session B4
Area Selective ALD I</td><td>Session C4
ALD Energy II</td></tr>
<tr><td>14:00-15:25</td><td>Session A5
ALD Memory I</td><td>Session B5
ALD Novel Process and Instrument I</td><td>Session C5
ALD Membrane</td></tr>
<tr><td>15:50-17:25</td><td>Session A6
ALD Memory II</td><td>Session B6
ALD Novel Process and Instrument II</td><td>Session C6
ALD Emerging Applications</td></tr>
<tr><td rowspan="2">Oct 20th</td><td>9:00-9:55</td><td>Session A7
ALD TFT I</td><td>ALD Display</td><td rowspan="2">Conference Committee Meeting</td></tr>
<tr><td>9:55-11:00</td><td>Session A8
ALD TFT II</td><td>Session B7
ALD Encapsulation</td></tr>
</table>

Friday, October 18, 09:00 –09: 10	
Opening	Shanghai Ballroom 2

Friday, October 18, 09:10 –10: 40		
Plenary Session P Shanghai Ballroom 2 **Session Chair:** Prof. Rong Chen, Huazhong University of Science and Technology, China.		
09:10-09:55	**ALD for Two Dimensional Chalcogenides Nanomaterials** Prof. Hyungjun Kim *School of Electrical and Electronic Engineering, Yonsei University, Korea*	2
09:55-10:40	**Process Technologies to Enable Future Device and Scaling** Dr. Yamato Tonegawa *Tokyo Electron Technology Solutions Ltd, Japan*	3

Friday, October 18, 10:40 –12: 10		
Special Keynote S Shanghai Ballroom 2 **Session Chair:** Prof. Soo-Hyun Kim, Ulsan National Institute of Science and Technology, Korea		
10:40-11:00	Coffee break	
11:00-11:35	**ALD for Photovoltaics** Dr. Weiming li *Jiangsu Leadmicro Nano Technology Co. Ltd. China*	4
11:35-12:10	**Atomic-Layer-Deposited Aluminum Oxide for Metal-Oxide Thin-Film transistors** Prof. Man Wong *Hongkong University of Science and Technology , Hong Kong, China*	5

Friday, October 18, 14:00 –15: 25		
Session A1 Meeting room A **Session Chair:** Prof. Hongliang Lu		
14:00-14:30	**Challenges of ALD Oxide Semiconductor Channel Materials for Emerging Semiconductor Applications (keynote)** Prof. Jin-Seong Park *Division of Material Science and Engineering, Hanyang University, Seoul, 04763 Republic of Korea*	7
14:30-14:50	**Oxide Semiconductors for Advanced DRAM Applications (invited)** Prof. Yanqing Wu *Division of Material Science and Engineering, Hanyang University, Seoul, 04763 Republic of Korea*	8

14:50-15:10	**Atomic Layer Deposition of Amorphous and Crystalline Oxide Semiconductors and Their Device Applications (invited)** Prof. Takanori Takahashi *Graduate School of Science and Technology, Nara Institute of Science and Technology, Ikoma, Nara, 630-0192*	9
15:10-15:25	**Atomic-Layer-Deposited Oxide Semiconductor Thin-Film Transistors for Monolithic 3D Integration** Jinxiong Li[1], Shanshan Ju[1], Jiye Li[2], Yuqing Zhang[3], Songjie Yang[1], Xu Tian[1], Lei Lu[2], Shengdong Zhang[2], and Xinwei Wang[1,*] *School of Advanced Materials, Peking University, Shenzhen 518055, China*	10

Friday, October 18, 14:00 –15: 25		
Session B1 Meeting room B **Session Chair:** Prof. Xinwei Wang		
14:00-14:20	**Fabrication of Various Functional Optoelectronic Devices Utilizing Atomic Layer Deposition Technique (invited)** Duan Yu *State Key Laboratory of Integrated Optoelectronics，College of Electronic Science and Engineering，Jilin University，Changchun 130012，China*	11
14:20-14:50	**The advantages and applications of UHV-ALD (keynote)** Sunan Ding *School of Integrated Circuits, Nanjing University Suzhou/Jiangsu/China, 215613*	12
14:50-15:10	**Physical and chemical properties of ALD precursors, from a structural perspective (invited)** Xiabing Lou *Shanghai Oriphant Chemicals Co., Ltd., Shanghai, China, 201500*	13
15:10-15:25	**Modeling Conformality of Silicon Nitride in High Aspect Ratio Trench Structure by Atomic Layer Deposition** Sen Deng1 , Hua Shao2*, Rui Chen 2*, Dandan Han1 ,Yayi Wei1,2* *School of Integrated Circuits, University of Chinese Academy of Sciences, Beijing, China, 100049*	14

Friday, October 18, 14:00 –15: 25		
Session C1 Meeting room C **Session Chair:** Prof. Yong Qin		
14:00-14:20	**Development of Catalytic Materials by Atomic Layer Deposition and its Application for Renewable Energy (invited)** Woo-Jae Lee *School of Nanotechnology and Semiconductor Engineering, Pukyong National University, Korea, 48513*	15

14:20-14:40	**Precise metal location control and dynamic catalysis (invited)** Bin Zhang *State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan, China, 030001*	16
14:40-14:55	**Spatially confined alloying of Pt accelerates mass transport for fuel cell oxygen reduction** Yuxin Gao, Hang Liu, Xiao Liu*, Bin Shan*, Rong Chen *School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People's Republic of China*	17
14:55-15:25	**Atom-by-atom Synthesis of Heterogeneous Catalysts using Atomic Layer Deposition (keynote)** Junling Lu *Key Laboratory of Precision and Intelligent Chemistry, School of Chemistry and Materials Science, (iChem)University of Science and Technology of China, Hefei, Anhui 230026 China*	18

Friday, October 18, 15:50 –17: 15		
Session A2 Meeting room A **Session Chair:** Prof. Jin-Seong Park		
15:50-16:20	**On the Reliabilities of ALD-based HZO Ferroelectric Memory Capacitors (Keynote)** Jiezhi Chen *School of Information Science and Engineering, Shandong University, Qingdao, China*	19
16:20-16:40	**Design of Ferroelectric $Hf_xZr_{1-x}O_2$ Thin Films by Atomic Layer Deposition (invited)** Takashi Onaya *Department of Advanced Materials Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8561, Japan*	20
16:40-17:00	**Metal-oxide Self-rectifying Memristors for In-memory Computing (invited)** Yi Li *School of Integrated Circuits, Huazhong University of Science and Technology, Wuhan, China, 430074*	21
17:00-17:15	**HfO_2-Based Ferroelectric Thin Films and Memory Device Adopting ALD Method** Jiajia Liao[1], Min Liao[1*], and Yichun Zhou[1]* *School of Advanced Materials and Nanotechnology, Xidian University, Xi'an, Shaanxi, 710126, China*	22

Friday, October 18, 15:50 –17: 15		
Session B2 Meeting room B **Session Chair:** Prof. Sunan Ding,		
15:50-16:10	**Virtual System of ALD: Visualize the Entire Life of Precursors Using Simulation (invited)** Liwei Zhuang *School of Chemical Engineering, East China University of Science and Technology, Shanghai 200237, China*	23
16:10-16:40	**Multistep Inorganic Synthesis: A Next Step of Chemical Synthesis with ALD (keynote)** Norifusa Satoh *Research Center for Macromolecules and Biomaterials,National Institute for Materials Science, Tsukuba, 305-0044*	25
16:40-17:00	**Comparative Study of H_2O and H_2O_2 Oxidants for SiO_2 Atomic Layer Deposition Using Tris(dimethylamino) silane: A Computational Investigation (invited)** Youngho Kang *Department of Materials Science and Engineering, Incheon National University, Incheon 22012, Korea*	26
17:00-17:15	**Density Functional Insights Coupled Numerical Nucleation Model for Inherently Selective Atomic Layer Deposition** Yanwei Wen[1], Yuxiao Lan[1], Haojie Li[1], Bin Shan[1] and Rong Chen[2,*] *School of Materials Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China*	27

Friday, October 18, 15:50 –17: 10		
Session C2 Meeting room C **Session Chair:** Prof. Junling Lu		
15:50-16:10	**Synthesizing atomically dispersed catalysts by Atomic Layer Deposition (invited)** Jiankang Zhang *Interdisciplinary Research Center of Biology & Catalysis, School of Life Sciences, Northwestern Polytechnical University, Xi'an 710072, P. R. China*	28
16:10-16:25	**ALD ultrathin amorphous TiO_2 film in a fluidized bed reactor for improving the weatherability of TiO_2 pigment** Jing Guo, Bingkang Niu, Huifang Lou, Zhengyi Chao，Youzhi Liu *Shanxi Province Key Laboratory of Chemical Process Intensification, North University of China, Taiyuan 030051, China*	29

16:25-16:40	**High Crystallinity Yttrium-doped ZrO_2 under 2 nm through Atomic Layer Modulation** Ngoc Le Trinh[1], Bonwook Gu[1], Wonjoong Kim[1], Byung-ha Kwak[2], Hyun-Mi Kim[3], Hyeongkeun Kim[3], Youngho Kang[1], Il-Kwon Oh[2] and Han-Bo-Ram Lee[1*] *Department of Materials Science and Engineering, Incheon National University, Incheon, Korea*	30
16:40-17:10	**Atomic layer deposition of the geometry separated Lewis and Brønsted acid sites for cascade catalysis glucose conversion (keynote)** Jun Huang *Laboratory for Catalysis Engineering, School of Chemical and Biomolecular Engineering, Sydney Nano Institute, the University of Sydney, Sydney, NSW 2006, Australia*	31

Saturday, October 19, 9:00 –10: 25		
Session A3 Meeting room A **Session Chair:** Prof. Lance Li		
09:00-09:30	**Improvement of GaN/dielectric interface properties using atomic layer deposition (Keynote)** Toshihide Nabatame *National Institute for Materials Science, Tsukuba, Ibaraki, Japan, 305-0044*	33
09:30-09:50	**Building a Spiking Sensory Neuron with Oxide-based Neuromorphic Devices (invited)** Changjin Wan *School of Electronic Science and Engineering, Nanjing University, Nanjing, Jiangsu Province, China, 210023*	34
09:50-10:10	**Evidence of Oxygen Vacancy Generation as Physical Origin of Endurance Fatigue of Si FeFET with TiN/$Hf_{0.5}Zr_{0.5}O_2$/SiO_x/Si Gate Stacks (invited)** Xiaolei Wang *Institute of Microelectronics of the Chinese Academy of Sciences (IMECAS), Beijing, 100029, China*	35
10:10-10:25	**Insight into Temperature-dependent Ferroelectric Polarization Switching Characteristics in Ga-Doped HfO_2 Thin Films** Yu-Chun Li[1], Zi-Ying Huang[1], and Hong-Liang Lu[1, *] *State Key Laboratory of ASIC and System, Shanghai Institute of Intelligent Electronics & Systems, School of Microelectronics, Fudan University, Shanghai 200433, China; Zhangjiang Fudan International Innovation Center, Shanghai 201203, China; National Integrated Circuit Innovation Center, Shanghai 201203*	36

<table>
<tr><td colspan="3">Saturday, October 19, 9:00 –10: 25</td></tr>
<tr><td colspan="2">Session B3 Meeting room B
Session Chair: Prof. Norifusa Satoh</td><td></td></tr>
<tr><td>09:00-09:20</td><td>A Paste-Like Patterning Resist for Area-Selective ALD (invited)
Yanhao Yu
Department of Materials Science and Engineering, Southern University of Science and Technology, Shenzhen, Guangdong, 518055</td><td>37</td></tr>
<tr><td>09:20-09:50</td><td>Rediscovery of Atomic Layer Deposition to Overcome the Limitations of Semiconductor Manufacturing (keynote)
Han-Bo-Ram Lee
Materials Science & Engineering, Incheon National University, Incheon, Korea, 22012</td><td>38</td></tr>
<tr><td>09:50-10:10</td><td>Study on Area-Selective Atomic Layer Deposition of Al_2O_3 with a Series of Al Precursors(invited)
Il-Kwon Oh
Department of Electrical and Computer Engineering, Ajou University, Korea</td><td>39</td></tr>
<tr><td>10:10-10:25</td><td>Atomic Layer Deposition of Molybdenum Film using Metal Organic Precursors
Bonwook Gu[1], Kieran G Lawford[2], Kwang Yong An[1], Seán T. Barry[2], Han-Bo-Ram Lee[1]*
Department of Materials Science and Engineering, Incheon National University, Incheon 22012, Republic of Korea</td><td>40</td></tr>
</table>

<table>
<tr><td colspan="3">Saturday, October 19, 9:00 –10: 25</td></tr>
<tr><td colspan="2">Session C3 Meeting room C
Session Chair: Prof. Se Hun Kwon</td><td></td></tr>
<tr><td>09:00-09:20</td><td>Advancements in Surface Engineering through Atomic Layer Deposition for Lithium Batteries (invited)
Jin Xie
School of Physical Science and Technology & Shanghai Key Laboratory of High-resolution Electron Microscopy, Shanghai Tech University, China</td><td>41</td></tr>
<tr><td>09:20-09:40</td><td>All-Perovskite Tandem Solar Cells (invited)
Dewei Zhao
College of Materials Science and Engineering, Sichuan University, Chengdu 610065, China</td><td>42</td></tr>
<tr><td>09:40-09:55</td><td>Highly Durable Pt Based Fuel Cell Catalysts via Atomic Layer Deposition
Xiao Liu[1], Hang Liu[2], Yuxin Gao[2], Bin Shan[2] and Rong Chen[1]
State Key Laboratory of Intelligent manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074</td><td>43</td></tr>
</table>

09:55-10:25	**Precise Surface Modification of Solid Fuel Particles by Atomic/Molecular Layer Deposition: Enhanced Safety, Stability, and Energy Release Performances (keynote)** Hao Feng *Xi'an Modern Chemistry Research Institute 168 E. Zhangba Road, Xi'an, Shaanxi, China, 710065*	44

Saturday, October 19, 10:50 –12:15		
Session A4 Meeting room A **Session Chair:** Prof. Toshihide Nabatame		
10:50-11:20	**Integration of Single-Crystal High-k Dielectrics with 2D Monolayer Transistors (keynote)** Lain-Jong Li *Department of Mechanical Engineering, The University of Hong Kong, Hong Kong, China*	45
11:20-11:40	**Atomic-layer-deposited elemental chalcogen thin films for nanoelectronics (invited)** Joonki Suh *Department of Materials Science and Engineering & Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology, Ulsan 44919, Republic of Korea*	46
11:40-12:00	**Direct deposition of high-k dielectrics on 2D-materials by ALD and its device applications (invited)** Li Zheng *State Key Laboratory of Materials for Integrated Circuits, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, Shanghai, 200050*	47
12:00-12:15	**Oxidizer Engineering of ALD for Efficient Production of ZrO_2 Capacitors in DRAM** Xinyi Tang, Yuanbiao Li, Songming Miao, Xiao Chen, Guangwei Xu, Di Lu, Shibing Long *University of Science and Technology of China, Hefei, 230026*	48

Saturday, October 19, 10:50 –12:15		
Session B4 Meeting room B **Session Chair:** Prof. Han-Bo-Ram Lee		
10:50-11:10	**Surface reaction kinetics for Inherent Selective Atomic Layer Deposition of Tantalum oxide on Cu/SiO_2 (invited)** Cao kun *School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074*	49

11:10-11:40	**Surface adsorption/desorption reactions and precursor design for ALD/ALE (keynote)** Sang Ick Lee *Semiconductor R&D Center, DNF Co. ltd.*	50
11:40-12:00	**Advanced Atomic Level Patterning Process (invited)** Woo Hee Kim *Department of Materials Science and Chemical Engineering, Hanyang University, Korea*	51
12:00-12:15	**High Temperature TiN Atomic Layer Deposition using Various Nitrogenating Reactants** Hyewon Park[1], Yoonseo Choi[1], and Han-Bo-Ram Lee[1*] *Department of Materials Science and Engineering, Incheon National University, Incheon 2012, Republic of Korea*	52

Saturday, October 19, 10:50 –12:10		
Session C4 Meeting room C **Session Chair:** Prof. Hao Feng		
10:50-11:10	**Emerging Applications for ALD: 2D Materials and Superconducting Nitrides for Quantum Computing** Eric W. Deguns – *Lead Product Manager, ALD* *Veeco ALD, Waltham, Massachusetts USA 15217*	53
11:10-11:25	**Revealing the mystery between Pt-Ti sites and exposed Pt sites in TiO_x-modified Pt catalyst** Huibin Ge[1], Yong Qin[2] *Interdisciplinary Research Center of Biology & Catalysis, School of Life Sciences, Northwestern Polytechnical University, Xi'an 710072, China*	54
11:25-11:40	**Catalytically Ultrathin Titania Coating to Enhance Energy Storage and Release of Aluminum Hydride via Atomic Layer Deposition** Zhijia Hu, Xiao Liu*, and Rong Chen* *State Key Laboratory of Intelligent Manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People's Republic of China*	55
11:40-12:10	**Atomic Scale Surface Modification of Nanomaterials for Electrochemical Applications (keynote)** Se Hun Kwon *School of Materials Science and Engineering, Pusan National University, Busan, 46241, Republic of Korea*	56

Saturday, October 19, 14:00–15:25		
Session A5 Meeting room A **Session Chair:** Prof. Yi Zhao		
14:00-14:30	**Plasma-Enhanced Atomic Layer Etching for Metal and Dielectric Materials (keynote)** Heeyeop Chae *School of Chemical Engineering, Sungkyunkwan University (SKKU), Suwon, 16419, Korea*	58
14:30-14:50	**Ferroelectric AlScN integrated on Silicon (invited)** Jiuren Zhou *Hangzhou Institute of Technology, Xidian University, Hangzhou, Zhejiang, 311200*	59
14:50-15:10	**Atomic layer etching of metals and metal oxides for semiconductor applications (invited)** Taewook Nam *Department of Semiconductor Systems Engineering, Sejong University, Seoul 05006, South Korea*	60
15:10-15:25	**Effect of ozone pulse time on the IGZO film Characteristics deposited by thermal atomic layer deposition** Yongqing Shen, Jinjuan Xiang*, Zhengying Jiao, Liguo Chai,Yuting Chen, Guilei Wang*, Chao Zhao *Beijing Superstring Academy of Memory Technology, Beijing, China,100176*	61

Saturday, October 19, 14:00–15:25		
Session B5 Meeting room B **Session Chair:** Prof. Sang Ick Lee		
14:00-14:20	**Atomic Layer Deposition of Platinum Group Metals and Its Application (invited)** Minsu Kim *Department of Advanced Materials Engineering, Kyonggi University, Suwon, Gyeonggi-do (Korea), 16227*	62
14:20-14:40	**Simulation of fluidization-atomic layer deposition of nanoparticle agglomerates by CFD-DEM approach (invited)** Daoyin Liu *Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, Southeast University, Nanjing 210096, Jiangsu, China*	63
14:40-14:55	**Direct Processing by µDALP™. Precision Coatings for Next Gen Devices** Masoud Akbari, Simone Santucci, Mira Baraket, Ivan Kundrata and Maksym Plakhotnyuk* *Masoud Akbari, Simone Santucci, Mira Baraket, Ivan Kundrata and*	64

	Maksym Plakhotnyuk ATLANT 3D, Taastrup, Denmark*	
14:55-15:10	**Nano to Micro: Or How to Combine ALD with PVD** Amit Sharma[1], Israel Ayala[1], Xavier Maeder[2], Carlos Guerra[1] *Swiss Cluster AG, Bahnhofstrasse 19, 3700 Spiez, Switzerland*	65
15:10-15:25	**Plasma-enhanced atomic layer deposited highly conductive niobium carbide thin films as next-generation diffusion barriers for Cu and Ru interconnects** Chaehyun Park[1], Minjeong Kweon, Sang Bok Kim, Soo-Hyun Kim* *School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Republic of Korea*	66

Saturday, October 19, 14:00–15:30		
Session C5 Meeting room C **Session Chair:** Prof. Junjie Zhao		
14:00-14:15	**Vapor phase deposition of conformal organic-inorganic hybrid films and their applications** Yixian Wang, Qingfeng Chang, Tuo Wang*, and Jinlong Gong *School of Chemical Engineering and Technology, Tianjin University, Tianjin, 300072*	67
14:15-14:30	**Low-temperature crystallization of $Hf_{0.5}Zr_{0.5}O_2$ thin films fabricated using H_2O_2 as the ALD oxidant** Haoming Che[1] , Takashi Onaya[1] , Masaki Ishii[2] , Hiroshi Taka[2] , and Koji Kita[1] *Department of Advanced Materials Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, Japan, 277-8561*	68
14:30-15:00	**Molecular Layer Deposition of Conjugated Microporous Polymers for Molecular Separations (keynote)** Yong Wang *School of Energy and Environment, Southeast University, Nanjing; College of Chemical Engineering, Nanjing Tech University, Nanjing 211816, P. R. China*	69
15:00-15:15	**A theoretical study on the adsorption of $Cp(CH_3)_5Ti(OMe)_3$ as a precursor for TiN ALD** Jae Min Jang[1], Hye Won Park[2], Soo-Hyun Kim[3], Han-Bo-Ram Lee[2], and Bonggeun Shong[1] *Chemical Engineering, Hongik University, Seoul, South Korea, 04066*	70
15:15-15:30	**Shielding CO_2-Philic Sites in Trimmed Covalent Organic Framework Pores by Atomic Layer Deposition** Zhiwen Chen,[a,b] Ming Zhang,[a,b] Yubin Hu,[a,b] Yingwu Luo,[a] Zheng Yang,[b] Junjie Zhao*[a,b] *State Key Laboratory of Chemical Engineering, College of Chemical and*	71

	Biological Engineering, Zhejiang University 866 Yuhangtang Rd, Hangzhou 310058, China	
Saturday, October 19, 15:50–17:15		
Session A6 Meeting room A **Session Chair:** Prof. Heeyeop Chae		
15:50-16:20	**Atomic Layer Deposition of $Hf_{1-x}Zr_xO_2$ Anti-ferroelectric Films for Advanced Memory Devices (Keynote)** Yi Zhao *College of Information Science and Electronic Engineering, Zhejiang University, Hangzhou, Zhejiang, 310027*	72
16:20-16:40	**ALD-based Memcapacitor for Efficient Computing (invited)** Zhigang Ji *School of Integrated Circuits，Shanghai Jiaotong University，200240*	73
16:40-17:00	**Recent Advances in ALD of Mo-Based Electrodes for High-Performance DRAM Capacitors (invited)** Jeong Hwan Han *Department of Materials Science and Engineering, Seoul National University of Science and Technology (Seoultech), Seoul 01811, Republic of Korea*	74
17:00-17:15	**Optimization and Application Study of the Device based on Hafnium oxide Ferroelectric Thin Films** Li zhenhai[1*], Li Qingxuan[1], and Chen lin[23]* *School of integrated Circuits, Anhui University, Anhui 230601*	75

Saturday, October 19, 15:50–17:15		
Session B6 Meeting room B **Session Chair:** Prof. Jiaming Sun		
15:50-16:10	**Multi-Scale Fluidized Bed Reactor for Surface Coating and Modification of Powder-Based Materials (invited)** Hao Van Bui *Faculty of Materials Science and Engineering, Phenikaa University, Hanoi 12116, Vietnam*	76
16:10-16:30	**User experience of hollow cathode plasma-assisted atomic layer deposition for various thin films (invited)** Byung Joon Choi *The Department of Materials Science and Engineering, Seoul National University of Science and Technology, Seoul 01811, Rep. of Korea*	77
16:30-16:45	**Impact of application requirements on ALD tool design** Sami Sneck *Beneq Oy, Olarinluoma 9, 02200 Espoo, Finland*	78
16:45-17:00	**High Performances of 3D Vertical Ferroelectric NAND FeFETs with HfLaO FE Layer and TiO_2-Channel** Xujin Song, Shangze Li, Dijiang Sun, Chenxi Yu, Xiaoyan Liu, and	79

	Jinfeng Kang *School of Integrated Circuits, Peking University, Beijing, 100871*	
17:00-17:15	**Theoretical prediction on the configuration of hydroxyls on the surfaces of HfO_2** Sujin Kwon and Bonggeun Shong *Chemical Engineering, Hongik University, Seoul, South Korea, 04066*	80

Saturday, October 19, 15:50–17:25		
Session C6 Meeting room C **Session Chair:** Prof. Yong Wang		
15:50-16:10	**Role of Atomic Layer Deposited ZnO in Confined Interfacial Synthesis of MOF Turing Patterns (invited)** Junjie Zhao *College of Chemical & Biological Engineering, Zhejiang University, Hangzhou, China*	81
16:10-16:25	**High-Temperature Atomic Layer Deposition of SiO_2 using Metal-Organic Si Precursor** Sojeong Eom[1], Sanghun Lee[1], Seonyeong Park[1], Seunggyu Na[1], Jisang Yoo[1], Seung-min Jung[2], Hyungjun Kim[1*] *School of Electrical and Electronic Engineering, Yonsei University, 50 Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Korea*	82
16:25-16:55	**ALD and Joule Heating-Induced Synthesis of High-Entropy Nano-Alloys for Enhanced Water Electrolysis Performance (keynote)** Kwan W. Tan *School of Materials Science and Engineering, Nanyang Technological University, Singapore 639798*	83
16:55-17:10	**Applications of atomic layer deposition in Perovskite Solar Cells** Weizhen Wang *Shenzhen Yuansu Optoelectronics Technology CO LTD, Shenzhen*	84
17:10-17:25	**Effects of Interlayer Formation by Oxidants and Substrates on Properties of ALD ZrO_2 Thin Film** Seonyeong Park *School of Electrical and Electronic Engineering, Yonsei University, Seodaemun-Gu, Seoul 03722, Korea*	85

18:00	**Banquet** (Shanghai Ballroom)

Sunday, October 20, 9:00–9:55		
Session A7 Meeting room A **Session Chair:** Prof. Lin Chen		
09:00-09:20	**ALD-driven passivation layer for IGZO-based TFTs devices (invited)** Gang He *School of Materials Science and Engineering, Anhui University, Hefei 230601, China*	87
09:20-09:40	**Optoelectronic Artificial Synaptic Devices Based on ALD/MLD Inorganic-Organic Hybrid Thin Films (invited)** Aidong Li *National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, P. R. China*	88
09:40-09:55	**PEALD TiO_2-based FeFET Memory with $Hf_{0.45}Zr_{0.55}O_x$ Ferroelectric Films** Wei Meng, Binbin Luo, Ze Shang, Ming Yang, Bao Zhu, Xiaohan Wu, Shi-Jin Ding* *School of Microelectronics, Fudan University, Shanghai, 200433*	89

Sunday, October 20, 9:00–9:55		
Session B7 Meeting room B **Session Chair:** Prof. Seong-Yong Cho		
09:00-09:20	**Electroluminescence from Rare Earth doped Gallium Oxide and Gallate Films grown by Atomic Layer Deposition (invited)** Jiaming Sun *School of Material Science and Engineering, Nankai University, City, Tianjin, 300350*	90
09:20-09:35	**Plasma Enhanced Atomic Layer Deposition of SiO_2 Thin Film for Efficient Encapsulation of Organic Light-emitting Devices** Zheng chen[1,2,] Yu Duan[1,2] *College of Physics, Changchun University of Science and Technology, Changchun, Jilin Province*	91
09:35-09:50	**Future of ultra-flexible thin film encapsulation of optoelectronic devices based on atomic layer deposition** Yuhan Wang, Yu Duan* *Affiliation: Coll Elect Sci & Engn, State Key Lab Integrated Optoelect, Jilin Univ, Changchun, Jilin province, 130012*	92

Sunday, October 20, 9:55–11:00		
Session A8 Meeting room A **Session Chair:** Prof. Gang He		
09:55-10:15	**ALD Based Flexible Memristor for Low Power In-memory computing (invited)** Tianyu Wang *School of Integrated Circuits, Shandong University, Jinan 250100, China*	93
10:15-10:30	**Atomic-Layer-Deposited InSnO Thin-Film Transistors with Scaled Channel Length** Binbin Luo1 and Shi-jin Ding* *School of Microelectronics, Fudan University, Shanghai 200433, China*	94
10:30-10:45	**Fluorine-Treated Top-gate InAlZnO TFT for 2T0C DRAM with >1 ks Retention Time at V_{hold} = 0 V** Linlong Yang1, Bao Zhu1, Xiaohan Wu1,2*, Shi-Jin Ding1,2* *School of Microelectronics, Fudan University, Shanghai 200433, China*	95
10:45-11:00	**First Demonstration of BEOL-Compatible InMgO Transistor by Atomic-Layer-Deposited** Ming Yang, Binbin Luo, Wei Meng , Bao Zhu, Xiaohan Wu, Shi-Jin Ding* *School of Microelectronics, Fudan University, Shanghai, 200433*	96

Sunday, October 20, 9:55–10:50		
Session B8 Meeting room B **Session Chair:** Prof. Yu Duan		
09:50-10:10	**Atomic Layer Deposition Approaches for Future Emissive AR/VR Applications (invited)** Seong-Yong Cho *Dept. of Photonics and Nanoelectronics, Hanyang University, Ansan 15588, Korea*	97
10:10-10:30	**Self-developed ALD Equipment and its Application in High Mobility IGZO-TFTs (invited)** Xinwei Ding *Key Laboratory of Advanced Display and System Application, Ministry of Education, Shanghai University, Shanghai, 200072*	98
10:30-10:45	**Low residual stress flexible thin film encapsulation of 2 mm bending radius based on atomic layer deposition** Guanran Wang, Yu Duan* *Affiliation: Coll Elect Sci & Engn, State Key Lab Integrated Optoelect, Jilin Univ, Changchun, Jilin province, 130012*	99

10:45-11:00	**Atomic-Scale Stress Modulation of Nanolaminate for Micro-LED Encapsulation** Di Wen, JiaCheng Hu, Ruige Ruan, Kun Cao, and Rong Chen* *State Key Laboratory of Intelligent Manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People's Republic of China*	100

Friday, October 18, 17:15-18:30 **Session Poster** Shanghai Ballroom Anteroom		
P01	**Atomic Layer Deposition of Aluminum-Molybdenum Oxide Films: Water and Waterless Processes** Abay M. Maksumova, Ilmutdin M. Abdulagatov *Department of Physical and Organic Chemistry, Dagestan State University, Makhachkala, Russian Federation, 367000*	103
P02	**Comparative Study on Lateral and Vertical Controlling of Atomic Arrangement in Multielement Oxides Grown by Atomic Layer Deposition; a Case Study of Dy-Doped HfO_2** Byung-ha Kwak,[1] Ngoc Le Trinh[2], Wonjoong Kim[2], Han-Bo-Ram Lee[2] and Il-kwon Oh[1,*] [1]*Department of Intelligence Semiconductor Engineering, Ajou University, Suwon, Korea* [2]*Department of Materials Science and Engineering, Incheon National University, Incheon, Korea*	104
P03	**Investigating the ALD Deposition Mechanism of AlO_x Barriers in Relation to ODT Coverage** Boxuan Li[1], Yanwei Wen[2], and Rong Chen [1] *School of Materials Science and Engineering,* [2]*School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.*	105
P04	**Voltage Shift Induced by Interfacial Dipole in the Dielectric Stack of Atomic-Layer Deposited Nb_2O_5 Ultrathin Insertion Layer** Caiyu Shi[1], Lei Shen[1], Ziying Huang[1], Xinbin Ying[1], Xing Yu[1] and Hongliang Lu[1*] *Affiliation: State Key Laboratory of ASIC and System, Shanghai Institute of Intelligent Electronics & Systems, School of Microelectronics, Fudan University, Shanghai, 200433, China.*	106
P05	**Growth and Corrosion Resistance of Ultrathin Al_2O_3/TiO_2 Films on Polydopamine-Modified Copper by Atomic Layer Deposition** Chi Yan[1], Jialin Li [1], Haobo Wang[1], CuiLiu[1] and Hongbo Li [1] *East China University of Science and Technology, Shanghai, China, 200237.*	107
P06	**ALD Conformality Analysis Using Lateral High Aspect Ratio Test Structures** Feng Gao[1], Anish Philip[2], Jussi Kinnunen[1], Mikko Utriainen[1] [1] *Chipmetrics Ltd., Joensuu, Finland, 80130* [2] *Aalto University, School of Science and Technology, Espoo, Finland, 02150*	108

Friday, Oct 18th , 2024

09:10-12:10

Shanghai Ballroom

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Plenary Lecture

Session Time:October 18 09:10-09:55 Location: Shanghai Ballroom

Prof. Hyungjun Kim

Hyungjun Kim is a professor at school of Electrical and Electronic Engineering at Yonsei University, Korea. Also, he is a director for Air Liquide-Yonsei Joint Research Center (ALYC), at Yonsei University. His main research interests include advanced thin film technology focusing on atomic layer deposition (ALD) and nanoscale device fabrication. Before he joined the faculty of Yonsei University in 2009, he was a faculty at the department of materials science and engineering of Pohang University of Science and Technology (Postech), Korea, from 2004 to 2009 and research staff member in the Silicon Technology Department, IBM Research Division (Yorktown Heights, NY) from 2000 to 2004. He pioneered plasma-enhance atomic layer deposition (PE-ALD) of metals and nitrides for Cu interconnect technologies and explored various thin film processes for CMOS and novel nanodevices fabrication. Prior to joining IBM Research in 2000, he was a visiting research professor at the University of Illinois, where he carried out research in the surface chemistry and growth of thin layers of silicon-germanium alloys and metal and nitride thin films.

Dr. Kim is an author of more than 250 technical publications in international journals and filed or awarded more than 50 patents. He has also given invited lectures/presentations at numerous technical conferences and is active in conference organizing. He served as an organizing chair for 2006 ALD topical conference on atomic layer deposition in Seoul, Korea. Also, he served as a director for Applied-Materials Yonsei Emerging Research Center (AYET) from 2009 to 2014. Currently, he is a member of organizing committee for several international conferences including American Vacuum Society, Materials Research Society, and topical conference on atomic layer deposition. He is also an editorial board member for Thin Solid Films and Metals and Materials International.

Dr. Kim received his Ph.D. degree in materials science and engineering from University of Illinois (Urbana-Champaign, 1998), and B.S. and M.S. degrees in the Inorganic Materials Department at Seoul National University (1990 and 1992, respectively). Dr. Kim is a member of the Institute for Electrical and Electronics Engineers and American Vacuum Society.

TOPIC

ALD for two dimensional chalcogenides nanomaterials

Hyungjun Kim
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ABSTRACT

The exclusive benefits of atomic layer deposition (ALD), including excellent conformality over nanoscale complex structures, high quality of deposited films even at low temperature down to room temperature, atomic scale thickness controllability, and high uniformity over nanoscale structure, make it viable tool for many emerging applications. Among various materials which can be prepared by ALD, two dimensional (2D) transition metal dichalcogenides (TMDCs) nanosheets have attracted great attention, since they have exotic electronic and optical properties: Indirect-to-direct bandgap transition depending on the number of layers, high carrier mobility and strong spin-orbit coupling due to their broken inversion symmetry. In contrast to conventional chemical vapor deposition (CVD), ALD makes it a promising synthesis method for 2D TMDCs. In this presentation, I will present the synthesis of various 2D TMDCs nanosheets including MoS_2, WS_2, WSe_2 and their alloys such as $Mo_{1-x}W_xS_2$ based on ALD process. Also, various applications of these materials will be presented such as gas sensors and catalysis for hydrogen evolution rate. In addition, ALD for other related materials including other 3D chalcogenides such as GeS, RuS_2 and carbon. Basic growth characteristics and applications for next generation semiconductor/display will be presented.

Plenary Lecture

Session Time:October 18 09:55-10:40 Location: Shanghai Ballroom

Dr. Yamato Tonegawa

Yamato Tonegawa currently serves as the Director of the Fundamental Technology Development Dept.1 at Tokyo Electron Technology Solutions Ltd, Japan. Throughout his illustrious career, he has dedicated himself to uncovering new insights in the field of thin film deposition process by introducing novel technologies and fundamental research. His current interest is to explore unique properties and various applications of dielectric thin films.

He joined Tokyo Electron Tohoku, Japan in 1999 as a CVD process engineer and has since been involved in several process technology development projects in Japan and worldwide. From 2007 to 2011, he worked in Tokyo Electron Taiwan to take an active role in the high-volume product manufacturing. After returning to Japan he took a leading role of the plasma ALD process team in the Development Department of Tokyo Electron Technology Solutions Ltd, Japan. He worked actively in that position for over 10 years. He has been recognized for his deep expertise, groundbreaking research, and visionary ideas. Due to his pioneering leadership the adoption of ALD over CVD has been accelerated with customers and his team become a leading authority in this area.

Tonegawa holds over 30 patents. Besides he has dynamic involvement and long standing collaboration with various universities for path finding projects.

TOPIC

Process Technologies to enable Future Device and Scaling

Yamato Tonegawa[1], Yusuke Suzuki[2]
Fundamental Technology Development Dept.1, Tokyo Electron Technology Solutions Ltd.
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ABSTRACT

Since the invention of the transistor, the semiconductor industry and technologies have evolved rapidly. This has been achieved by adopting new materials and manufacturing processes to increase the integration density of semiconductors. However, the manufacturing processes are required to be more advanced and precise as the complexity of semiconductor devices increases, which presents a significant challenge for semiconductor manufacturers. In order to meet the requirement of device manufacturers, continuous process and tool advancements are necessary and ALD is one of the essential technologies to meet such requirements.

This keynote speech will explore the outlook for semiconductor manufacturing from the perspective of a semiconductor equipment supplier, focusing on the utilization of advanced technology, with some examples of the ALD reactor and their applications for current thin film formation.

Special Keynote Lecture

Session Time:October 18 11:00-11:35 Location: Shanghai Ballroom

Dr. Wei-Min Li

Dr.Wei-Min Li received his M.Sc. and Ph.D. degrees in Inorganic Chemistry from the University of Helsinki in 1994 and 2000, respectively. He worked at ASM Microchemistry Ltd., Silecs Oy, and Picosun in Finland and held multiple roles for process/application management, project management, sales and marketing, and product development. In 2015, he co-founded Leadmicro and currently serves as Vice Chairman and CTO, in charge of technology development strategy.

TOPIC

ALD for Photovoltaics

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ABSTRACT

ALD has become an enabling technology for current photovoltaic industry that has transformed global clean-energy and sustainability. ALD is instrumental for increasing conversion efficiency and reducing the manufacturing cost of solar cells manufacturing, and catalyst the quest for grid parity. Today, hundreds of GW ALD enabled PV modules are in operation either in power plants or on roof tops worldwide. Both ALD and PEALD are now well recognized in solar cell production lines not only for PERC/PERL/PERT cell manufacturers, but also for next generation TOPCon, IBC, HJT, as well as tandem solar cell technology. Batch type reactors are widely used for the critical layers for silicon-based cell manufacturing. ALD enabled novel n-TOPCon solar cells have reached a conversion efficiency above 25.5% in production with record throughput at well over 20000 wafers per hour. At mean time, rapid progress of novel materials, for example perovskite for solar cell is providing new opportunities for ALD innovation for PV industry. In-line ALD that can handle 1.2 x 2.4 m glass sheet is entering pilot production line for critical applications. With continuous improvement of materials and process integration, ALD technology is expected to play a wider role in PV industry.

Special Keynote Lecture

Session Time:October 18 11:35-12:10 Location: Shanghai Ballroom

Prof. Man Wong

Man Wong obtained his BS and MS degrees from the Massachusetts Institute of Technology and his PhD degree from Stanford University, all in Electrical Engineering. From 1988 to 1992, he was with the Semiconductor Process and Design Center of Texas Instruments. Since 1992, he has been with the Department of Electronic and Computer Engineering at Hong Kong University of Science and Technology, Hong Kong. His research interests include micro-fabrication technology, device structure and material; physics and technology of thin-film transistor; organic light-emitting diode display technology; modeling and implementation of integrated micro-systems; solar cells, etc.

TOPIC

Atomic-layer-deposited aluminum oxide for metal-oxide thin-film transistors

Wei Jiang and Man Wong
Department of Electronic and Computer Engineering, State Key Laboratory of Advanced Displays and Optoelectronics and Technologies, The Hong Kong University of Science and Technology, Hong Kong, China

ABSTRACT

Thermal atomic-layer-deposited aluminium oxide (AlO_z) deposited in a home-grown machine using trimethylaluminum and water as precursors has been incorporated in a variety of metal-oxide thin-film transistors (TFTs). The deposition pressure is set at 340 mTorr with an argon dilution gas flow rate of 50 sccm. 0.1-nm of AlO_z is deposited per each 20-s cycle of deposition. As the high-κ gate dielectric of indium-tin-zinc oxide (ITZO) TFTs with channel length (L) down to 0.8 µm, a 50-nm-thick AlO_z deposited at 250 °C offers excellent insulating and interfacial properties (Fig. 1a). As a barrier against hydrogen (H) diffusion, a 30-nm-thick AlO_z deposited at 300 °C protects indium-gallium-zinc oxide (IGZO) TFTs from undesired drift in characteristics (Fig. 1b) caused by the incorporation of unwanted H. A 50-nm silicon nitride (SiN_y) deposited by plasma-enhanced chemical vapor deposition is used as a source of H.

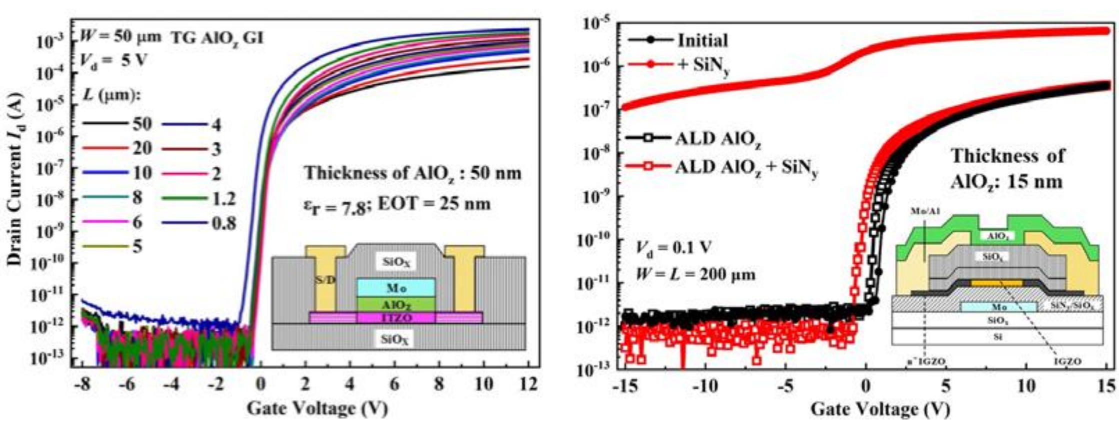

Fig. 1. The transfer characteristics of (a) top-gated ITZO TFTs with different L's (b) bottom-gated IGZO TFTs w/ or w/o AlO_z barrier layer under a layer of SiN_y as a source of H.

Friday, Oct 18th , 2024

14:00-17:15

Shanghai Ballroom

www.ap-ald.org

Keynote Lecture

Session Time:October 18 14:00-14:30 Location:Meeting room A

Prof. Jin-Seong Park

Professor Jin-Seong Park is a faculty member at Hanyang University, holding dual appointments in the Division of Material Science and Engineering and the Division of Nano-scale Semiconductor Engineering. His research primarily focuses on semiconductor materials and devices through Atomic Layer Processes (ALP). Key areas of his study include oxide semiconductor channel layers (both n-type and p-type), gate insulators (such as SiO_2, SiN_x, and high-k dielectrics), area-selective atomic layer deposition, and atomic layer etching. From 2005 to 2009, Professor Park played a pivotal role at Samsung SDI, where he led the development of active-matrix devices utilizing IGZO semiconductor technology for AMOLED applications. His work significantly contributed to the commercial production of AMOLED televisions and flexible AMOLED displays based on IGZO transistors. Prior to this, from 2003 to 2005, Professor Park was a postdoctoral researcher in Harvard University's chemistry department. His research during this period focused on developing novel precursors and advancing oxide and metal Atomic Layer Deposition (ALD) processes. Professor Park earned his Ph.D. from KAIST in 2002, with a dissertation titled "TiN, TiSiN, and TaN for Cu Diffusion Barriers using Plasma Enhanced ALD." Over the course of his career, he has published more than 280 SCI(E) papers and holds over 90 patents related to active-matrix devices and ALD materials. In addition to his research, Professor Park serves as an Associate Editor for the IEEE Transactions on Electronic Devices and is the executive director of the Thin Film Division of the American Vacuum Society.

TOPIC

Challenges of ALD Oxide Semiconductor Channel Materials for Emerging Semiconductor Applications

Yoon-Seo Kim1, Su-Hwan Kim2, and Jin-Seong Park1, 2
1Division of Material Science and Engineering, Hanyang University, Seoul, 04763 Republic of Korea
2Division of Nanoscale Semiconductor Engineering, Hanyang University, Seoul, 04763 Republic of Korea

ABSTRACT

Since the discovery of amorphous In-Ga-Zn-O-based thin-film transistors, oxide semiconductors have gained significant attention due to their high mobility, low off-current, low processing temperatures, and exceptional compositional and process flexibility. Despite these advantages, conventional deposition methods like physical vapor deposition face challenges, particularly in fabricating high-resolution displays and integrated memory devices. These methods often struggle with limited process adaptability and inadequate conformal coverage on complex surfaces.

In response to these limitations, atomic layer deposition (ALD) has emerged as a promising technique that offers precise control, conformal coverage, and high-quality thin-film deposition. As a result, research on ALD-based oxide semiconductors has grown considerably. However, a comprehensive understanding of how ALD deposition parameters influence the film properties of oxide semiconductors remains incomplete, as does our insight into the practical challenges of applying ALD in real-world devices.

This talk will introduce ALD-based oxide semiconductors (n-type and p-type), emphasizing the advantages of ALD for oxide semiconductor deposition. Key topics will introduce high mobility n-type IGZO ALD, p-type SnO material/process, and complementary field effect transistor (CFET) on 2D/3D structures based on all ALD channel layers. The presentation will offer valuable insights into how ALD is advancing the mass production of active-matrix devices, making it an essential discussion for researchers and professionals in semiconductor materials and electronic device applications

REFERENCES

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2. Y. S. Kim et al., Small Methods 2023, 2300549
3. D. G. Kim et al., Small Struct. 2023, 2300375
4. S. H. Kim et al., Nano Lett. 2024, 24, 4, 1324-1331

Invited Lecture

Session Time:October 18 14:30-14:50 Location:Meeting room A

Prof. Yanqing Wu

Professor Yanqing Wu obtained BSEE from Fudan University in 2005, and PhD in microelectronics from Purdue University in 2009. He then joined IBM T.J. Watson Research Center as a Postdoc and later as Research Staff Member. Since 2012, he joined Huazhong University of Science and Technology as a professor and moved to Peking University since 2019. His main research areas include devices based on novel channel material for logic, memory and RF applications. He has pioneered several research directions in ultrathin body semiconductors such as oxide semiconductor ITO with record high performance. He has published more than 100 papers in Nature, Nature Materials, Nature Electronics, Nature Nano, IEEE EDL, TED and IEDM.

TOPIC

Oxide semiconductors for advanced DRAM applications

Yanqing Wu
chool of Integrated Circuits and Advanced Innovation Center for Integrated Circuits, Peking University, Beijing, 100871

ABSTRACT

Severe power consumption in the continuous scaling of Si-based DRAM technology quests for a transistor technology with a much lower off-state leakage current. Wide bandgap amorphous oxide semiconductors, especially IGZO exhibit many orders of magnitude lower off-state leakage. However, they are typically heavily n-doped and require negative gate voltage to turn off. The efforts on doping density reduction typically result in mobility degradation and high Schottky barriers at contacts, causing severe degradation of on-current and operation speed of the DRAM cells. Furthermore, pitch scaling can bring in more severe challenges in terms of threshold voltage negative shift and ohmic contact, which are key figure-of-merits for advanced DRAM applications. Here, we successfully demonstrate high-speed true nonvolatile DRAM cells by deep suppression of doping density in the IGZO channel using in-situ oxygen ion beam treatment, composition adjustment during the ALD growth and post-anneal treatments. More importantly, we introduced new ohmic contact engineering approach by inserting a thin In-rich ITO at contact regions, which results in excellent ohmic contact even at scaled pitch.

REFERENCES

1, Q. Hu, Q. Li, S. Zhu, C. Gu, S. Liu, R. Huang, and Y. Wu. "Optimized IGZO FETs for capacitorless DRAM with retention of 10 ks at RT and 7 ks at 85 °C at zero Vhold with sub-10 ns speed and 3-bit operation," in IEDM Tech. Dig., Dec. 2022, pp. 26.6.1-26.6.4, doi: 10.1109/IEDM45625.2022.10019435.
2, Q. Hu, C. Gu, Q. Li, S. Zhu, S. Liu, Y. Li, L. Zhang, R. Huang and Y. Wu. True nonvolatile high-speed DRAM cells using tailored ultrathin IGZO. in Advanced Materials, vol. 35. no.20, pp. 2210554. Mar. 2023, doi: 10.1002/adma.202210554

Invited Lecture

Session Time:October 18 14:50-15:10 Location:Meeting room A

Prof. Takanori Takahashi

Takanori Takahashi was born in Japan in 1995. He received his B.E. degree in Engineering from the National Institution for Academic Degrees and Quality Enhancement of Higher Education, Japan. He obtained his master's degree in engineering from the Nara Institute of Science and Technology (NAIST), Japan, in 2020. He was a research fellow at the Japan Society for the Promotion of Science and received his Ph.D. in Engineering from NAIST in 2023. In the same year, he joined NAIST as an Assistant Professor. His research interests include oxide semiconductors, thin-film transistors, atomic layer deposition, and semiconductor devices.

TOPIC

Atomic layer deposition of amorphous and crystalline oxide semiconductors and their device applications

Takanori Takahashi and Yukiharu Uraoka
Affiliation: Graduate School of Science and Technology, Nara Institute of Science and Technology, Ikoma, Nara, 630-0192

ABSTRACT

Oxide semiconductors are standard semiconductor materials used in thin-film transistors (TFTs) in the display field. They have been attracting attention as channel materials for next-generation large-scale integrated circuits and memory devices due to their unique physical properties, such as ultra-low off-state leakage current and reasonably high electron mobility, which contribute to lower power consumption.

Many oxide semiconductor materials and related technologies have been developed and concentrated with the goal of satisfying the performance and reliability requirements for TFTs in displays. We believe that the performance and functionality of oxide semiconductors need to be optimized and reviewed to accelerate their application in integrated devices. In the case of 3D-integrated devices, the deposition method must be changed from conventional sputtering to atomic layer deposition (ALD) when applying oxide semiconductors. For instance, when depositing a quaternary complex oxide system such as In-Ga-Zn-O using ALD, three types of precursors are required, and the super-cycle method is used to stack each oxide layer. Unlike conventional sputtering methods, simpler material systems, such as ternary systems, are more compatible with the ALD process than quaternary systems. We propose a thermally stable ternary oxide semiconductor based on the In-X-O system for 3D integration. In this study, we discuss ternary amorphous and crystalline oxide semiconductors from the perspective of thermal stability and reliability. This paper also presents the atomic layer deposition of the designed oxide semiconductor and discusses device performance with respect to reliability.

Oral Lecture

Session Time:October 18 15:10-15:25 Location:Meeting room A

Jinxiong Li

Jinxiong Li received the B.E. degree from South China University of Technology in 2021. He is currently a Ph.D. student in Materials Physics at Peking University. His research interests include the device physics and integration applications of OS TFTs.

TOPIC

Atomic-Layer-Deposited Oxide Semiconductor Thin-Film Transistors for Monolithic 3D Integration

Jinxiong Li[1], Shanshan Ju[1], Jiye Li[2], Yuqing Zhang[3], Songjie Yang[1], Xu Tian[1], Lei Lu[2], Shengdong Zhang[2], and Xinwei Wang[1,*]
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[2] School of Electronic and Computer Engineering, Peking University, Shenzhen 518055, China
[3] Department of Electronic and Computer Engineering, Hong Kong University of Science and Technology, Hong Kong 999077, China

ABSTRACT

Monolithic 3D (M3D) integration with oxide semiconductor (OS) thin-film transistors (TFTs) offers a promising solution for the continuation of the Moore's Law. Herein, we report the high-performance OS TFTs enabled by ALD towards the BEOL applications. With careful engineering of the involved surface chemistry, a-IGZO TFTs with a 4 nm ALD Al_2O_3 dielectric showed a fairly low subthreshold swing (SS) of only 60.8 mV/dec and excellent bias stress stability [1]. The afforded a-IGZO TFTs exhibited good immunity to short channel effect when the gate length down-scaled to sub-100 nm, and the eDRAM bit cell based on the a-IGZO TFTs achieved a wide sensing margin and a long retention time of over 500 s [2]. Aside from the gate-dielectrics, we also demonstrated the high-performance ALD In_2O_3 TFTs [3]. With plasma fluorination, the afforded In_2O_3:F TFTs showed good electrical characteristics and stability, including a high mobility (μFE) of 35.9 cm²/V·s, a positive threshold voltage (V_{th}) of 0.36 V, and small V_{th} shifts (<111 mV) under bias stress conditions. These results highlight the high promise of the ALD OS TFTs for advanced M3D integration and BEOL applications.

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Invited Lecture

Session Time:October 20 09:00-09:20 Location:Meeting room B

Prof. Duan Yu

Duan Yu is a Tang Kang Distinguished Professor at Jilin University. He specializes in research on semiconductor optoelectronic devices and has published over 150 papers, applied for more than 50 invention patents, and served as an editor for the "Journal of Electronic Materials".

TOPIC

Fabrication of Various Functional Optoelectronic Devices Utilizing Atomic Layer Deposition Technique

Yu Duan[1]
1.State Key Laboratory of Integrated Optoelectronics，College of Electronic Science and Engineering，Jilin University，Changchun 130012，China

ABSTRACT

We conduct research on low-temperature ALD encapsulation of organic light-emitting diodes (OLEDs) and perovskite photovoltaic devices to improve their water and oxygen resistance and lifetime. Furthermore, we have developed various optoelectronic devices with different functionalities, such as electro-reflective displays. Although they still have shortcomings in terms of switching speed and cycle life, we hope to address these key issues through the use of ALD technology and ultimately achieve industrialization.

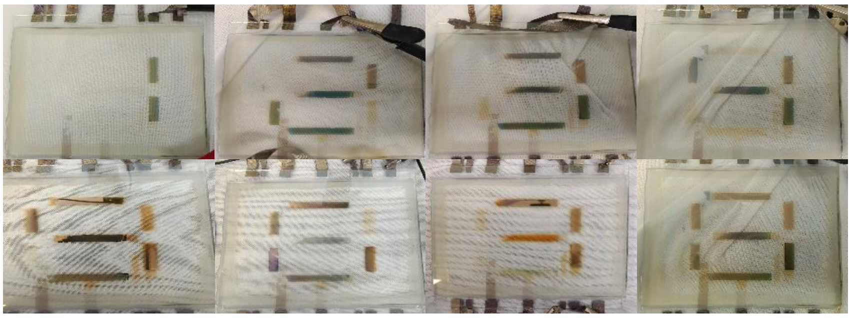

Figure 1. Electro-reflective display of 8-segment code

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Keynote Lecture

Session Time:October 18 14:20-14:50 Location:Meeting room B

Prof. Sunan Ding

Dr. Sunan Ding is a professor at Nanjing University with a Ph.D. in Physics from the Institute of Semiconductor, CAS. After post-doctoral work at the Max Planck Society and visiting scientist roles in Japan and the USA, he joined Lucent Technologies and later Intel Corporation. Since 2014, as Deputy Director at the Suzhou Institute of Nano-tech and Nano-bionics, CAS, he has overseen the creation of a leading UHV system for nano-materials and devices. His expertise lies in semiconductor physics, atomic manufacturing, chiplet technology, and vacuum technology.

TOPIC

The advantages and applications of UHV-ALD

Xiaohong Zeng, Shicheng Yang, Shicheng Han,Ying Wu, Sunan Ding*
School of Integrated Circuits, Nanjing University
Suzhou/Jiangsu/China, 215613

ABSTRACT

Atomic layer deposition (ALD) is a pivotal technique extensively utilized in both research and industrial manufacturing for the precise fabrication of thin films. Despite its widespread use, conventional ALD processes often result in a few percent contamination due to residual impurities in the reaction chamber, which is attributed to the limitations of a low background vacuum. To address this, the implementation of ultra-high vacuum ALD (UHV-ALD) has facilitated the creation of ultra-pure thin films, exhibiting remarkable characteristics such as exceptional electrical conductivity and enhanced thermal stability. The integration of the UHV-ALD system with ultra-high vacuum analytical instruments enables 'in-situ' examination of the films' growth dynamics and intrinsic attributes, thereby advancing the understanding of material synthesis at the atomic scale.

Invited Lecture

Session Time:October 18 14:50-15:10 Location:Meeting room B

Dr. Xiabing Lou

Dr. Xiabing Lou received his chemistry Ph.D. from Harvard under the supervision of Prof. Roy Gordon. He had developed a series of ALD epitaxial high-k dielectrics and applied them in a variety of compounded semiconductor devices. During his staying in Cambridge Electronics, he developed the dielectric process for GaN devices and led the taping out of the world's first 8 enhancement mode GaN/Si. Currently he is serving as the General Manager of Shanghai Oriphant Chemicals Co., Ltd.,

TOPIC

Physical and chemical properties of ALD precursors, from a structural perspective.

Xiabing Lou
Affiliation: Shanghai Oriphant Chemicals Co., Ltd., Shanghai, China, 201500

ABSTRACT

Atomic Layer Deposition (ALD) relies on the selection of appropriate precursors, where physical and chemical properties are critical for their efficacy in thin film deposition. Physical properties such as melting point and vapor pressure are important for determining the vapor transport methods. Concurrently, understanding the chemical properties, particularly decomposition behavior, is essential for determining the lifetime and defining the deposition window. By comparing precursors with varied molecular structures, this analysis elucidates the correlations between molecular architecture and their functional properties.

Oral Lecture

Session Time:October 18 15:10-15:25 Location:Meeting room B

Sen Deng

Sen Deng, born in July 1994, graduated from Huangshan University with a bachelor's degree in Electronic Information Engineering. His research direction is embedded development. He completed his master's degree at the School of Integrated Circuits, University of Chinese Academy of Sciences, majoring in Electronic and Communication Engineering. His research focus is defect analysis and yield improvement in 28nm integrated circuit manufacturing processes. From August 2018 to December 2019, he interned at SMIC's YE department. Currently, he is a doctoral student at the School of Integrated Circuits, University of Chinese Academy of Sciences. His main research direction is the simulation of Atomic Layer Deposition processes in advanced process nodes.

TOPIC

Modeling Conformality of Silicon Nitride in High Aspect Ratio Trench Structure by Atomic Layer Deposition

Sen Deng[1], Hua Shao[2*], Rui Chen [2*], Dandan Han[1],Yayi Wei[1,2*]
[1]School of Integrated Circuits, University of Chinese Academy of Sciences, Beijing, China, 100049
[2]State Key Laboratory of Fabrication Technologies for Integrated Circuits, Institute of Microelectronics, Chinese Academy of Sciences, Beijing, China, 100029

ABSTRACT

Silicon nitride thin films(SiNx) are extensively utilized in the Integrate Circuits(ICs) manufacturing process, serving as gate dielectrics, gate spacers, barrier layer and contact etch stop layer. However, as the demand for new semiconductor devices increases, particularly those that are miniaturized and high-performance, atomic layer deposition (ALD) of SiNx has become increasingly necessary. Comparing to other thin film deposition techniques, ALD SiNx thin film has better conformality in high aspect ratio structures due to its excellent atomic-level control over film thickness. In this work, we build a novel simulation model of SiNx thin film deposition to predict its conformality and profile evolution in trench structures with varying aspect ratios under different process conditions by thermal ALD. In this model, we adopt a two-dimensional diffusion-reaction equation integrated with distance regularized level set method to describe the precursor $SiCl_4$ and co-reactant NH_3 transport and surface profile evolution, respectively. The simulation results demonstrate that increasing the gas pressure, the pulse time, and the initial sticking probability of both $SiCl_4$ and NH_3, we can get Si3N4 thin films with better conformality in structures with various aspect ratios. Furthermore, a reduced deposition temperature can also result in superior Si_3N_4 film conformality. This model enables the optimization of ALD processes with reduced time and cost, thereby improving film conformality in advanced semiconductor manufacturing.

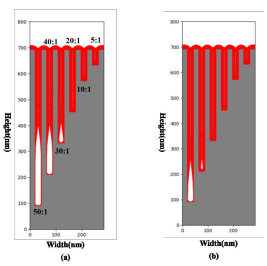

Figure 1. Simulation results of pulse time of SiCl4 on profile evolution (a) pulse time t = 0.1s, cycles = 250, (b) pulse time t=0.2s, cycles = 250

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2. Klaus, J. W.; Ott, A. W.; Dillon, A. C.; George, S. M. Atomic layer controlled growth of Si3N4 films using sequential surface reactions. Surface Science. 1998 418, L14-L19.

Invited Lecture

Session Time:October 18 14:00-14:20 Location:Meeting room C

Prof. Woo-Jae Lee

Woo-Jae Lee is an assistant professor in the School of Nanotechnology and Semiconductor Engineering at Pukyong National University (PKNU) in the Republic of Korea since 2023. He focuses on material synthesis via ALD and explores a wide range of ALD-based applications, including fuel cell, hydrogen electrolysis, electrode thin films, anti-corrosion coatings, high-k thin films, low-k materials, and more.

TOPIC

Development of Catalytic Materials by Atomic Layer Deposition and its Application for Renewable Energy

Woo-Jae Lee
School of Nanotechnology and Semiconductor Engineering, Pukyong National University, Korea, 48513

ABSTRACT

A catalyst accelerates or induces chemical reactions, making it key for producing renewable energy and useful products from carbon-based feeds (oil, gas, coal, biomass). Catalyst performance depends on factors such as size, heterointerface, and active sites. To achieve optimal activity, selectivity, and stability, precise control of reactive sites is needed. While wet-based synthesis has advanced catalyst design, it faces challenges in large-scale use and atomic-level control. Alternatively, atomic layer deposition (ALD) is an effective method for synthesizing porous catalysts. It uses alternating gas-phase reactions to manufacture nanoparticles, thin films, and overlayers at the angstrom level. A self-limiting mechanism of ALD allows for atomic-level precision and uniformity on high-surface materials.[1] Additionally, mass production reactors offer scalability and commercialization potential for ALD catalysts.

We demonstrate that an efficient ALD technique involving deposition of Pt-based nanoparticles onto carbon supports was introduced using a modified ALD system (fluidizing bed reactor) for proton exchange membrane fuel-cell devices. In addition, Ru catalysts was also synthesized for anion exchange membrane fuel cells. Interestingly, the performance of ALD catalysts was superior to the commercial catalyst with the similar metal loading due to the high uniformity and conformality. Finally, perovskite catalyst was also synthesized via rotating & dual zone ALD systems for reforming the carbon oxide.

REFERENCES

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Invited Lecture

Session Time:October 18 14:20-14:40 Location:Meeting room C

Prof. Bin Zhang

Prof. Bin Zhang is a staff at the State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences (ICC-CAS). He received his B.S. degree in Applied Chemistry from Shaanxi Normal University in 2008 and obtained his Ph.D. degree in Chemical Engineering from ICC-CAS in 2013. His long-standing interests mainly focus on the rational design of heterogeneous catalysts by ALD and the dynamic catalysis for Energy & Chemical conversion. He has published more than 60 academic papers in Angew. Chem. Int. Ed., The Innovation, ACS Catal., J. Catal., etc.

TOPIC

Precise metal location control and dynamic catalysis

Bin Zhang
State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan, China, 030001

ABSTRACT

For supported metal catalysts, the location and multilevel structure of the active components determine the catalyst performance. However, the dynamic evolution of metal location and structure is always complex for many catalysts. We have synthesized many advanced metal catalysts by developing atomic layer deposition (ALD) strategies to control the metal structure and location. The surprised catalytic mechanisms were also clearly revealed using many in-situ technologies. Firstly, a multiple-pulse bonding strategy was developed to precisely control the spatial distribution of single atoms/molecules. Novel ligand field switching catalysis and mobile catalysis were discovered. Secondly, precise control over the spatial distribution of metal sites and additives was achieved through kinetics regulation of ALD and atomic layer etching techniques. Moreover, self-made ALD-FTIR-MS and XAS-XRD systems were utilized to identify interfacial active sites, elucidating catalytic mechanisms at these interfaces. Thirdly, careful manipulation of the spatial position and distance between two components facilitated understanding of subnanometer distance effects in tandem catalysis.

REFERENCES

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Oral Lecture

Session Time:October 18 14:40-14:55 Location:Meeting room C

Yuxin Gao

Yuxin Gao is a graduate student majoring in Materials Science and Engineering at the School of Materials Science and Engineering, Huazhong University of Science and Technology. She obtained her Bachelor's degree in Material Science and Engineering from Shandong University in 2022. Her research interests are the oxygen reduction reaction and the practical applications of PEMFCs.

TOPIC

Spatially confined alloying of Pt accelerates mass transport for fuel cell oxygen reduction

Yuxin Gao, Hang Liu, Xiao Liu*, Bin Shan*, Rong Chen
Affiliation: School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People’s Republic of China.

ABSTRACT

Pt-based alloy with high mass activity and durability is highly desired for proton exchange membrane fuel cells, yet a great challenge remains due to the high mass transport resistance near catalysts with lowering Pt loading. Herein, an extensible approach is reported[1] through employing atomic layer deposition to accurately introduce a gas-phase metal precursor into platinum nanoparticles (NPs) pre-filled mesoporous channels, achieved by controlling both the deposition site and quantity. Following the spatially confined alloying treatment, the prepared PtSn alloy catalyst within mesopores demonstrates a small size and homogeneous distribution. The membrane electrode assembly with mesoporous carbon-supported PtSn alloy catalyst achieves a high initial mass activity, which is attributed to the smallest local oxygen transport resistance ever reported. And the catalyst represent superior full-cell durability among the reported Pt-based alloy catalysts. The enhanced activity and durability are attributed to the decreased adsorption energy of oxygen intermediates on Pt surface and the strong electronic interaction between Pt and Sn inhibiting Pt dissolution. Overall, the ALD process serves as a well-controlled approach for the confined alloying of Pt-based alloy NPs, facilitating the development of advanced catalysts for PEMFCs.

REFERENCES

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Keynote Lecture

Session Time:October 18 14:55-15:25 Location:Meeting room C

Prof. Junling Lu

Junling Lu received his Ph.D degree from Institute of Physics, Chinese Academy of Sciences under the supervision of Prof. Hong-Jun Gao in 2007. During his Ph.D studies (2004-2006), he visited Prof. Hans-Joachim Freund's group at Fitz-Haber-Institute, Max Planck Society as an exchange student. After graduation, he spent three years in Prof. Peter C Stair's group at Northwestern University and then about two and a half years in Dr. Jeffrey W. Elam's group at Argonne National Laboratory as a Postdoc. In March 2013, he joined USTC as a Professor. His current research interest is atom-precise design of heterogeneous catalysts through a combined wet-chemistry and ALD approach.

TOPIC

Atom-by-atom Synthesis of Heterogeneous Catalysts using Atomic Layer Deposition

Junling Lu
Key Laboratory of Precision and Intelligent Chemistry, School of Chemistry and Materials Science, (iChem) University of Science and Technology of China, Hefei, Anhui 230026 China

ABSTRACT

Catalyst precise synthesis at the atomic level is of great importance for establishing the structure-activity relationship and developing advanced catalysts with high efficiency. Atomic layer deposition (ALD) relies on sequential molecular self-limiting surface reactions on substrates. Such unique features ensure not only uniform deposition on powder surfaces with high surface areas, but also offers a unique capability of control of the deposited materials with near atomic precision. This perspective will discuss the great opportunities of atomically-precise synthesis of supported catalysts offered by ALD. As examples, the recent key developments in ALD synthesis of supported metal single atoms, dimers, trimers bimetallic nanoparticles as well as precise design of metal-oxide interfaces will be described.

REFERENCES

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2. J. L. Lu*, J. W. Elam, P. C. Stair, Atomic Layer Deposition-Sequential Self-limiting Surface Reactions for Advanced Catalyst "bottom-up" Synthesis, Surf. Sci. Rep. 2016, 71, 410-472.

Keynote Lecture

Session Time:October 18 15:50-16:20 Location:Meeting room A

Prof. Jiezhi Chen

Jiezhi Chen (Senior Member, IEEE) earned his Ph.D. from the Department of Informatics and Electronics at the University of Tokyo in 2009. In 2010, he joined the Research and Development Center at Toshiba Ltd., Japan, where he focused on the development of NAND Flash memory technologies. Currently, he is a full Professor at the School of Information Science and Engineering at Shandong University, China. His research interests include NAND flash memory, emerging non-volatile memories, field-effect transistors, and computing-in-memory architectures. He has published extensively in prestigious journals and conference proceedings and has served as a reviewer for numerous international journals. He has served on Characterization, Reliability and Yield subcommittee of IEDM in 2016-2017, and the Modeling and Simulation subcommittee of IEDM in 2022-2023. He also held the position of Memory Reliability Subcommittee Chair for the IEEE International Reliability Physics Symposium (IRPS) in 2021 and was the Semiconductor Devices Subcommittee Chair for the IEEE Electron Devices Technology and Manufacturing Conference (EDTM) in 2022.

TOPIC

On the Reliabilities of ALD-based HZO Ferroelectric Memory Capacitors

Jiezhi Chen
School of Information Science and Engineering, Shandong University, Qingdao, China

ABSTRACT

The advent of 3D architectures in Flash memory and emerging non-volatile memory technologies has significantly increased bit densities through the vertical stacking of memory layers. However, 3D stacked memories differ from traditional 2D planar memories in various aspects, such as fabrication processes, unit cell structures, and memory array designs. All these necessitate a thorough analysis of reliability factors to better understand the underlying physics, enabling more informed storage system design and optimization strategies. This presentation will explore the key mechanisms influencing the reliability of Sub-10nm ALD-based HZO ferroelectric memory capacitors. Additionally, we will discuss approaches to enhance the reliabilities of HZO ferroelectric memories, along with future scaling technologies.

Invited Lecture

Session Time:October 18 16:20-16:40 Location:Meeting room A

Prof. Takashi Onaya

Takashi Onaya received Ph.D. degree from Meiji University(Prof. Atsushi Ogura Lab.), Japan, in 2021. From 2019 to 2020, I was a visiting researcher at the University of Texas at Dallas (Prof. Jiyoung Kim Lab.), USA. From 2021 to 2022, I was a Japan Society for the Promotion of Science Research Fellow PD at National Institute of Advanced Industrial Science and Technology, Japan. Since 2022, I have been an assistant professor at the University of Tokyo (Prof. Koji Kita Lab.), Japan and a visiting researcher at National Institute for Materials Science. My research interests are atomic layer deposition techniques for ferroelectric HfO_2-based thin films and high-k dielectric thin films for future semiconductor devices.

TOPIC

Design of Ferroelectric $Hf_xZr_{1-x}O_2$ Thin Films by Atomic Layer Deposition

Takashi Onaya[1] and Koji Kita[1]
Affiliation: 1. Department of Advanced Materials Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8561, Japan

ABSTRACT

Ferroelectric $Hf_xZr_{1-x}O_2$ (HZO) is attractive materials for future nonvolatile memory devices due to their scalability and excellent CMOS compatibility[1]. The origin of ferroelectricity for HZO is thought to be the metastable orthorhombic (O) phase. To obtain superior ferroelectricity, it is important to clarify the effect of atomic layer deposition (ALD) process condition on the crystal structure of HZO thin films.HZO films typically fabricated by forming HfO_2/ZrO_2 nanolaminate films deposited by alternately depositing HfO_2 and ZrO_2 layers using an ALD method. It has been reported that the crystal structure of HfO_2/ZrO_2 nanolaminate films were affected by each $HfO_2$and ZrO_2 thickness[2] and we found that the ferroelectric O phase formation was prompted when each HfO_2 and ZrO_2 thickness of HfO_2/ZrO_2 nanolaminate films was 1-2 monolayer compared to HZO solid-solution films.

In case of an ALD oxidant for HZO films, the as-grown HZO films fabricated using H_2O as an oxidant typically formed amorphous structure. Therefore, a higher annealing temperature > 400 °C is required to be crystallized and to obtain ferroelectric O phase.On the other hand, HZO films formed nanocrystals with O phase when O_2 plasma, which consists of highly reactive oxygen radicals and ions, was used as an oxidant. Therefore, the crystallization and O phase formation was promoted even using a low temperature annealing process at 300 °C, resulted in superior ferroelectricity[3].Based on our experiment results, the importance of design of HZO thin films using ALD techniques will be discussed.

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Invited Lecture

Session Time:October 18 16:40-17:00 Location:Meeting room A

Prof. Li Yi

Li Yi is the vice dean of the School of Integrated Circuits at Huazhong University of Science and Technology (HUST) and the deputy director of the Hubei Provincial Key Laboratory of Advanced Memory. He received the Ph.D. degree in microelectronics from HUST, Wuhan, China, in 2014. He is currently a Full Professor and his major research interests include memristors and their applications in neuromorphic computing and in-memory computing.

TOPIC

Metal-oxide self-rectifying memristors for in-memory computing

Yi Li
Affiliation: School of Integrated Circuits, Huazhong University of Science and Technology, Wuhan, China, 430074

ABSTRACT

Computing-in-memory (CIM) is regarded as a promising unconventional computing paradigm in the beyond Moore era. Among various nonvolatile nanodevices, metal-oxide memristors stand out for their high resistive switching performance, high integration density, and especially, CMOS process compatibility. In this talk, I will introduce a bilayer-type Pt/HfO_2/TaO_X/Ta self-rectifying memristor (SRM). Specifically, I will discuss how excellent resistive and self-rectifying characteristics can be achieved through energy band engineering simultaneously. In addition, I will show the 3D stacking process and recent results with four-layer arrays, and how the unique device can be applied to energy-efficient in-memory computing tasks, such as the solution of matrix equations.

REFERENCES

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3, Sheng-Guang Ren, Yi Li,* et al., Self-rectifying memristors for three-dimensional in-memory computing. Advanced Materials, 36(4), 2307218, 2024.

Oral Lecture

Session Time:October 18 17:00-17:15 Location:Meeting room A

Prof. Jiajia Liao

Jiajia Liao received the Ph.D. degree in materials science and engineering from Xiangtan Univerisity, Xiangtan, China, in 2021. She is currently a lecturer at school of advanced materials and nanotechnology, Xidian University, Xi’an, China. Her research interests include HfO2-based ferroelectric thin films and ferroelectric memory devices.

TOPIC

HfO2-based ferroelectric thin films and memory device adopting ALD method

Jiajia Liao[1], Min Liao[1*], and Yichun Zhou[1*]
[1]School of Advanced Materials and Nanotechnology, Xidian University, Xi’an, Shaanxi, 710126, China

ABSTRACT

Owing to the CMOS-compatible, mature atomic layer deposition (ALD) fabrication process and excellent scalability of HfO_2 thin films, their unexpected ferroelectricity brings huge attention in the past decade owing to their potentials for emerging non-volatile memory applications. Several challenges still remain for industrialization. First, the origin of ferroelectricity in HfO_2 is still not clear because of the known metastable ferroelectric phase and complex interface effects. Moreover, the integration process and device design for wakeup and fatigue-free memories have not been comprehensively investigated. In this paper, we report our group’s recent progress focusing on the above challenges. The mechanisms of both thermodynamics and kinetics to induce and stabilize the ferroelectric phase are clarified. The ferroelectric field-effect transistors are designed by the device physics model, exhibiting excellent memory window and high stability. Furthermore, we also report the service performances of HfO_2-based ferroelectric thin films and devices under complex environment, such as radiation, high-temperature, stress and etc.

Invited Lecture

Session Time:October 18 15:50-16:10 Location:Meeting room B

Prof. Liwei Zhuang

Liwei Zhuang is currently an associate professor at the school of chemical engineering in East China University of Science and Technology(ECUST). He was a visiting scholar at Johns Hopkins University (JHU) working with Michael Tsapatsis during 2019 to 2020. Before visiting JHU, he was a post-doctoral fellow with Zhen-Liang Xu at ECUST (2016 to 2018). He obtained his Ph.D. degree of chemical engineering after a 5-year (2011 to 2016) research on the numerical simulation of hollow fiber membrane modules under the supervision of Gance Dai in ECUST. He was a research scientist who participated in the project led by Michael Tsapatsis on “Permeation Properties of Disordered Metal-Organic Framework Membranes Made by Vapor Phase Ligand Treatment” granted by US Department of Energy during 2020 to 2023. He has received the PuJiang Scholar Award for the research on the “multiscale simulation of the ALD process with the 12 inch nanostructured wafers”. His research group works on the modelling and simulation of ALD processes and reactors with application in the areas of membranes, batteries, perovskite solar cells, catalysts, and chips. He received funding from the National Natural Science Foundation of China, Shanghai PuJiang Program, and industrials related to ALD precursors, delivery systems, and reactors.

TOPIC

Virtual System of ALD: visualize the entire life of precursors using simulation

Liwei Zhuang [1,*], Dennis T. Lee[2], Peter Corkery[2], and Michael Tsapatsis[2]
[1] School of Chemical Engineering, East China University of Science and Technology, Shanghai 200237, China
[2] Department of Chemical and Biomolecular Engineering & Institute for NanoBio Technology, Johns Hopkins University, Baltimore, Maryland 21218, USA

ABSTRACT

ALD process development relies much on the precursor behavior within the ALD reactor. We have proposed a conceptual virtual system of ALD which can visualize the entire life of precursor enabled by numerical simulation. The precursor starts its life from the container, and then to the delivery pipe network, and then to the reaction chamber, and ultimately to the planer/nanostructured substrate where deposition is realized. ALD should be treated as a multicomponent system when one attempts to design an ALD reactor or develop an ALD process. From upstream to downstream, the gas-liquid or gas-solid equilibrium, vaporization kinetics, diffusivity, and reactivity(including different kinds of sub-reactions) of the precursors are all vital to the film thickness, composition, properties, and their spatial distributions. We have developed a series of models for the ALD system which can be combined or inter-communicate allowing for the total solution to ALD reactor design and process development. The aforementioned models have been applied to the design of containers of solid precursors, delivery systems, reaction chambers related to the areas of membranes, batteries, perovskite solar cells, catalysts, and chips. Although ALD has been widely adopted in different areas, there still are gaps in the understanding of the ALD surface kinetics, precursor behavior within holes/trenches with high aspect ratios, and the complexity caused by the wide range of Knudsen number in industrial ALD systems.

Key words: ALD Virtual System, precursor, numerical simulation, process development, reactor design

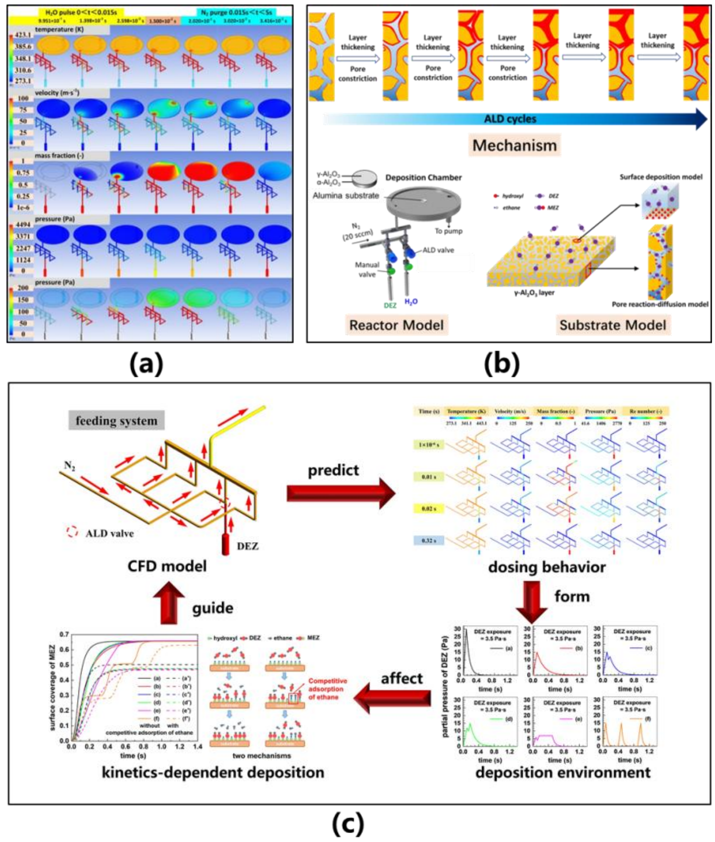

Figure 1 Virtual System of ALD

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2, G. Hao, D.T. Lee, P. Corkery, Y. Miao, Y. Yuan, Z. Xu, G. Dai, G. Parsons, I.G. Kevrekidis, L. Zhuang*, M. Tsapatsis*. Modeling of deposit formation in mesoporous substrates via atomic layer deposition: Insights from pore-scale simulation. AIChE. J.**2022**, 68(12): e17889.

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Acknowledgments

This work is sponsored by the National Natural Science Foundation of China (22078091), Shanghai Pujiang Program (2022PJD016), and the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences and Biosciences under Award DE-SC0021212.

Keynote Lecture

Session Time: October 18 16:10-16:40 Location: Meeting room B

Prof. Norifusa Satoh

Norifusa Satoh is a chemist, received his Ph.D degree from Keio University in 2006. He has also worked at Keio University, Japan, Harvard University, USA, and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.His passion for this research derives from an idea to originate a different form of chemistry.

TOPIC

Multistep inorganic synthesis: a next step of chemical synthesis with ALD

Norifusa Satoh
Research Center for Macromolecules and Biomaterials,National Institute for Materials Science, Tsukuba, 305-0044

ABSTRACT

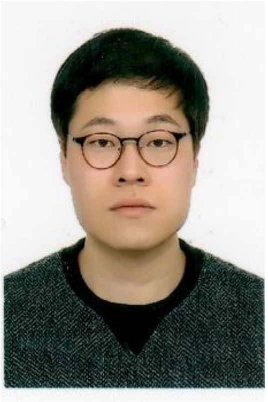
Atomic layer deposition (ALD) controls sites and the number of atoms for chemical reactions in a multistep manner through self-terminated chemisorption to contribute to building up 3-dimensional (3D) complex inorganic structures, such as 3D flash memory, gate-all-around transistor and so forth. It means 200-years of struggling in multistep organic synthesis has been already applied to inorganic synthesis. To move chemical synthesis forward and achieve atomically precise dot stuck structures no deposition techniques including Nobel-prized ones have ever archived, we set a working hypothesis of multistep inorganic synthesis as a combination of vacuum-process-based ALD and solution-process-based atomically oxide dot deposition [1-3]. This talk presents experimental data to support the working hypothesis.

REFERENCES

1. Satoh et al., Quantum size effect in TiO_2 nanoparticles prepared by finely controlled metal assembly on dendrimer templates. Nat. Nanotech. 2008, 3, 106-111.
2. Satoh et al., Metastability of anatase: Size dependent and irreversible anatase-rutile phase transition in atomic-level precise titania. Sci. Rep. 2013, 3, 1959.
3. Satoh, Multistep inorganic synthesis of thin films. Interdiscip. J. Chem., 2017, 1, 52-57.

Invited Lecture

Session Time:October 18 16:40-17:00 Location:Meeting room B



Prof. Youngho Kang

Youngho Kang received his B.S. and Ph.D. degrees in materials science and engineering from Seoul National University, Seoul, South Korea, in 2011 and 2015, respectively. From 2016 to 2017, he worked as a postdoctoral researcher at the University of California, Santa Barbara, USA. In 2017, he joined the Korea Institute of Materials Science as a senior researcher. Since February 2020, he has been a professor in the Department of Materials Science and Engineering at Incheon National University. He has authored over 67 SCI-indexed journal papers and is an expert in first-principles simulations of semiconductor properties and processes. His research covers a wide range of topics, including electronic structure, point defects, doping, and atomic layer deposition mechanisms.

TOPIC

Comparative study of H_2O and H_2O_2 oxidants for SiO_2 atomic layer deposition using tris(dimethylamino)silane: A computational investigation

Youngho Kang
Department of Materials Science and Engineering, Incheon National University, Incheon 22012, Korea

ABSTRACT

Aminosilane precursors are promising candidates for low-temperature SiO_2 atomic layer deposition (ALD) when used with mild oxidants, such as H_2O, to prevent degradation and undesirable oxidation of predeposited films. In this presentation, we will report on first-principles simulations of the oxidation pathways for the tris(dimethylamino)silane (TDMAS) precursor using H_2O and H_2O_2 as oxidants in SiO_2 ALD. Our simulations reveal that the dimethylamine ligand in the adsorbed precursor is initially converted into -OH, followed by the hydrogen ligand, regardless of the oxidant considered. However, the oxidation process appears to be more favorable when using H_2O_2 compared to H_2O, as the former results in oxidation pathways with lower activation energies. Consequently, H_2O_2 can provide a higher growth rate and a lower ALD window for thermal SiO_2 ALD using TDMAS. Nonetheless, the activation energy remains significant (~0.82 eV), even with H_2O_2. As a result, experimental SiO_2 growth temperatures reach a minimum of 450°C. The detailed oxidation reactions and implications of these results will be discussed further in the presentation.

Oral Lecture

Session Time:October 18 17:00-17:15 Location:Meeting room B

Prof. Yanwei Wen

Yanwei Wen, Associate Professor in Huazhong University of Science and Technology since 2017. He achieved the B.S. and PhD in Physics from Wuhan University in 2006 and 2011. His research interests cover the multiscale simulations of physical and chemical properties of low-dimensional materials.

TOPIC

Density Functional Insights Coupled Numerical Nucleation Model for Inherently Selective Atomic Layer Deposition

Yanwei Wen[1], Yuxiao Lan[1], Haojie Li[1], Bin Shan[1] and Rong Chen[2,*]
[1] School of Materials Science and Engineering, [2]School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.

ABSTRACT

Based on the theoretical investigation of $M(N^tBU)(NEt_2)_3$ (M=Nb and Ta) on Cu and SiO_2 substrates using Density Functional Theory (DFT) calculations, we propose an anisotropic growth model framed within micro-kinetics and numerical nucleus expansion approaches. Our model integrates the defects, ALD reaction and diffusion-induced nucleation parameters, aligning closely with experimental growth curves and accurately quantifying ALD nucleation delays in the initial stages. Such model builds a direct link between the observed nucleation delay and ALD experimental parameters from the atomic scale. Furthermore, this DFT-based nucleation model demonstrates a robust predictive capacity for nucleation delay cycles for a wide range of materials, aligning well with experimental findings. This advancement offers a theoretical method for assessing the selectivity of S-ALD from the bottom up, enhancing our understanding and control of these critical processes.

REFERENCES

1, G.N. Parsons, J. Vac. Sci. Technol. A 2019, 37, 020911.
2. Yanwei Wen, Yuxiao Lan, Haojie Li, Yicheng Li, Kun Cao, Feifeng Wu, Rong Chen, Bin Shan. J. Phys. Chem. C 2024, 128, 24, 9915–9925.

Invited Lecture

Session Time:October 18 15:50-16:10 Location:Meeting room C

Prof. Jiankang Zhang

Jiankang Zhang received his Ph.D. degree from University of Chinese Academy of Sciences in 2018. He joined the Northwestern Polytechnical University in June 2020 as associate professor. His main research areas include application of ALD, design of nanocatalysts with specific structure and function, photocatalytic hydrogen production, and selective hydrogenation. Dr. Zhang has published more than 30 papers in peer-reviewed journals such as Adv. Mater., Nature. Commun. and Angew. Chem. Int. Ed.

TOPIC

Synthesizing atomically dispersed catalysts by Atomic Layer Deposition

Jiankang Zhang*
Interdisciplinary Research Center of Biology & Catalysis, School of Life Sciences, Northwestern Polytechnical University, Xi’an 710072, P. R. China

ABSTRACT

Integrating different reaction sites such as single atom (SA) and cluster in a specific catalyst afford a new prospect to break through the limit of SA catalysis. As an alternative and powerful technique for synthesizing catalysts at the atomic level, atomic layer deposition (ALD) has received considerable attention in recent decades because it allows regulating the catalyst structure by precisely tuning the particle size from NPs and NCs/atomic clusters to SAs, which can be achieved by adjusting deposition parameters such as pulse time and number of cycles. Numerous advanced catalysts with excellent catalytic performance, including photocatalysts, have been synthesized via ALD. ALD is a promising tool to synthesize atomically dispersed catalysts with high efficiency, which is also beneficial for gaining in-depth insights into the catalytic mechanisms.

REFERENCES

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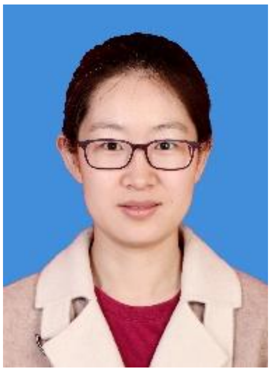
2, J. Zhang, Z. Yu, Z. Gao, H. Ge, S. Zhao, C. Chen, S. Chen, X. Tong, M. Wang, Z. Zheng, Y. Qin, Angew. Chem. Int. Ed. 2017, 56, 816-820.
3, J. Zhang, Z. Gao, S. Wang, G. Wang, X. Gao, B. Zhang, S. Xing, S. Zhao, Y. Qin, Nat. Commun. 2019, 10, 4166.

Oral Lecture

Session Time:October 18 16:10-16:25 Location:Meeting room C



Prof. Jing Guo

Jing Guo, associate professor in School of Chemistry and Chemical Engineering of North University of China. She received her Bachelor (2012) and PhD (2017) degrees from Sichuan University, both in chemical engineering. In 2015, she got the Chinese Government Award for Outstanding Students Aboard, as a visiting PhD student worked in the Department of Chemical Engineering of Delft University of Technology in the Netherlands nearly 2 years. She joined the Shanxi Province Key Laboratory of Chemical Process Intensification in 2017. Her research included high gravity technology, nanoparticle fluidization and ALD nanoparticle surface modification. Her current research focuses on nanostructured materials for pollutant control and energy conversion. In recent years, she chairs 1 National Nature Science Foundation of China and 4 science and technology projects in Shanxi Province.

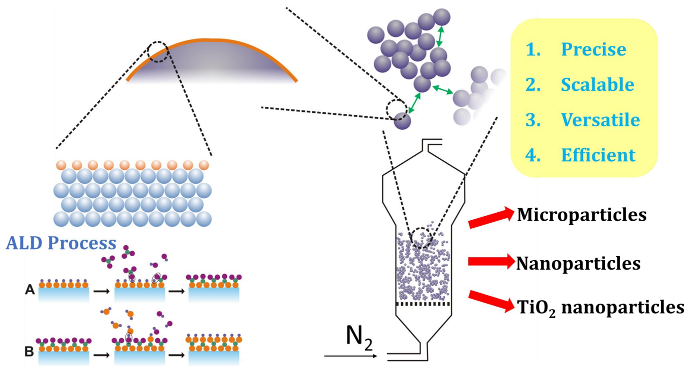
TOPIC

ALD ultrathin amorphous TiO_2 film in a fluidized bed reactor for improving the weatherability of TiO_2 pigment

Jing Guo, Bingkang Niu, Huifang Lou, Zhengyi Chao，Youzhi Liu
Shanxi Province Key Laboratory of Chemical Process Intensification, North University of China, Taiyuan 030051, China

ABSTRACT

Normally, a transparent inert film is coated on the surface of TiO_2 particles to enhance the weatherability of the pigment. Liquid-phase coating process is mainly used in industry, which difficult to get really uniform films. This work combining nanoparticle fluidization technology with atomic layer deposition (ALD) technology to achieve precise surface modification of a large number of micro-nano particles. Firstly, we explored the fluidization characteristics of TiO_2 nanoparticles in a home-made atmospheric fluidized bed ALD reactor to ensure the uniform fluidization of a large number of nanoparticles. Then at room temperature, $TiCl_4$ and H_2O were used as precursors to deposit amorphous TiO_2 films on the surface of TiO_2 nanoparticles. Compared with other traditional coating materials, amorphous TiO_2 has higher light refractive index, and realizes the suppression of the photocatalytic activity of TiO_2 without introducing other substances, demonstrating greater application potential in TiO_2 pigment coating field. The process is a gas-phase coating method, which is efficient, no waste water, and easy to scale up. This work shown the excellent property of interface engineering in improving pigment weatherability and can also provide guidance for the design of nanoparticle surface modification.



Oral Lecture

Session Time:October 18 16:25-16:40 Location:Meeting room C

Ngoc Le Trinh

Ngoc Le Trinh is a Ph.D. student in Materials Science and Engineering at Incheon National University, South Korea, since 2021. The main topic of his research is fabrication and understanding of multicomponent thin film deposition using theoretical and experimental approaches for Si device applications. During his Ph.D. studies, he worked under the supervision of Prof. Han-Bo-Ram Lee and published impactful results.

TOPIC

High Crystallinity Yttrium-doped ZrO_2 under 2 nm through Atomic Layer Modulation

Ngoc Le Trinh[1], Bonwook Gu[1], Wonjoong Kim[1], Byung-ha Kwak[2], Hyun-Mi Kim[3], Hyeongkeun Kim[3], Youngho Kang[1], Il-Kwon Oh[2] and Han-Bo-Ram Lee[1*]
[1]Department of Materials Science and Engineering, Incheon National University, Incheon, Korea
[2]Department of Electrical and Computer Engineering, Ajou University, Suwon, Korea
[3]Electronic Convergence Materials and Devices Research Center, Korea Electronics Technology Institute (KETI), Seongnam, Korea

ABSTRACT

The rapid scaling down of integrated circuits presents challenges for most of the Si devices, including DRAM capacitors and 3D transistors, which require both high capacitance density and low leakage current density. As the size of device is decreased more, the required thicknesses of thin films are further reduced, however, it is very challenging to maintain physical properties of films at the reduced thickness range. In this work, we studied high crystallinity dielectric thin films with Y-doped ZrO_2 (YZO) under 2 nm of film thickness. Atomic layer modulation (ALM) based on atomic layer deposition (ALD) has been utilized for better compositional uniformity in-plane and out-of-plane direction at atomic level. In ALM process, the surface is sequentially exposed to the precursors with an intervening purging step between each exposure, followed by a reaction with a counter-reactant, resulting in the growth of the YZO film within a single atomic layer. The ratio of Y and Zr in ALM film could be determined by steric hindrance and chemical reactivity of the precursors. To design and interpret the experiment, two theoretical approaches, density functional theory (DFT) and Monte Carlo (MC) simulation were used. In ALM process, the intervening purging step effectively removes physiosorbed molecules or byproducts from the reactive sites on the surface, thereby increasing the adsorption density of the precursors. Furthermore, the formation energy of the crystalline phase in the ALM films is anticipated to be lower than in the ALD film. In ALM film, Y atoms are formed closer to Zr atoms, with Y−O−Zr bonds forming both laterally and vertically within a few atomic layers. Consequently, the ALM film requires a lower energy barrier for diffusion to form the YZO crystalline phase, which enhances film density and improves crystallinity. The study demonstrates that Y doping into ZrO_2 induces change of crystal structure, resulting in phase transformation from monoclinic to the cubic (111)-plane-dominant phase. As a result, YZO ALM exhibits an approximately 200 times lower leakage current density compared to conventional YZO ALD at 2 nm thickness scale. This finding highlights the noteworthy finding that YZO exhibits simultaneous enhancement in dielectric constant and reduction in leakage current density at low thickness, indicating its potential as a promising candidate to meet the requirements of future Si devices.

Keynote Lecture

Session Time:October 18 16:40-17:10 Location:Meeting room C

Prof. Jun Huang

Professor Jun Huang joined the University of Sydney as a permanent faculty in 2010, moving up the ranks to Professor at Sydney. Jun is the Domain Leader of Materials in Nanoscale at Sydney Nano and CO_2 Zero Grand Challenge Champion. His research is to develop emerging sustainable technologies using in situ characterization techniques, coupled with new catalyst design and reaction engineering. Jun has published over 230 journal publications in high-rank Journals. He has been awarded many prestigious awards including 2021 ACS Sustainable Chemistry & Engineering Lectureship Award, 2020 Australia's Most Innovative Engineer, 2022 ARC Future Fellowship, and the 2017 Vice-Chancellor's Awards for Outstanding Research. Jun is the Editor-in-Chief of Materials Today Sustainability, Editorial Group Member of high-rank journals like National Science Review and ACS Sustainable Chemistry & Engineering.

TOPIC

Atomic layer deposition of the geometry separated Lewis and Brønsted acid sites for cascade glucose conversion

Wenjie Yang,[1] Xiao Liu,[2] Luke A. O'Dell,[3] Xingxu Liu,[1] Lizhuo Wang,[1] Wenwen Zhang,[4] Bin Shan,[5] Yijiao Jiang,[4] Rong Chen,[2]* Jun Huang[1]*
1 Laboratory for Catalysis Engineering, School of Chemical and Biomolecular Engineering, Sydney Nano Institute, the University of Sydney, Sydney, NSW 2006, Australia
2 State Key Laboratory of Digital of Manufacturing Science and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei, 430074, PR China
3 Institute for Frontier Materials, Deakin University, Geelong, VIC 3220, Australia
4 Department of Engineering, Macquarie University, Sydney, NSW 2019, Australia
5 State Key Laboratory of Materials Processing and Die and Mould Technology, School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei, 430074, PR China

ABSTRACT

Solid acid catalysts with bi-acidity are promising to be the workhouse catalysts in bio-refining to produce high-quality chemicals and fuels. Herein, we report a new strategy to develop bi-acidic cascade catalysts by separating both acid sites in geometry via the atomic layer deposition (ALD) of Lewis acidic alumina on Brønsted acidic supports. Visualized by Transmission Electron Microscopy and Electron Energy Loss Spectroscopy mapping, the ALD-deposited alumina forms a conformal alumina domain with a thickness of around 3 nm on the outmost surface of mesoporous silica-alumina. Solid State Nuclear Magnetic Resonance investigation shows that the dominant Lewis acid sites distribute on the outmost surface, whereas intrinsic Brønsted acid sites locate inside the nanopores within the silica-rich substrate. In comparison to other bi-acidic solid catalysts counterparts, the special geometric distance of Lewis and Brønsted acid sites minimized the synergetic effect, leading to a cascade reaction environment. For cascade glucose conversion, the designed ALD catalyst showed highly enhanced catalytic performance.

REFERENCES

W. Yang, X. Liu, L.A. O'Dell, X. Liu, L. Wang, W. Zhang, B.Shan, Y. Jiang, R. Chen, **J. Huang (2023)** Atomic Layer Deposition of the Geometry Separated Lewis and Brønsted Acid Sites for Cascade Glucose Conversion, **JACS Au**, 3, 9, 2586-2596.

Saturday, Oct 19th , 2024

09:10-12:10

Shanghai Ballroom

www.ap-ald.org

Keynote Lecture

Session Time: October 19 09:00-09:30 Location: Meeting room A

Dr. Toshihide Nabatame

I worked Hitachi and Renesas Technology for 22 years and moved to National Institute for Materials Science in 2009. I have been investigated fabrication and characteristics of DRAM, FeRAM and MOSFET, especially High-k films using ALD process since 2001.

TOPIC

Improvement of GaN/dielectric interface properties using atomic layer deposition

Toshihide Nabatame
National Institute for Materials Science, Tsukuba, Ibaraki, Japan, 305-0044

ABSTRACT

For future GaN power device, it remains big issues of poor characteristics at GaN/dielectric interface because native GaO_x layer formed on GaN surface. We present a unique method, named as the dummy SiO_2 process for improving GaN/interface properties.[1] This process consists of three steps: dummy SiO_2 deposition on GaN substrate vis PE-ALD using TDMAS and O_2 plasma, subsequent annealing, and dummy SiO_2 removal using BHF solution. The GaN surface was modified the stable GaO_x layer. The GaN/Al_2O_3/Pt capacitor with the stable GaO_x layer exhibited superior V_{fb} stability and reliability under PBS. This method can also be applied to other GaN/dielectric systems. This work was in part supported by the MEXT Program for Creation of Innovative Core Technology for Power Electronics (JPJ00977) and ARIM (JPMXP1223NM5088).

REFERENCES

1, Y. Irokawa, T. Nabatame et al., A Powerful Method to Improve Dielectric/GaN Interface Properties: A Dummy SiO2 Process. ECS J. Solid State Sci. Technol. **13**, 085003 (2024).

Invited Lecture

Session Time: October 19 09:30-09:50 Location: Meeting room A

Prof. Changjin Wan

Changjin Wan received his Ph.D. degree from the University of Chinese Academy of Sciences in 2016. Between 2016 and 2020, he was a postdoctoral researcher in Prof. Xiaodong Chen's (academician of both Singapore Science Academy and Singapore Engineering Academy) group at Nanyang Technological University. He joined the School of Electronic Science and Engineering of Nanjing University in 2020. He is the recipient of the New Prominent Scientist by Nano-Micro Letters (2024), Overseas High-Level Talent (2020), Springer Theses Award (2018), the Chinese Academy of Science President Award (2016), etc. Dr. Wan's current research focus is on neuromorphic electronics. He has published more than 90 papers in Advanced Materials, Nature Communication, IEEE Electron Device Letters, Applied Physics Letters, etc. with total citations of over 8500 and H-index of 42 (by Google Scholar). He is among the top 0.5% scholar worldwide according to ScholarGPS. He published a book "Electric-double-layer coupled oxide-based neuromorphic transistors studies" by Springer Nature, with a time downloads of more 2200. He is youth editor of International Journal of Extreme Manufacturing (IF=15.8), Frontiers of Optoelectronics (IF=5.4), and More than Moore. He is also the referee of ACS NANO, Adv. Funct. Mater., Adv. Electron. Mater., IEEE Elctron Dev. Lett., Appl. Phys. Lett., Mater. Horiz., Small, etc.

TOPIC

Building a Spiking Sensory Neuron with Oxide-based Neuromorphic Devices

Changjin Wan[1]
Affiliation: School of Electronic Science and Engineering, Nanjing University, Nanjing, Jiangsu Province, China, 210023

ABSTRACT

The in-depth understanding of information processing in the central nervous system, is of great implications for new insight into the limitations and challenges of nowadays' semiconducting technologies. External information is perceived by the sensory neural system, interpreted into spiking language, and processed by the central nervous system, resulting in the interaction with real-world by the motor neural system. Therefore, the design of biologically plausible information processing devices, such as in-memory computing and in-sensor computing devices, are of great interesting for endowing electronics with sensory-motor abilities.
This talk will focus on the oxide based spiking sensory neuron. Firstly, the scientific and technological issues concerning on the construction of such device and our recent progress on the mimicking of thermoreceptor and photoreceptor will be introduced. Next, an oxide-based photoreceptor with structural and functional similarity to biological cone-type photoreceptor will be discussed. Finally, the application of such spiking sensory neuron on multimodal sensory data processing, human action recognition, and low energy consumption and computing load edge computing system would be highlighted as the proof-of-concept. The aim of this device is to develop a highly biologically plausible sensory neuron with spike-encoding capability and ultralow power consumption, which would propel the development for artificial intelligent systems, humanoid robotics, future manufacturing, and so on.

REFERENCES

1, M. Pei, Y. Zhu, S. Liu, H. Cui, Y. Li, Y. Yan, Y. Li*, C. Wan*, Q. Wan*. Power-Efficient Multisensory Reservoir Computing based on Zr-doped HfO_2 Memcapacitive Synapse Arrays. Adv. Mater. 2023, 202305609.
2, X. Wang, C. Chen, L. Zhu, K. Shi, B. Peng, Y. Zhu, H. Mao, H. Long, S. Ke, C. Fu, Y Zhu, C Wan*, and Q. Wan*. Vertically integrated spiking cone photoreceptor arrays for color perception. Nat. Commun.2023, 14, 3444.

Invited Lecture

Session Time: October 19 09:50-10:10 Location: Meeting room A

Prof. Xiaolei Wang

Xiaolei Wang received the B.E. degree in applied physics from Northwestern Polytechnical University, Xi'an, China, in 2008, and the Ph.D. degrees in electronic engineering from University of Chinese Academy of Sciences, Beijing, China, in 2013. Then he joined the Institute of Microelectronics, Chinese Academy of Sciences. He is currently engaged in research of HfO2 based Si channel FeFET NAND.

TOPIC

Evidence of Oxygen Vacancy Generation as Physical Origin of Endurance Fatigue of Si FeFET with $TiN/Hf_{0.5}Zr_{0.5}O_2/SiO_x/Si$ Gate Stacks

Xianzhou Shao, Junshuai Chai, and Xiaolei Wang
[1] Institute of Microelectronics of the Chinese Academy of Sciences (IMECAS), Beijing, 100029, China.
[2]School of Integrated Circuits, University of Chinese Academy of Sciences, Beijing 100049, China.

ABSTRACT

We investigate the physical origins of endurance fatigue in silicon ferroelectric field-effect transistors (Si FeFETs) with $TiN/Hf_{0.5}Zr_{0.5}O_2/SiO_x/Si$ gate stacks. Our study employs electrical characterization techniques, including gate leakage current measurements, as well as physical characterization methods containing scanning transmission electron microscopy (STEM) and electron energy-loss spectroscopy (EELS). We identify the presence of a TiO_xN_y interlayer at the $TiN/Hf_{0.5}Zr_{0.5}O_2$ interface and a $Hf_xZr_ySi_zO_2$ interlayer at the $Hf_{0.5}Zr_{0.5}O_2/SiO_x$ interface. The thicknesses of the TiO_xN_y, $Hf_{0.5}Zr_{0.5}O_2$, and SiO_x layers remain constant during cycling, while the thickness of the $Hf_xZr_ySi_zO_2$ layer increases with endurance cycling. Furthermore, we observe that oxygen vacancy generation occurs throughout the entire gate stack during endurance, specifically in the $Hf_{0.5}Zr_{0.5}O_2$, $Hf_xZr_ySi_zO_2$, and SiO_x layers. This finding is also corroborated by the electrical characterization of gate leakage measurements. These oxygen vacancies contribute to the degradation of endurance in Si FeFETs with $TiN/Hf_{0.5}Zr_{0.5}O_2/SiO_x/Si$ gate stacks.

Oral Lecture

Session Time: October 19 10:10-10.25 Location: Meeting room A

Yu-Chun Li

Yu-Chun Li receives his bachelor's degree from the School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan, China in 2020. He is currently a Ph.D candidate in Microelectronics and Solid-State Electronics, School of Microelectronics, Fudan University, Shanghai, China. His research interests include novel non-volatile ferroelectric memory materials and devices.

TOPIC

Insight into Temperature-dependent Ferroelectric Polarization Switching Characteristics in Ga-Doped HfO_2 Thin Films

Yu-Chun Li[1], Zi-Ying Huang[1], and Hong-Liang Lu[1 *]
[1]State Key Laboratory of ASIC and System, Shanghai Institute of Intelligent Electronics & Systems, School of Microelectronics, Fudan University, Shanghai 200433, China; Zhangjiang Fudan International Innovation Center, Shanghai 201203, China; National Integrated Circuit Innovation Center, Shanghai 201203

ABSTRACT

HfO_2-based devices particularly are well-suited for high-temperature memory applications, where the demand for reliable data storage under elevated temperatures is becoming increasingly critical as technology advances[1]. However, maintaining consistent performance under varying temperature conditions remains a significant challenge for HfO_2-based ferroelectric materials due to the limited understanding. In this work, the ferroelectric properties, polarization switching kinetics, and endurance characteristics of ALD-fabricated Ga-doped HfO_2 (Ga-HfO_2) capacitors have been systematically investigated across a temperature range of 300 K to 473 K. The results reveal a strong temperature dependence: remanent polarization (P_r) increases, coercive voltage decreases, the imprint effect intensifies, polarization switching slows, and endurance degrades with rising temperature. Notably, the Ga-HfO_2 device still maintains stable ferroelectricity at 473 K, with a $2P_r$ of 44 μC/cm^2. Besides, for 100×100 μm^2 Ga-HfO_2 devices, over 80% polarization reversal can be achieved with 3.2 V/500 ns excitation. Moreover, the endurance properties of Ga-HfO_2 devices surpass 2×105 cycles at 3.0 V/100 kHz at 473 K. The study suggests that defect behaviors primarily drive the temperature dependence in HfO_2 devices, providing valuable insights for high-temperature ferroelectric memory applications.

REFERENCES

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Invited Lecture

Session Time: October 19 09:00-09:20 Location: Meeting room B

Prof. Yanhao Yu

Dr. Yu is an associate professor at the Southern University of Science and Technology. He got his bachelor’s degree in chemical engineering from Dalian University of Technology, China, in 2011, and his Ph.D. degree in materials engineering from the University of Wisconsin-Madison, US, in 2017. From 2018 to 2020, he was a postdoctoral research fellow at Harvard University. He joined SUSTech in January 2021. Dr. Yu’s research interests center on soft electronic packaging materials and non-lithographic patterning techniques. He has published 50 papers in high-impact journals including Nat. Energy, Nat. Commun., and Adv. Mater., with a total citation above 5000 times. He is a recipient of the NSFC award for Distinguished Young Scholars (Overseas).

TOPIC

A Paste-Like Patterning Resist for Area-Selective ALD

Yanhao Yu
Department of Materials Science and Engineering, Southern University of Science and Technology, Shenzhen, Guangdong, 518055

ABSTRACT

Area-selective atomic layer deposition (AS-ALD) can selectively deposit thin films on specific areas of a substrate while avoiding unwanted deposition on others, relying on self-assembled monolayers (SAMs) to serve as a patterning resist. However, the weak thermal and chemical stabilities of SAMs limit the selectivity to below 90% due to defective depositions. In this talk, I will introduce a paste-like patterning resist that can endure long-cycle ALD. The selectivity of 300-cycle ALD using this resist reached 99.9%, while that using SAMs was nearly zero. This paste structure remains steady under molecular bombardment but can be broken down by ultrasonic force, making it thermally stable, shape-preservable during processing, hermetic at the molecular level, and easily removable after use. Based on a wetting-driven self-assembly process, we developed a non-photolithographic patterning procedure for this paste resist and achieved high-accuracy and defect-free bottom-up patterning of dielectrics, semiconductors, and conductors. Beyond AS-ALD, this resist is compatible with etching and wet-chemistry manufacturing, providing fruitful implications for bottom-up patterning.

Keynote Lecture

Session Time: October 19 09:20-09:50 Location: Meeting room B

Prof. Han-Bo-Ram Lee

Professor Han-Bo-Ram Lee hold his Ph.D degree from MSE at POSTECH in Korea in 2009, and had been a postdoctoral scholar at Stanford University from 2010 to 2013. He joined Department of MSE in Incheon National University as an assistant professor in 2013, and was tenured with full professor promotion in 2022. In 2018, he started an appointment of Associate Editor in Chemistry of Materials, American Chemical Society. In addition, he worked at SK hynix as a consulting professor from 2021 to 2022. Prof. Lee's current research interests and topics are focused on understanding and controlling surface chemistry and reactions, and applying this knowledge to ALD, ASD, and ALM with atomic-level theoretical calculations using DFT and Monte Carlo simulation. He organized ASD Workshop in 2023 and is organizing ALD/ALE 2025 as a chair.

TOPIC

Rediscovery of Atomic Layer Deposition to Overcome the Limitations of Semiconductor Manufacturing

Han-Bo-Ram Lee
Materials Science & Engineering, Incheon National University, Incheon, Korea, 22012

ABSTRACT

Atomic layer deposition (ALD) is an irreplaceable method for the thin film deposition of the Si chip fabrication in the era of 3D devices. In this talk, other opportunities of ALD to overcome the limitations of Si device fabrication caused from the smaller device size and the thinner film thickness will be presented. Area-selective atomic layer deposition (AS-ALD) has been received great attentions from the Si industry due to its potentials for another patterning toolbox. In addition, alloying and multilayering of ALD films have been used to tune film properties in the given conditions without big changes of materials in the industry. In the few nanometer thickness ranges, however, it is hard to keep using the tricks without materials and process modifications. Our group has studied various types of precursor inhibitors for better blocking property with higher process compatibility in AS-ALD. By combining experimental and theoretical approaches, we have proposed atomic layer modulation (ALM) for an evenly mixed multicomponent film in few nanometer ranges and successfully fabricated ALM HfZrO films. The results could provide insights for the next generation nanofabrication in the semiconductor technology using ALD.

Invited Lecture

Session Time: October 19 09:50-10:10 Location: Meeting room B

Prof. Il-Kwon Oh

Prof. Oh's current research interests and topics are focused on fabricating emerging electronic devices; the fabrication of electronic devices with novel nanostructures by controlling surface chemical reaction. He got a Ph.D degree at Department of Electrical and Electronic Engineering, Yonsei University, 2016, and had been a post-doc researcher at Department of Chemical Engineering, Stanford University. He joined Ajou University at 2021, March. He has published 82 SCI papers and 61 patents.

TOPIC

Study on Area-Selective Atomic Layer Deposition of Al_2O_3 with a Series of Al Precursors

Il-Kwon Oh[1,2]
[1]Department of Electrical and Computer Engineering, Ajou University, Korea
[2]Department of Intelligence Semiconductor Engineering, Ajou University, Korea

ABSTRACT

In this work, I will present the effect of different ligands on the growth mechanisms of Al_2O_3 for ALD and blocking mechanism for AS-ALD by comparing a series of metal precursors. We choose the series of Al precursors $Al(CH_3)_xCl_{3-x}$ and $Al(C_yH_{2y+1})_3$ as a model due to their simple structures and also because $Al(CH_3)_3$ is considered an excellent starting point for comparison. Changing both the number of methyl and chloride groups in $Al(CH_3)_xCl_{3-x}$ (x = 0, 1, 2, and 3) and the chain length of alkyl ligands in $Al(C_yH_{2y+1})_3$ (y = 1 and 2) provides key variables that can be used for precursor design. For instance, the series of $Al(CH_3)_xCl_{3-x}$ offers insights into the effect of Lewis acidity on precursor reactivity while keeping the precursor size almost constant. In contrast, the series of alkyl precursors, $Al(C_yH_{2y+1})_3$, has different sizes but similar reactivity, offering an analysis of steric hindrance effects on growth characteristics. This thorough study of precursor properties using both experimental and theoretical methods will allow us to determine the role of precursor selection in important ALD and AS-ALD parameters.

Oral Lecture

Session Time: October 19 10:10-10.25 Location: Meeting room B

Bonwook Gu

Bonwook Gu is a Ph.D. student in Materials Science and Engineering at Incheon National University, South Korea, since 2021. The main topic of his research is understanding thin film deposition using theoretical and experimental approaches. During his Ph.D. studies, he worked under the supervision of Prof. Han-Bo-Ram Lee and published results about MC simulation and ASD.

TOPIC

Atomic Layer Deposition of Molybdenum Film using Metal Organic Precursors

Bonwook Gu[1], Kieran G Lawford[2], Kwang Yong An[1], Seán T. Barry[2], Han-Bo-Ram Lee[1*]
[1]Department of Materials Science and Engineering, Incheon National University, Incheon 22012, Republic of Korea
[2]Department of Chemistry, Carleton University, Ottawa, Ontario K1S 5B6, Canada

ABSTRACT

The resistivity of metal films tends to rise significantly as their thickness approaches sub-10 nm, posing a major challenge. Molybdenum thin films have emerged as a promising alternative due to their potential to retain low resistivity at sub-10nm. However, traditional atomic layer deposition (ALD) processes for Mo film often use solid phase precursors, which can lead to issues such as line clogging and particle formation on the Mo film surface. These issues, in turn, negatively impact the step coverage and reliability of the Mo films. In this study, we evaluated four novel molybdenum precursors—MoCp, SiOMo, ClOMo, and ClNMo—alongside a conventional precursor, $MoCl_2O_2$, in combination with atomic hydrogen (at-H) generated by a heated tungsten wire (>1800 °C). These Mo precursors are particularly advantageous due to their low melting point and high vapor pressure compared to the conventional precursor, $MoCl_2O_2$. The at-H radicals efficiently remove the ligands containing impurities from the precursor, facilitating the deposition of Mo films. As a result, the high quality of MoC and $MoSiO_2$ films deposited using these new metal-organic precursors was formed. The resistivity of the MoC films was measured at 40 μΩcm with nitrogen and oxygen impurities below 4%. The purity of the $MoSiO_2$ film was observed with carbon and nitrogen impurities below 5% as confirmed by X-ray photoelectron spectroscopy (XPS). This approach advances the development of interconnect and barrier materials in the future semiconductor industry and opens up new possibilities for achieving high-purity Mo thin films.

Invited Lecture

Session Time: October 19 09:00-09:20 Location: Meeting room C

Prof. Jin Xie

Dr. Jin Xie is a tenured associate professor in the School of Physical Science and Technology at ShanghaiTech University and a member of the Shanghai Key Laboratory of High-resolution Electron Microscopy. He earned his B.S. in Chemistry from Fudan University in 2009 and his Ph.D. in Chemistry from Boston College in 2015. From 2015 to 2018, he served as a postdoctoral scholar in the Department of Materials Science and Engineering at Stanford University. His research interests focus on designing, synthesizing, and characterizing novel nanoscale material interfaces. He has published over 70 scientific papers in academic journals such as Nature Nanotechnology, Nature Communications, Science Advances, Journal of the American Chemical Society, Angewandte Chemie International Edition, Advanced Materials, and Matter, with more than 14000 citations and an h-index of 44.

TOPIC

Advancements in Surface Engineering through Atomic Layer Deposition for Lithium Batteries

Jin Xie
School of Physical Science and Technology & Shanghai Key Laboratory of High-resolution Electron Microscopy, ShanghaiTech University, China

ABSTRACT

With the assistance of in-situ/in-operando tools, the research in my group has delved into the development of various surface engineering strategies, with a special focus on Atomic Layer Deposition (ALD) and Vapor Phase Infiltration (VPI) as methods for precisely tuning the surface and sub-surface of layered oxide cathodes and polymer electrolytes. These efforts encompass the following key aspects: (1) Comprehensive study of the transformation process of ALD coating films during post-deposition annealing. Specifically, we made two discoveries. In the hexagonal layered $LiCoO_2$ material with a R-3m space group, we found that the migration of Mg^{2+} during annealing is anisotropic, leading to its replacement of Li^+ at the 3a site. In cubic spinel $LiMn_2O_4$ with a Fd-3m space group, we observed that the migration of Mg^{2+} during annealing is isotropic, resulting in its occupation of 8a tetrahedral sites. (2) Pioneering a novel method that utilizes ALD to coat hydroxide precursors, essential raw materials for solid-state NCM synthesis. This innovative approach enables us to tailor the grain structures of layered oxides during subsequent solid-state synthesis steps. (3) Employing VPI and reticular chemistry as tools, our research group modified electrolytes at the molecular level and developed a series of novel lithium-ion battery electrolytes, aiming to achieve a balance between ionic conductivity and mechanical properties of solid polymer electrolytes.

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3.S. Yang, P. Yan, W. Bao, H. Zhu, X. Cai, L. Zhao, Y. Zhang, W. Lin, Y. Deng, Y. Wu and J. Xie, ACS Energy Lett. **8**, 4278-4286 **(2023).**

Invited Lecture

Session Time: October 19 09:20-09:40 Location: Meeting room C

Prof. Dewei Zhao

Prof. ZHAO Dewei is a professor from College of Materials Science and Engineering, Sichuan University, Chengdu, China. Prof. Zhao's research interest includes organic/inorganic hybrid optoelectronic devices, such as thin-film solar cells, light-emitting diodes, and photodetectors.

TOPIC

All-Perovskite Tandem Solar Cells

Dewei Zhao
College of Materials Science and Engineering, Sichuan University, Chengdu 610065, China

ABSTRACT

All-perovskite tandem solar cells show great promise for next-generation solar cells in terms of reduced cost, flexibility, and high efficiency, an effective way to break the Shockley-Queisser limit of single-junction cells. Low-bandgap mixed tin (Sn)-lead (Pb) and wide-bandgap perovskite solar cells, as the key to make highly efficient all-perovskite tandem solar cells, have been gaining extensive interest due to their appropriate bandgaps and promising application to build efficient all-perovskite tandem cells. Growth process of perovskites plays a crucial role in the formation of high-quality perovskites. Here, we will present new self-assembly monolayer (SAM) materials for efficient wide-bandgap and low-bandgap perovskite subcells for record efficiencies of all-perovskite tandem solar cells. We will also present the crystallization regulation strategies that increase grain size, enhance crystallinity, and prolong carrier lifetimes in low-bandgap (~1.25 eV) perovskite films, as well as defect passivation strategies. We will then discuss the design and optimization of interconnecting layers for all-perovskite tandems.

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Oral Lecture

Session Time: October 19 09:40-09:55 Location: Meeting room C

Prof. Xiao Liu

Dr. Xiao Liu, associate professor, whose research interests are focused on particle atomic layer deposition and the rational design and controllable synthesis of environment and energy-related materials. He has published more than 50 papers in refereed journals, such as Nat. Commun., Angew. Chem. Int. Ed. and so on. Now, he has presided over the National Natural Science Foundation general projects, youth projects, National Key R&D Program projects, and Postdoctoral Innovative Talents Support Program, among others.

TOPIC

Highly Durable Pt Based Fuel Cell Catalysts via Atomic Layer Deposition

Xiao Liu[1], Hang Liu[2], Yuxin Gao[2], Bin Shan[2] and Rong Chen[1*]
[1] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074
[2] School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074

ABSTRACT

The activity and durability of carbon supported Pt based electrocatalysts are unchanging goals for the widespread application of hydrogen fuel cells. Under the harsh operation conditions of fuel cell, pure Pt nanoparticles suffer from great electrochemical dissolution, leading to serious stability decay. Herein, an effective strategy based on selective atomic layer deposition is developed to improve the activity and durability of Pt catalyst for hydrogen fuel cell based on atomically surface and interface modification on Pt nanoparticle. The behaviors of selective deposition of oxides such as ZnO, TiO_2, B_2O_3 on Pt/C electrocatalysts are controlled by the reactor temperature, oxygen source and number of ALD cycle. Following post treatments such as high temperature nitriding or reduction are performed to precisely control the surface structure of supported Pt nanoparticles. The activity and durability of Pt based electrocatalysts have been enhanced via selective ALD and following post treatment.

Keynote Lecture

Session Time: October 19 09:55-10:25 Location: Meeting room C

Prof. Feng Hao

Feng Hao, born in 1979, holds a Bachelor's degree from Peking University, a PhD from Northwestern University, and a postdoctoral fellow at Argonne National Laboratory in the United States. Currently serving as a researcher and doctoral supervisor at the Xi'an Institute of Modern Chemistry (204 Institute) in China's weapons industry. The research work mainly focuses on atomic layer deposition (ALD) technology, including the development of advanced ALD devices, nano energetic materials, nano catalysis, functional thin film materials, etc. He has been selected for the National "Ten Thousand Talents Plan" for outstanding young talents and leading talents in scientific and technological innovation, as well as the National Defense "Outstanding Youth" Talent Plan, and has received special government allowances and awards from the State Council.

TOPIC

Precise Surface Modification of Solid Fuel Particles by Atomic/Molecular Layer Deposition: Enhanced Safety, Stability, and Energy Release Performances

Hao Feng*, Lijun Qin, Yiyun Hu, Dan Li
Xi'an Modern Chemistry Research Institute
168 E. Zhangba Road, Xi'an, Shaanxi, China, 710065

ABSTRACT

High energy solid fuels, including fine particles of metal materials such as Al, Mg, Zr, and Ti, metal hydrides such as ZrH_2 and AlH_3, and nonmetal materials such as B, are widely employed in the aerospace and defense industries due to their high energy density and low cost. For example, adding solid fuel particles to explosives can increase the heat release and achieve a larger working capacity; and adding them to rocket propellant formulations can significantly boost the combustion rate and specific impulse. However, real-world applications of solid fuel particles are still facing serious challenges in terms of safety, stability, and energy release performances. Many of these problems are related to the unique surface properties of these materials.

Utilizing atomic/molecular layer deposition, the solid fuel particles can be coated by various ALD/MLD surface modification layers. The excellent step coverage of ALD ensures complete encapsulation of the fuel particles, which can effectively alter the surface properties of these materials. The precise coating thickness control implies minimum loss of the energy density. With ALD/MLD surface modification layers, significantly enhanced safety, stability, ignition and/or energy release properties have been demonstrated for various solid fuel particles such as Al, Zr, B, and AlH_3. Moreover, kilogram scale surface modification of typical solid fuels has been achieved by using rotary ALD reactors with proper reaction parameters, which remarkably promotes the efficiency of the ALD process and reduces the production cost.

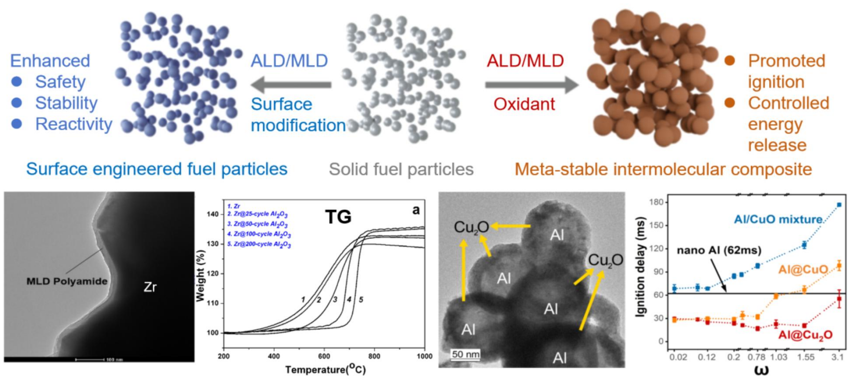

Fig 1. Enhanced energy release performances of metal fuels by ALD/MLD surface modification

Keynote Lecture

Session Time: October 19 10:50-11:20 Location: Meeting room A

Prof. Lain-Jong Li

Current position:
Professor, Chair of Future Electronics & Chair of Physics by Courtesy (Mar2021-)
Director, HKU Microelectronics center
Mechanical Engineering, University of Hong Kong
Associate Editor of Nano Letters (ACS)
Education:
BA (1994) and MSc (1996) of Chemistry, National Taiwan University
D.Phil (2006) of Condensed Matter Physics, Oxford University.
Experiences:
Assistant Professor, MSE, NTU (Singapore) Jun 2006 - Dec 2009
Associate Research Fellow, Academia Sinica (Taiwan) / Feb 2010 - Apr 2014
Research Fellow (Tenured), Academia Sinica (Taiwan) / May 2014 - Jul 2014
Associate Professor, King Abdullah University of Science and Technology (Saudi Arabia) / Aug 2014 - Jul 2016
Full Professor, King Abdullah University of Science and Technology (Saudi Arabia) / Aug 2016 - Dec2017
Director, Corporate Research in Taiwan Semiconductor Manufacturing Company (Taiwan)/Dec2017-Dec2020

TOPIC

Integration of Single-Crystal High-k Dielectrics with 2D Monolayer Transistors

Ni Yang[1], Jing-Kai Huang[2], and Lain-Jong Li[1]
[1]Department of Mechanical Engineering, The University of Hong Kong, Hong Kong, China.
[2]Department of Systems Engineering, City University of Hong Kong, Hong Kong, China

ABSTRACT

Atomically thin 2D semiconductors, such as MoS_2, are seen as promising options for the channels in ultra-scaled transistors. However, improving their integration with conventional high-κ gate insulators is crucial for creating energy-efficient devices. This calls for 2D MoS_2 FETs with a capacitance equivalent thickness (CET) of less than 1 nm. Our research demonstrates that transferrable single-crystal $SrTiO_3$ thin dielectrics offer a gate leakage significantly below the low-standby-power limit of 1.5×10^{-2} A/cm^2. The short-channel devices show strong reliability and competitive performance, including a steep subthreshold swing (SS) of approximately 75 mV/decade and a high ON/OFF current ratio of 10^6 [1]. Additionally, by carefully integrating various transferrable single-crystal dielectrics, MoS_2 transistors can potentially achieve hysteresis-free operation with exceptional performance, such as a steep SS of about 68 mV/decade, an ON/OFF ratio greater than 10^9 at a 25 nm channel length, a high ON current of 623 μA/μm, and ultra-low hysteresis.

REFERENCES

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Invited Lecture

Session Time: October 19 11:20-11:40 Location: Meeting room A

Prof. Joonki Suh

Dr. Joonki Suh is presently an associate professor in the Department of Materials Science and Engineering at UNIST where he is leading a research group in a new class of atomically-thin semiconductors and non-volatile memory devices. Prior to the current position, he graduated from Yonsei University in 2006, and then received a M.S. from Stanford University and a Ph.D. from the University of California, Berkeley, respectively. All his degrees are in materials science and engineering, and his doctoral research focused on defect and device physics based on phase-change materials and layered chalcogenides.

TOPIC

Atomic-layer-deposited elemental chalcogen thin films for nanoelectronics

Joonki Suh
Affiliation: Department of Materials Science and Engineering & Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology, Ulsan 44919, Republic of Korea

ABSTRACT

In this talk, I present the wafer-scale growth of mono-elemental 2D tellurium (Te) thin films using an annealing-free, low-temperature ALD process. As-deposited Te films exhibit exceptional homogeneity, precise layer controllability, and 100 % step coverage in high aspect ratio nanostructures. As a 2D building block with intrinsic p-type transport characteristics, ALD-grown Te films are employed for fabricating 2D/2D and mixed-dimensional 2D/3D vertical *p-n* heterojunction diodes exhibiting well-defined current rectification. Additionally, we showcase an ALD-Te-based selector device with fast switching time, selectivity and low V_{th}. With those developed low-temperature processing, I will share more recent progress toward BEOL-compatible cryogenic nonvolatile memory devices and reservoir computing hardware, all based on synthetic chalcogenide thin films.

Invited Lecture

Session Time: October 19 11:40-12:00 Location: Meeting room A

Prof. Li Zheng

Li Zheng is a professor, doctoral supervisor and deputy director of the Silicon-based Materials and Integrated Devices of Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences. He earned his B.S. degree in physics from Nanjing University in 2011 and Ph.D. degree in microelectronics and solid-state electronics from University of Chinese Academy of Sciences in 2016. He has extensive experience in semiconductor and integrated circuit chips with over 100 SCI papers and over 40 patent applications. He has received numerous national and provincial honors, including the National Youth Post Expert, Special Prize of Shanghai Science and Technology Progress Award, the CAS Science and Technology Promotion Award, the National Youth Skills Competition Gold Award, Shanghai 35U35, Shanghai May Fourth Medal and so on.

TOPIC

Direct deposition of high-k dielectrics on 2D-materials by ALD and its device applications

Li Zheng[1,2], Xuetong Zhou[1], Changzhe Zhao[1], Lingyan Shen[1], Xinhong Cheng[1,2]
[1]State Key Laboratory of Materials for Integrated Circuits, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, Shanghai, 200050
[2]School of Integrated Circuits, University of Chinese Academy of Sciences, Beijing, 100049

ABSTRACT

Amid the continuous evolution of cutting-edge manufacturing processes, the dimensions of devices should undergo a continuous reduction. The amalgamation of 2D materials with high-κ dielectrics stands out as a pivotal technological trajectory. ALD emerges as a prime method for depositing high-κ dielectrics onto semiconductors. Nonetheless, the surfaces of 2D materials (e.g. graphene) exhibit chemical inertness and lack dangling bonds. Within this study, we have conducted a systematic investigation into the direct deposition of high-k dielectrics onto 2D materials using ALD. In addition, we have delved into its applications in the realms of logic, power, and photoelectric devices.

Oral Lecture

Session Time: October 19 12:00-12:15 Location: Meeting room A

Xinyi Tang

Ms. Tang Xinyi studies at the School of Microelectronics at the University of Science and Technology of China. She is currently engaged in research related to high-k dielectrics for DRAM capacitors, with a focus on ALD processes within HZO system. Her work encompasses the investigation of critical parameters affecting capacitance and reliability.To date, Dr. Tang has authored or co-authored five research articles in prominent journals within the semiconductor microelectronics field, including the Electron Device Letters (EDL) and Transactions on Electron Devices (TED), with two papers published in EDL as the first author and others as the second author.

TOPIC

Oxidizer Engineering of ALD for Efficient Production of ZrO_2 Capacitors in DRAM

Xinyi Tang, Yuanbiao Li, Songming Miao, Xiao Chen, Guangwei Xu, Di Lu, Shibing Long
University of Science and Technology of China, Hefei, 230026

ABSTRACT

This manuscript aims to enhance the production efficiency while maintaining the electric properties of the dynamic random-access memory capacitor dielectric ZrO_2 by optimizing its growth processes (Fig. 1(a)). This is achieved through oxidizer engineering by increasing the O_3 flux (1k sccm to 10k sccm) and using an extremely fast pulse time (1.5 s) during the atomic layer deposition of ZrO_2, showing in Fig. 1(b). This “short pulse - high oxidizer flux” method elevates the k value, effectively reduces leakage, and cuts off the growth time. Fig. 1(c) and Fig. 1(d) benchmark the leakage current density J at 0.5 V and the ALD cycle time of our oxidizer-engineered film in 10k sccm O_3 flux against other reported ZrO_2-based dielectrics. The application of this method yields ZrO_2-based capacitors of low leakage current densities (2×10^{-8} A/cm^2) and low equivalent oxide thicknesses of 0.55 nm (at 0.5 V, 10k sccm O_3 flux), holding significant potential as a key facilitator for future ultra-high-density DRAM systems.

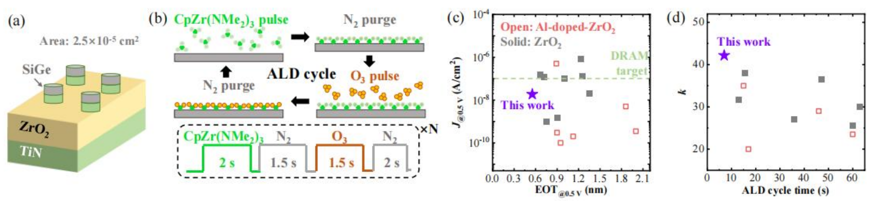

Fig. 1. (a) Structure of the ZrO_2-based DRAM capacitors. (b) Schematics of the typical ALD growth cycle for ZrO_2. (c) Benchmark plot of $J@V$=0.5 V as a function of EOT, highlighting the best results achieved with such a low EOT of 0.55 nm in ZrO_2-based capacitors. (d) The highest k value vs ALD cycle time of our film and other reported capacitors,showing the superiority of the “short pulse - high oxidizer flux” method.

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Invited Lecture

Session Time: October 19 10:50-11:10 Location: Meeting room B

Prof. Kun Cao

Kun Cao is an associate professor at Huazhong University of Science & Technology (HUST). Kun received his Ph.D. degree in materials science and engineering in 2016 at HUST. Kun carried out his postdoctoral research at the school of mechanical science and engineering at HUST in 2016-2018, where he investigated the reaction mechanisms and in-situ characterizations of ALD. Currently, his research focuses on area selective atomic layer deposition, by understanding surface science, and applying this knowledge to a range of problems in semiconductor processing, such as dielectrics alignment, metal interconnects etc.

TOPIC

Surface reaction kinetics for Inherent Selective Atomic Layer Deposition of Tantalum oxide on Cu/SiO_2

Kun Cao[1], Yicheng Li[1], Yuxiao Lan[2], Zilian Qi[1], Bin Shan[2] and Rong Chen[1]
Affiliation: [1]School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074
[2] School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074

ABSTRACT

The chemical principal and mechanisms that enable selective atomic layer depositions are gaining rapid growing interests, which have unlocked attractive avenues for the development of novel nanostructures by depositing atoms at desired surface locations. In this talk, the inherently selective atomic layer deposition processes will be discussed. Tantalum oxide was studied on a series of oxide substrates. Although the oxides have -OH groups on the surface and proposed to have similar nucleation sites, there are long nucleation delays on basic oxides. The H-transfer reaction is a key factor to influence the reaction barrier. It is hard to nucleate on basic substrates because the H-transfer reaction is blocked. Another demonstration is the redox-coupled inherently selective ALD for self-alignment of tantalum oxide on SiO_2/Cu nanopatterns. By adding an in-situ ethanol reduction pulse before each traditional binary ALD cycle, and the ‘reduction-adsorption-oxidation’ ALD process increases the selectivity. Self-aligned manufacturing on nanoscale Cu/SiO_2 patterns without excessive mushroom growth at the edge and undesired nucleation defects on the Cu region. The process can be reliably repeated to yield more than 5 nm-thick Ta_2O_5 on the SiO_2 region, while no undesired deposition occurs on Cu patterns. In addition, an anisotropic growth model with the dynamical competition of expansion and dissociation of the nucleus is proposed to nucleation delay are quantitively predicted and the model provides a practical method to evaluate the selectivity of ALD theoretically. It provides a new strategy for inherently selective ALD, which will expand the selective toolbox of nanofabrication for next-generation nanoelectronic applications.

Keynote Lecture

Session Time: October 19 11:10-11:40 Location: Meeting room B

Dr. Sang-Ick Lee

2011 ~ Director, Semiconductor R&D Center, DNF Co. ltd.
2007-2009 Researcher, Dept. of Mechanical Engineering, UC Berkeley
2004-2006 Principal Research Engineer, R&D, Samsung Corning
1997-2003 Senior Research Engineer, R&D, SK Hynix
1997 Ph.D. in Chemistry, Korea Advanced Institute of Science and Technology

TOPIC

Surface Adsorption/Desorption Reactions and Precursor Design for ALD/ALE

Sang-Ick Lee, Sangyong Jeon, Taeseok Byun, Yonghee Kwon, Sangchan Lee

Key words: Precursor, ALD, Semiconductor, Display, Deposition

ABSTRACT

The “Atomic Layer Deposition (ALD)” technology, which deposits thin films in atomic layer, was developed to overcome the limitations of existing semiconductor technologies, enabling new semiconductor processes and structure formation to make smaller semiconductors. Semiconductor devices formed using ALD have become a key technology enabling higher speed and lower power consumption. Precursors are the core of ALD, an edge technology that enables these future semiconductor requirements. This presentation represent to explain the design concept of Precursors that enables the implementation of High Step-Coverage, High Reactivity (Deposition Rate) at Low Temperature, Area Selective Deposition, Functional Deposition, Gap-Fill with New Reactants, and Encapsulation for OLED from the viewpoints of Chemical Structure, Surface Reaction, Surface Reactivity, Surface Adsorption & Desorption, and Process Design for a solution [1-3].

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Invited Lecture

Session Time: October 19 11:40-12:00 Location: Meeting room B

Prof. Woo-Hee Kim

Woo-Hee Kim received the Ph.D. degree from POSTECH, Pohang, South Korea, in 2011. Before joining Hanyang University as a faculty member, he had been a senior engineer in Samsung Electronics and Micron Technology, a postdoctoral scholar in Stanford University, and an assistant professor in Jeonbuk National University. Since 2019, he has been an associate professor with the Department of Materials Science and Chemical Engineering, Hanyang University. His current research interests are mostly focused on atomic scale thin film processing, which not only involve atomic layer deposition of metal/high-k films for advanced nanoelectronics, but also include area-selective atomic layer deposition and atomic layer etching processes for advanced nanopatterning processes.

TOPIC

Advanced Atomic Level Thin Film Patterning Process

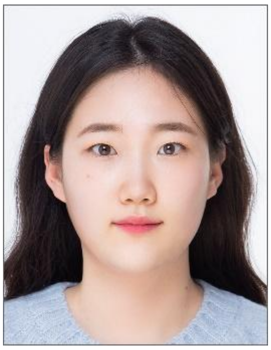
Woo-Hee Kim
Department of Materials Science and Chemical Engineering, Hanyang University, Korea

ABSTRACT

As advanced semiconductor devices require even narrower dimensions toward sub 3nm scale, area-selective atomic layer deposition (AS-ALD) has attracted considerable attention as a complementary bottom-up nanopatterning technique that can eliminate misalignment ssues in conventional top-down approaches requiring multiple lithography and etch steps, through accurate pattern placement onto desired area. Most common AS-ALD research has focused on achieving selective deposition on growth area by deactivating the region where no deposition is desired (referred to non-growth area). For this purpose, functionalization of surfaces with inhibitory molecules, called “Self-assembled monolayers (SAMs)” with hydrocarbon moieties is the most popular strategy, but several technical hurdles remain challenging despite their efficacy in effectively blocking against subsequent ALD process. Accordingly, alternative AS-ALD methodology for modulating surface characters is essentially necessary, including vapor-dosed attachment of various inhibitor agents that can chemo-selectively prevent precursor adsorption during subsequent ALD process Therefore, we introduce various methods to successfully demonstrate high enough deposition selectivity for many materials system composed of Si, oxides, and metals as widely utilized substrates in semiconductor manufacturing.

Oral Lecture

Session Time: October 19 12:00-12:15 Location: Meeting room B



Hyewon Park

Hyewon Park is a graduate student in Materials Science and Engineering at Incheon National University, South Korea, beginning in 2024. Her research focuses on the deposition of nitride films, with a particular emphasis on Titanium Nitride (TiN). Under the supervision of Prof. Han-Bo-Ram Lee, she has contributed to advancements in thin film technology during her graduate studies.

TOPIC

High Temperature TiN Atomic Layer Deposition using Various Nitrogenating Reactants

Hyewon Park, Yoonseo Choi, and Han-Bo-Ram Lee*
Department of Materials Science and Engineering, Incheon National University, Incheon 2012, Republic of Korea

ABSTRACT

Due to consistent miniaturization and downscaling of Si semiconductor devices, the downscaling of Cu interconnects has led to problems such as increased resistivity. Ru, with a shorter electron mean free path compared to Cu, is being considered as a potential new interconnect material. Therefore, extensive research has been conducted on TiN, which can enhance Ru adhesion to insulating substrates, while also offering low resistivity and high thermal stability. In atomic layer deposition (ALD) processes, higher deposition temperatures generally improve the electrical properties of thin films. However, high temperatures also result in the incorporation of impurities, such as carbon, to the film, degrading the film properties. Previous research using halide precursors, particularly those based on chlorine, minimized impurities but formed hydrogen chloride (HCl) as a by-product, which could damage both the chamber and the thin film. In this study, we deposited TiN thin films at high temperatures using Trimethoxy (pentamethylcyclopentadienyl) titanium(IV) ($Ti(Me_5Cp)(OMe)_3$), a metal-organic precursor that does not produce HCl by-products. Additionally, we evaluated three nitrogenating counter reactants: NH_3 gas, NH_2 radicals generated by a heated tungsten wire (>1800 °C), and hydrazine (N_2H_4). ALD growth was confirmed through ellipsometry and FE-SEM analysis. X-ray photoelectron spectroscopy (XPS) analysis showed that the stoichiometry of Ti:N ratio was 1:1, confirming the formation of a TiN thin film. High temperature ALD TiN using a Ti metal-organic precursor can produce high-quality TiN films without corrosive by-products.

Invited Lecture

Session Time: October 19 10:50-11:10 Location: Meeting room C

Eric W. Deguns, Ph.D.

TOPIC

Emerging Applications for ALD: 2D Materials and Superconducting Nitrides for Quantum Computing

Eric W. Deguns, Ph.D. – Lead Product Manager, ALD
Veeco ALD, Waltham, Massachusetts USA 15217

ABSTRACT

Continued progress for scalability and computing power increases depends on next generation device architectures. Such advancements require the integration of novel materials onto 3D patterns and devices, for which ALD is ideally suited.
Two examples of ALD enabling next generation 3D devices that will be discussed are the integration of: 1) 2D materials such as MoS2 and the integration of thin film superconductors for quantum computing (Q-bit fabrication). Continued challenges and recent progress of these materials will be overviewed.

Oral Lecture

Session Time: October 19 11:10-11:25 Location: Meeting room C

Prof. Huibin Ge

Huibin Ge, Associate Professor at Northwestern Polytechnical University. In 2017, he was awarded his PhD from Shanxi Institute of Coal Chemistry, Chinese Academy of Sciences. Now, His main research directions involve atomic layer deposition technology and interface catalysis. He has obtained two projects from NSFC. Until now, he has about 20 peer-reviewed papers published in international journals such as Angew. Chem. Int. Ed., ACS Catal., Appl. Catal. B-Environ., ChemCatChem, and so on.

TOPIC

Revealing the mystery between Pt-Ti sites and exposed Pt sites in TiOx-modified Pt catalyst

Huibin Ge[1], Yong Qin[2]
[1]Interdisciplinary Research Center of Biology & Catalysis, School of Life Sciences, Northwestern Polytechnical University, Xi'an 710072, China.
[2]State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan 030001, China.

ABSTRACT

The metal-support interaction (MSI) has a profound impact on the catalytic performance of the oxide-supported metal catalysts. Herein, inspired by the selective modification of the catalysts through ALD, we selectively blocked the high-coordinated Pt atoms in the Pt/Al_2O_3 catalyst with TiOx to form the Pt-Ti interfaces and leave the low-coordinated Pt sites. The Pt-Ti interfaces can act as an acceptor of electron from the exposed low-coordinated Pt sites to make the latter a slight electron loss, which is beneficial for H_2 activation and efficient utilization in hydrogenation of *p*-CNB. Meanwhile, the Pt-Ti interfaces provided sites for the parallel adsorption of *p*-CNB. The synergy between the Pt-Ti sites and the exposed low-coordinated Pt sites can significantly improve the catalytic performance.

REFERENCES

1, Huibin Ge*, Linsen Li, Haoyu Wang, Siwen Yi, Yujing Ren, Zhao Jiang*, and Yong Qin*, Revealing the mystery of the synergy between Pt-Ti sites and exposed low-coordinated Pt sites in TiOx-modified Pt catalyst for catalytic hydrogenation, Under Review.

Oral Lecture

Session Time: October 19 11:25-11:40 Location: Meeting room C

Zhijia Hu

Zhijia Hu obtained her B. Sc degree in Mechanical Engineering from Jinan University of Science and Technology, China in 2022. She is currently a master student in the School of Mechanical Engineering at Huazhong University of Science and Technology. She is interested in ultra-thin coating stabilization of energetic materials and particle atomic layer deposition methods and equipment (atomic scale extreme manufacturing).

TOPIC

Catalytically Ultrathin Titania Coating to Enhance Energy Storage and Release of Aluminum Hydride via Atomic Layer Deposition

Zhijia Hu, Xiao Liu*, and Rong Chen*
School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People's Republic of China

ABSTRACT

Aluminum hydride (AlH_3) has attracted much attention owing to its extraordinary hydrogen storage performance, yet AlH_3 is prone to hydrogen release reaction during long-term storage, leading to a decrease in energy and hindering its practical application. Herein, AlH_3 particles are stabilized by catalytically ultrathin TiO_2 coating via atomic layer deposition (ALD), the hydrogen content of which is controllable and reduces only 0.0026 wt% per ALD cycle of TiO_2 coating. 30 cycles of TiO_2 (2.4 nm) coated AlH_3 exhibits a peak decomposition temperature of 208.97 ℃ and decomposition activation energy of 112.39 kJ mol^{-1}, which are 7.83 ℃ and 25.62 kJ mol^{-1} higher than those of bare AlH_3. The hydrogen content loss of TiO_2 coated AlH_3 under hydrothermal aging conditions is much lower than that of bare AlH_3 due to the passivation of defects on native Al_2O_3 by forming inert Al_2O_3 and catalytic TiO_2 double-shell coating structure. TiO_2 coated AlH_3 exhibits enhanced combustion performance with stronger flame radiation intensity compared to bare AlH_3. The density functional theory calculations indicate that the contact between AlH_3 and TiO_2 can weaken the strength of Al-H ion bond and promote the release of hydrogen. Our work offers a feasible method for simultaneously improving the stability and energy release of AlH_3.

Keynote Lecture

Session Time: October 19 11:40-12:10 Location: Meeting room C

Prof. Se Hun Kwon

Dr. Se Hun Kwon is a professor at the School of Materials Science and Engineering of Pusan National University, Korea. He obtained his Ph. D. degree (2008) in Materials Science and Engineering from KAIST, Korea. His current research focuses on the design and synthesis of electrocatalytic materials for hydrogen fuel generation and hydrogen fuel cells, and surface engineering of electrocatalytic materials using atomic layer deposition.

TOPIC

Atomic Scale Surface Modification of Nanomaterials for Electrochemical Applications

Se Hun Kwon
School of Materials Science and Engineering, Pusan National University, Busan, 46241, Republic of Korea

ABSTARCT

Surface functionalization plays an important role in various nanomaterials with large surface area to volume ratios. And, effective and precise surface functionalization of various nanomaterials are essential for obtaining a desired properties in various industrial and scientific applications. Among various techniques, atomic layer deposition has emerged as a powerful technique for surface functionalization due to its noteworthy merits such as atomically precise thickness and composition control of ultrathin films with extremely high uniformity, which is based on its inherent self-limiting growth mechanism. Regarding the commercial applications of ALD, ALD process has already demonstrated its unique significance in the advanced semiconductor industries. And, there has been a growing interest in utilizing ALD in various electrochemical devices, further highlighting its significance. Therefore, in this presentation, we will introduce our atomic-scale strategy aimed at providing efficient methods to enhance the electrochemical performance of various nanomaterials for various electrochemical applications, including fuel cells and photoelectrochemical devices. Uniform, ultrathin, and precisely controlled thin film fabrication of ALD showed many beneficial properties in terms of the performance. Also, some technical challenges involved during ALD and recent efforts to overcome them will be discussed.

Saturday, Oct 19th , 2024

14:00-17:15

Shanghai Ballroom

www.ap-ald.org

Keynote Lecture

Session Time:October 19 14:00-14:30 Location:Meeting room A

Prof. Heeyeop Chae

Heeyeop CHAE is a professor in the School of Chemical Engineering at Sungkyunkwan University (SKKU) since 2004. His research interests include i) plasma-enhanced atomic layer etching and deposition, ii) low global warming etching gas development, iii) plasma monitoring and machine learning and iv) light emitting quantum dot materials and devices.

TOPIC

Plasma-Enhanced Atomic Layer Etching for Metal and Dielectric Materials

Heeyeop Chae
School of Chemical Engineering, Sungkyunkwan University (SKKU), Suwon, 16419, Korea

ABSTRACT

In this talk, various plasma-enhanced ALE (PEALE) processes will be discussed for isotropic and anisotropic patterning of metals and dielectric materials such as molybdenum, ruthenium, cobalt, titanium nitride, tantalum nitride, hafnium oxide, zirconium oxides. Typical ALE processes consist of surface modification step and removal step. For the surface modification, various fluorination, chlorination and oxidation schemes were applied including fluorocarbon deposition, halogenation, oxidation with radicals generated plasmas. For the removal or etching step, various schemes were applied including ion-bombardment, heating, ligand volatilization, ligand exchange, and halogenation. The surface characteristics and requirements of plasma-enhanced ALE will be also discussed.

Invited Lecture

Session Time:October 19 14:30-14:50 Location:Meeting room A

Prof. Jiuren Zhou

Jiuren Zhou, Professor. Hangzhou Institute of Technology, Xidian University.
Since 2015, he has joined Professor Sayeef Salahuddin/Chenming Hu’s team at the University of California, Berkeley, Professor Xiao Gong’s team at SNDL Laboratory at National University of Singapore, and Academician Hao Yue’s team at Xidian University Hangzhou Research Institute. Mainly conducts research on new energy-efficient ferroelectric nanoelectronic devices, including the basic physical mechanism, engineering preparation technology, and device performance regulation of ferroelectric logic/memory devices, and actively innovates device structures for the application requirements of memory and computing integrated neuromorphic chips.

TOPIC

Ferroelectric AlScN integrated on Silicon

Jiuren Zhou[1], Wenxin Sun[2], Ning Liu[2], Siying Zheng[1], Faxin Jin[1], Yan Liu[2], Yue Hao[2], and Genquan Han[2]
[1]Hangzhou Institute of Technology, Xidian University, Hangzhou, Zhejiang, 311200
[2]School of Microelectronics, Xidian University, Xi’an, Shaanxi, 710126

ABSTRACT

Ferroelectric memory is the key memory device structure to break the energy efficiency bottleneck of von Neumann's architecture. Among PZT, HZO, and AlScN ferroelectric materials, AlScN has substantial remnant polarization, single crystal, low thermal budget, superior thermal stability, and CMOS compatibility, which have played a crucial role in advancing high-density and high-reliability ferroelectric memory. This report demonstrates the feasibility of integrated ferroelectric AlScN on Silicon and provides a systematic characterization evaluation of the breakdown, retention, multivalue, temperature stability, and uniformity of MFS-structural Fe-memory designs. This represents a seminal advancement in the structural evolution towards wurtzite MFS-structural memories and their high-density integration, with profound implications for both fabrication and design.

REFERENCES

1, K.-H. Kim et al., “Wurtzite and fluorite ferroelectric materials for electronic memory,” Nature Nanotechnol., vol. 18, no. 5, pp. 422–441.
2, W. Sun et al., “Integration of Ferroelectric Al0.8Sc0.2N on Si (001) Substrate,” in IEEE Electron Device Letters, vol. 45, no. 4, pp. 574-577.

Invited Lecture

Session Time:October 19 14:50-15:10 Location:Meeting room A

Prof. Taewook Nam

Dr. Taewook Nam is an assistant professor in the Department of Semiconductor Systems Engineering at Sejong University, South Korea. Dr. Nam received his Ph.D. degree in electrical and electronic engineering from Yonsei University (supervisor: Prof. Hyungjun Kim) in 2018. Prior to joining SejongUniversity, he studied thermal atomic layer etching (ALE) at the University of Colorado Boulder under the supervision of Prof. Steven M. George. His research interests include ALE, atomic layer deposition (ALD), and device fabrication using ALD and ALE. Dr. Nam has published more than 30 papers and holds 10 granted patents related to ALD and ALE. His recent work has focused on sub-5 nm scale device fabrication using ALE and ALD for next-generation devices. Additionally, his research includes area-selective deposition (ASD), as well as applications in display and energy using cutting-edge deposition and etching processes. He has served as a peer reviewer for several journals in materials science and chemistry, including Chemistry of Materials, ACS Applied Materials & Interfaces, Journal of Vacuum Science & Technology A, and among others.

TOPIC

Atomic Layer Etching of Metal and Metal Oxide for Semiconductor Applications

Taewook Nam
Department of Semiconductor Systems Engineering, Sejong University, Seoul 05006, South Korea

ABSTRACT

Etching is a key step in semiconductor process. Up to date, most of etching process had been conducted by using plasma, generating highly energetic radicals in order to make a volatile etch species by the reaction with materials. However, damage induced by the energetic species cannot be negligible anymore as device scales down to sub-10 nm. Thus, a need of a new etching process which doesn't use plasma or high energy radicals becomes more and more important.Thermal atomic layer etching (ALE), the opposite reaction of atomic layer deposition (ALD), is considered as a promising etch technique that can overcome the damage. ALE is based on sequential, self-limiting surface reaction, same with ALD. A precursor modifies surface of a material, then a following precursor reacts with the modified layer, making volatile species. In this manner, the ALE ensures 1) atomic thickness controllability, 2) large area uniformity, and 3) isotropic etching. In particular, the traditional etching techniques such as reactive ion etching (RIE) have anisotropic etching due to the directionality of energetic ion species, whereas thermal ALE etches isotropically, it can be used for uniform etching to fabricate 3-d structured devices such as nanowire field effect transistor (NW FET).In this talk, two types of ALE will be presented: 1) molybdenum (Mo) ALE for an interconnect application and 2) ZnO ALE for an BEOL application. The etching characteristics and mechanisms were characterized using in situ techniques, such as quartz crystal microbalance (QCM) and quadrupole mass spectrometry (QMS). In addition, low-temperature thermal ALE was available for both materials, which can be beneficial for semiconductor manufacturing.

REFERENCES

1. T Nam et al., Thermal Atomic Layer Etching of Molybdenum Using Sequential Oxidation and Deoxychlorination Reactions. Chem. Mater., 2024, 36, 3, 1449-1458
2. T Nam et al., Thermal Atomic Layer Etching of ZnO, in preparation.

Oral Lecture

Session Time:October 19 15:10-15:25 Location:Meeting room A

Prof. Yongqing Shen

Yongqing Shen received her Ph.D. degree from Beijing normal University in 2020. She worked in the Beijing Academy of Science and Technology as an assistant professor for 2 years. Now she is an assistant researcher in Beijing Superstring Academy of Memory Technology (SAMT). Her current research interests include amorphous oxide semiconductor-based field-effect transistors and their applications.

TOPIC

Effect of ozone pulse time on the IGZO film Characteristics deposited by thermal atomic layer deposition

Yongqing Shen, Jinjuan Xiang*, Zhengying Jiao, Liguo Chai,Yuting Chen, Guilei Wang*, Chao Zhao
Beijing Superstring Academy of Memory Technology, Beijing, China,100176

ABSTRACT

Recently, In-Ga-Zn-O (IGZO) material has been widely studied as channel material due to its advantages of low off current and high mobility. Thermal atomic layer deposition (TALD) has the advantages of controllable thickness and conformal step coverage capability, which is a promising method for the deposition of channel material in three-dimensional transistors. ALD is based on continuous self-terminating gas-solid reaction, and the deposition process of IGZO films usually requires sufficient pulse time to ensure the saturation of the surface reactions of In_2O_3, Ga_2O_3 and ZnO film. However, long ozone pulse time can cause oxidation of the source/drain material in the top-gate device, increasing the contact resistance and lead to performance degradation.

In this work, the effects of ozone pulse time, including unsaturated TALD reaction, on the physical and electrical properties of InO, IZO and IGZO films were investigated. It was found that the electrical properties of the InO/IZO/IGZO films can be improved by shortening the ozone pulse time during TALD process. After shorten the ozone pulse time, the mean sheet resistance of IGZO@10nm film with cyclic ratios of In_2O_3: GaO: ZnO to be 1:1:1, decreases from 4.5E4 Ω/sq. to 2.7E4 Ω/sq., carrier concentration increases from 4.3E18 to 25E18 cm^{-3}. XPS results show that the amounts of oxygen vacancies almost the same (12.71% to 12.88%). In addition, despite the unsaturated reaction, the content of impurities such as C in the films does not increase. Based on these results, the IGZO films deposited under insufficient ozone pulse time have better properties than the films deposited at saturated surface reaction from the points of impurity and carrier concentration. It can be inferred that the ALD reaction process of IGZO film does not necessarily require complete saturation, which breaks the conventional perception. Our research provides new technical strategies for improving IGZO TFT performance.

Key words: In–Ga–Zn–O (IGZO); thermal atomic layer deposition; unsaturated reaction;

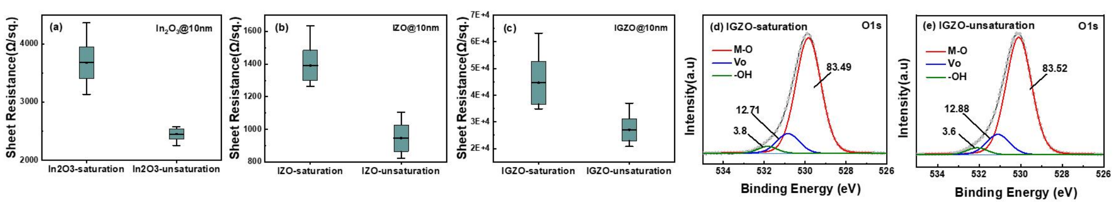


Figure 1. The material characterization results detected by four probe test (a-c) and O 1s XPS spectra with deconvoluted sub-peaks of IGZO films (d-e)

Invited Lecture

Session Time:October 19 14:00-14:20 Location:Meeting room B

Prof. Minsu Kim

Dr. Minsu Kim is an assistant professor in the Department of Advanced Materials Engineering at Kyonggi University. He received a bachelor's degree in ceramics engineering from Yonsei University and a doctor's degree in materials science and engineering from Seoul National University (Korea). He served as a staff engineer at Samsung Electronics and a post-doctoral researcher at Korea Research Institute of Chemical Technology (KRICT). His recent research interests are focused on ALD and CVD process for the development of next-generation electronic materials such as 2D materials and noble metals.

TOPIC

Atomic Layer Deposition of Platinum Group Metals and Its Application

Minsu Kim
Department of Advanced Materials Engineering, Kyonggi University, Suwon, Gyeonggi-do (Korea), 16227

ABSTRACT

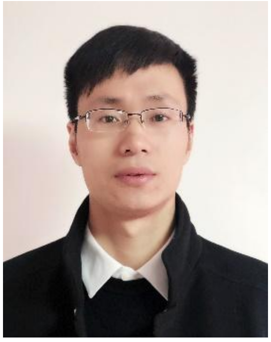
Platinum group metals (PGMs) have remarkable properties such as various electrochemical functionalities and excellent electrical conductivity in microstructures. Furthermore, the high reducibility of PGM importantly contributes to the development of deposition process of pure metal or compounds. Atomic layer deposition (ALD) enables atomic-level control of film thickness and chemical composition, which creates a synergistic effect leading to the development of various ALD processes of PGMs and their applications. This presentation proposes the development direction of PGM ALD technology by introducing studies on Ru/RuO_2 ALD for next-generation metallization and Ir ALD for functional composites.

REFERENCES

1, Minsu Kim et al., Atomic Layer Deposited RuO_2 Diffusion Barrier for Next Generation Ru-Interconnects. Advanced Functional Materials, 2022 34, p.220667.

Invited Lecture

Session Time:October 19 14:20-14:40 Location:Meeting room B



Prof. Daoyin Liu

Daoyin Liu is Professor in Department of Energy Engineering, Southeast University. His research work focuses on multiphase flow and gas phase synthesis of micro/nano-particles. Since 2015, he has published around 50 papers in international journals covering powder technology, chemical engineering and energy engineering areas.

TOPIC

Simulation of fluidization-atomic layer deposition of nanoparticle agglomerates by CFD-DEM approach

Zuyang Zhang, Daoyin Liu
Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, Southeast University, Nanjing 210096, Jiangsu, China

ABSTRACT

Fluidized bed atomic layer deposition (FB-ALD) is a high-flux ALD for micro and nano particle substrates. The coverage uniformity and precursor utilization are critical factors in evaluating the quality and cost-effectiveness of FB-ALD. The computational fluid dynamics-discrete element model (CFD-DEM) is employed to simulate the fluidization-ALD process of nanoparticle agglomerates in a fluidized bed. Effects of fluidization and precursor concentration on coating quality and precursor utilization are investigated. A cohesive contact model is utilized to model the contact behavior between micron-scale primary agglomerates, which undergo continuous sticking and breaking during fluidization. Additionally, Langmuir adsorption model and a series of heterogeneous reaction models are applied to describe the complete process involving TMA and H_2O precursors in ALD, including adsorption-desorption and surface reactions. The influence of agglomerate cohesion and precursor concentration is thoroughly analyzed. Both fluidization and reaction affect coating uniformity, while precursor utilization primarily depends on the precursor concentration. A decrease in cohesion or precursor concentration results in improved coating uniformity. This study provides insights into precursor reactions and coating behaviors in FB-ALD.

Oral Lecture

Session Time:October 19 14:40-14:55 Location:Meeting room B

Dr. Masoud Akbari

Jan. 2024 – nu 10 måneder,Copenhagen, Capital Region, Denmark,Visiting PhD Student,University of Waterloo, Mar. 2022-Sep. 2023 1 år 7 måneder, Waterloo, Ontario, Canada, Functional Nanomaterials Group, PhD Student, Laboratoire des Matériaux et du Génie Physique (LMGP), Nov. 2019-Sep. 2023 3 år 11 måneder, Grenoble, France, Spatial Atomic Layer Deposition (SALD) Team, Thesis title: Open-air fabrication of oxide-based cantilever gas sensors, Visiting PhD Student, Laboratoire TIMA/TIMA Laboratory, Feb. 2021-Feb. 2022 1 år 1 måned.

TOPIC

Direct Processing by µDALP™. Precision Coatings for Next Gen Devices

Masoud Akbari, Simone Santucci, Mira Baraket, Ivan Kundrata and Maksym Plakhotnyuk*
ATLANT 3D, Taastrup, Denmark

ABSTRACT

Advancements in the microelectronics sector demand the ability to create high-quality films with nanoscale accuracy to pattern complex features on substrates. Area-selective deposition (ASD) meets this demand by enabling the selective formation of films on specific surface regions while preventing deposition elsewhere. Atomic Layer Deposition (ALD), a well-established technique in the semiconductor field, has been widely investigated for ASD applications. However, this method often requires initial surface treatments, surface functionalization, or alterations to the process.

ATLANT 3D has introduced an innovative technology named microreactor Direct Atomic Layer Processing - µDALP™, enabling precise localized thin film deposition with accuracy down to a few hundred microns, incorporating all conventional ALD advantages. This technology leverages a specialized design of micronozzles to spatially separate precursors and reactants, facilitating rapid film deposition at atmospheric conditions. The µDALP™ technology stands out for its vertical atomic monolayer precision, achieving an accuracy of 0.2 nm. It is especially effective for selective patterning across diverse surfaces, including microfluidic channels, optical gratings, and nanostructured interfaces, showcasing its versatility and precision. Moreover, this technology enables fast and cost-effective prototyping of devices, facilitating a level of design creativity and optimization that is challenging with traditional thin film deposition approaches.

ATLANT 3D's technology has been successfully utilized to innovate in fields such as optics and photonics, quantum devices, microelectromechanical systems (MEMS), RF electronics, cutting-edge memory technologies, advanced packaging, and energy storage, showcasing its wide-ranging application potential. In this talk, we will explain the significant contributions of our µDALP™ technology to the evolution and expansion of thin-film manufacturing and discuss the wide applications it offers.

Oral Lecture

Session Time:October 19 14:55-15:10 Location:Meeting room B

Dr. Amit Sharma

Dr. Amit Sharma is a Senior Scientist at Swiss Cluster AG. With 15+ years in thin film deposition and characterization, and with over 70 publications, he focuses on developing new materials, optimizing processes and driving materials innovation.

TOPIC

Nano to Micro: Or How to Combine ALD with PVD

Amit Sharma[1], Israel Ayala[1], Xavier Maeder[2], Carlos Guerra[1]
[1]Swiss Cluster AG, Bahnhofstrasse 19, 3700 Spiez, Switzerland
[2]Empa Thun, Feuerwerkerstrasse 39, 3602 Thun, Switzerland

ABSTRACT

Atomic layer deposition (ALD) and Physical Vapor Deposition (PVD) have shaped and progressed a significant number of industrial technologies.
These techniques have been mostly growing in their own field of application, but when combined, they become an unparalleled materials factory. This combination offers endless variations of coatings with superior properties.
We will present the incorporation of both techniques in a new way leading to the development of the first system combining ALD and PVD in a compact equipment. The SC-1 can fabricate complex coatings with hundreds of nanolayers from the ALD and PVD materials library. The properties of such multinanolayered coatings are strongly influenced by their interfaces. Carefully engineered coatings translate to lighter and cheaper materials with improved mechanical and thermal properties. We will show a few examples of multinanolayered coatings and its mechanical properties behavior, surpassing the yield strength of existing materials. One of these examples show the capabilities of the system, fabricating a ~2.2 μm thick coating composed by 100 layers of 20 nm of magnetron sputtered aluminum alternating with 100 layers of 1 nm of Al_2O_3 deposited by ALD. This translates in a coating that is 2 times harder and stronger than any other aluminum alloy and can maintain 50% of its mechanical behaviour at temperatures close to the melting temperature of aluminum.

Oral Lecture

Session Time:October 19 15:10-15:25 Location:Meeting room B

Chaehyun Park

Chaehyun Park is currently enrolled in the integrated master's and doctoral program at the Graduate School of Semiconductor Materials and Devices Engineering at UNIST, majoring in Semiconductor Materials and Devices Engineering. Her research focuses on Nb-based compounds using ALD and their applications in semiconductors.

TOPIC

Plasma-enhanced atomic layer deposited highly conductive niobium carbide thin films as next-generation diffusion barriers for Cu and Ru interconnects

Chaehyun Park, Minjeong Kweon, Sang Bok Kim, Soo-Hyun Kim*
Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 44919, Republic of Korea

ABSTRACT

Transition metal carbides (TMCs) and nitrides (TMNs) have attracted significant interest as electrode materials due to their remarkable physical properties, such as high melting points, excellent electrical conductivity, and strong chemical stability. These characteristics not only make them ideal for advanced applications but also increasingly important in fields like energy storage, quantum computing, and as diffusion barriers for copper interconnects in semiconductor devices. Although TMNs have numerous established processes, TMCs are still in their early stages. In this regard, niobium carbide (NbC) thin films, a subset of TMCs, and their properties also remain relatively unexplored. Therefore, research is needed to assess ALD deposition feasibility for NbC_x thin films, suitable for future microelectronics with complex features. This study reports the deposition of PEALD-NbC_x (ca. 10 at.% nitrogen) using a new liquid cyclopentadienyl-based Nb precursor with H_2 plasma as a reactant. Further experiments were done mainly changing process temperature and H_2 plasma power to deposit high-quality NbC_x with sufficient carbon content and reduced oxygen impurities. The NbCx thin films were grown at the temperature of 350 °C by shower head type PE-ALD reactor (IOV dX1 PEALD, ISAC RESEARCH, Korea). The self-limiting growth behavior was shown with both precursor and reactant pulsing, with a saturated growth rate of approximately 0.19 Å/cycle. We applied the PEALD-NbC_x films to a diffusion barrier for Cu and Ru interconnects and the results will be presented at the conference.

ACKNOWLEDGEMENTS

This work was supported by the the Technology Innovation Program (No. 20024909, Development of Carbon-based Multi-Layer Thin Film Materials and Films for Protection of EUV Circuit Patterns based on ALD) and (RS-2024-00420281, Developed MOCVD equipment technology for single-cluster, 6-inch class nitride high-temperature growth for highly uniform (wavelength uniformity ≤ ±2 ㎚) LED characteristics) funded By the Ministry of Trade, Industry & Energy (MOTIE, Korea).This work also was supported by Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (P0023703, HRD Program for Industrial Innovation).

Oral Lecture

Session Time:October 19 14:00-14:15 Location:Meeting room C

Yixian Wang

Yixian Wang obtained his Bachelor's degree from Tianjin University in 2020 and now is pursuing PhD candidate at school of chemical engineering and technology, Tianjin University. His research focuses on atomic layer deposition (ALD) and molecular layer deposition (MLD), along with their related applications.

TOPIC

Vapor phase deposition of conformal organic-inorganic hybrid films and their applications

Yixian Wang, Qingfeng Chang, Tuo Wang*, and Jinlong Gong
School of Chemical Engineering and Technology, Tianjin University, Tianjin, 300072

ABSTRACT

Vapor phase deposition techniques, such as chemical vapor deposition (CVD), atomic layer deposition (ALD), and molecular layer deposition (MLD), have been extensively studied for their ability to enable precise control in the preparation of thin films and coatings[1]. MLD, an ALD-derived technique for the synthesis of organic-inorganic hybrid films, has been widely employed in the fabrication of dielectric materials, functional coatings, and other advanced materials. However, MLD is heavily dependent on the high reactivity of precursors, which inherently limits the diversity of reaction pathways. Our investigation of the $Hf(NMe_2)_4$-caprolactone system revealed the substantial impact of precursor ligands on the deposition mechanism. Notably, these ligands can be incorporated into the film during the ring-opening reaction, providing a novel strategy for fabricating hybrid films with tunable structures. In contrast, iCVD facilitates the formation of polyolefin films via surface-initiated free radical polymerization, and our research group has employed iCVD-modified electrodes to improve mass transfer efficiency. We propose that integrating these two deposition techniques offers a more versatile approach for the preparation of hybrid films, unlocking significant potential for the advancement of functional films.

Oral Lecture

Session Time:October 19 14:15-14:30 Location:Meeting room C

Haoming Che

Haoming Che, from Chengdu, Sichuan Province, China, graduated from Sichuan University and attended Waseda University for graduate studies. Currently, as a Ph.D. candidate at the University of Tokyo, specializing in materials science in Kita Lab., the focus is on an ALD process of HfO_2-based ferroelectric thin films. The research aim is to do systematical research on the influence of different oxidants of ALD process on the film quality, crystallinity, and ferroelectric properties of HfO_2-based thin films.

TOPIC

Low-temperature crystallization of $Hf_{0.5}Zr_{0.5}O_2$ thin films fabricated using H_2O_2 as the ALD oxidant

Haoming Che[1], Takashi Onaya[1], Masaki Ishii[2], Hiroshi Taka[2], and Koji Kita[1]
[1]Department of Advanced Materials Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, Japan, 277-8561
[2]Electronics Development Dept. Tsukuba Laboratory, R&D Unit, TAIYO NIPPON SANSO Corporation, 10 Okubo, Tsukuba, Ibaraki, Japan, 300-2611

ABSTRACT

Among HfO_2-based ferroelectric materials, $Hf_{0.5}Z_{0.5}O_2$ (HZO) has demonstrated the capability to achieve relatively high remanent polarization over 40 μC/cm^2 at a low process temperature [1], and this ferroelectricity comes from the metastable orthorhombic (O) phase. In the atomic layer deposition (ALD) process of HZO thin films, the choice of oxidants is crucial, as it can significantly influence the film quality. H_2O_2 is expected to reduce the impurity levels of ALD-HZO films because of its higher oxidizing ability compared to the conventional oxidant of H_2O [2]. However, the effects of H_2O_2 on the crystallinity of HZO films and the underlying mechanism are still unclear. In this study, we studied the impact of employing H_2O_2 on the impurity levels, film density, and crystallinity of the HZO films.First, we prepared HZO/SiO_2/p-Si samples. A 10-nm-thick HZO film was deposited by an ALD process at 250°C using (Hf/Zr)[N(C_2H_5)CH_3]$_4$ (Hf/Zr=1:1) as a precursor and H_2O_2 or H_2O as an ALD oxidant. For both H_2O_2- and H_2O-based HZO films, the impurity levels of the residual C and N in the as-grown films were under the detection limit of X-ray photoelectron spectroscopy. However, the density of H_2O_2-based HZO films had a higher density of 8.0 g/cm^{3}compared to H_2O-based films (7.8 g/cm^3), suggesting that H_2O_2 effectively reduced residual impurities in HZO films during an ALD process. Next, we prepared HZO/TiN samples. HZO films were fabricated using the same ALD process as mentioned before. After formation of HZO/TiN samples, post-deposition annealing (PDA) was performed at 400°C in N_2 atmosphere. Even though the as-grown films showed a small diffraction peak corresponding to the ferroelectric O, tetragonal (T), or cubic(C) phases at $2\theta \approx 30.8°$ evaluated by X-ray diffraction(XRD), the crystallization of H_2O_2-based HZO films was significantly promoted after the PDA process. For the H_2O-based HZO films, on the other hand, both as-grown and PDA-treated films did not show notable peaks. The higher crystallinity of H_2O_2-based HZO film is considered due to reduction of residual impurities thanks to the high oxidizing ability of H_2O_2. The film with less impurities would promote the crystallization.In conclusion, H_2O_2 can reduce residual impurity and increase film density of HZO filmscompared with H_2O, and a low-temperature (400°C) crystallization was achieved.

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2. Y. C. Jung et al., Robust low-temperature (350 °C) ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ fabricated using anhydrous H_2O_2 as the ALD oxidant. Appl. Phys. Lett. 2022, 121, 222901.

Keynote Lecture

Session Time:October 19 14:30-15:00 Location:Meeting room C

Prof. Yong Wang

Yong Wang received his Ph. D. in Chemistry from Institute of Chemistry, Chinese Academy of Sciences in 2005. He worked as Research Scientist at P&G (2005-2006) and Humboldt Fellow at the Max Planck Institute of Microstructure Physics (2006-2009). Now he is working as Professor both in Nanjing Tech University and Southeast University. He was granted the highly competitive National Basic Research Program of China (2015) and National Science Fund for Distinguished Young Scholars (2018), and received several awards including the Chinese Chemical Society Prize for Young Scientists (2012) and National Prize for Progress in Science and Technology (2019). Starting from 2021, Prof. Wang serves as Associate Editor for Macromolecules.

TOPIC

Molecular Layer Deposition of Conjugated Microporous Polymers for Molecular Separations

Yong Wang
School of Energy and Environment, Southeast University, Nanjing; College of Chemical Engineering, Nanjing Tech University, Nanjing 211816, P. R. China

ABSTRACT

Conjugated microporous polymers (CMPs) offer significant potential for membrane-based molecular separations due to their intrinsic micropores, high porosity, adjustable pore structure, and excellent stability. However, the remarkable solvent resistance of CMPs restricts their film-forming ability. Among the efforts to process CMPs into membranes, molecular layer deposition (MLD) stands out for its precise control over the nanostructure and thickness of the selective layer. However, the potential of MLD in fabricating high-quality separation membranes has not yet been fully explored. Recently, we demonstrated successful MLD processes in fabricating CMP membranes for effective molecular separations. With terephthalaldehyde (PDA) and m-phenylenediamine (MPD) served as precursors, selective PDA-MPD layer was successfully deposited on mesoporous AAO substrates, thus-fabricated membranes exhibit tunable perm-selectivity with decent molecular sieving capability. For molecular separations in organic systems, 3,3′-bithiophene monomers were polymerized with $MoCl_5$ via oMLD. The resultant membranes exhibit rapid solvent transport with effective molecular separations including dye and pharmaceutical molecules. Our MLD strategy highlights the potential of MLD for high-quality functional membranes in diverse applications.

Oral Lecture

Session Time: October 19 15:00-15:15 Location: Meeting room C

Jae Min Jang

I have been pursuing my studies in the Department of Chemical Engineering at Hongik University, starting from my undergraduate years and continuing through my master's program. Throughout this journey, I developed a strong interest in atomic layer deposition (ALD), characterized by deposition occurring through surface reactions, which has led to detailed investigations of the surface reactions of precursors. My research primarily focuses on computational chemistry, where first-principles calculations, specifically density functional theory (DFT) and machine learning potentials (MLP), are utilized to explore the deposition of materials widely used in semiconductor devices.

My initial work involved investigating the assembly of lithium precursors, which laid the foundation for understanding the field. Through the study of lithium precursor assembly, I learned to analyze processes such as oligomer formation and dissociation using first-principles calculations, particularly with DFT.

Recently, I have been researching transition metal nitrides, particularly titanium nitride (TiN). My work on TiN involves elucidating the surface structures under various processing conditions and understanding the surface structures formed during an ALD cycle, where the precursor and counter-reactant are each pulsed.

In addition to my studies, collaboration with various institutions in Korea has enriched my experience. Participation in several domestic symposiums has provided opportunities to exchange ideas with researchers from diverse fields, broadening my perspectives on research.

Currently, my focus is on how different deposition conditions, such as temperature and pressure, influence the surface reactions of transition metal nitrides in various environments. Excitement continues for advancing research and contributing to developments in this field.

TOPIC

A theoretical study on the adsorption of $Cp(CH_3)_5Ti(OMe)_3$ as a precursor for TiN ALD

Jae Min Jang[1], Hye Won Park[2], Soo-Hyun Kim[3], Han-Bo-Ram Lee[2], and Bonggeun Shong[1]
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[2]Materials Science and Engineering, Incheon National University, Incheon, South Korea, 22012
[3]Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology, Ulsan, South Korea, 44919

ABSTRACT

In the field of semiconductor technology, titanium nitride (TiN) plays critical role as a versatile material, serving as either diffusion barrier, adhesion layer, and conductor. As semiconductor devices continue to miniaturize, there is a demand for deposition methods of ultra-thin, easy thickness control, improved uniformity, and conformality. The deposition of TiN thin films via atomic layer deposition (ALD) using $TiCl_4$ and NH_3 has been extensively explored. However, usage of chlorine-containing precursors during semiconductor fabrication process may cast concerns regarding contamination and unwanted etching. On the other hand, some alternative Ti precursors pose limitations in ALD temperature window due to lack of thermal stability. In this work, possible surface chemistry of $Cp(CH_3)_5Ti(OMe)_3$ (trimethoxy (pentamethylcyclopentadienyl) Ti, also known as Ti-star or TMPMCT) as a precursor for high-temperature ALD of TiN was investigated. Machine learning potential (MLP) calculations are applied to investigate the surface reaction mechanisms. The TiN surface can be expected to have low coverage of NH_x and H species due to desorption of NH_3 and H_2 at high temperatures, even after exposure to NH_3 pulse process. Therefore, the adsorption behavior of Ti-star on the bare TiN surface was considered. An analysis of dissociation and desorption of the ligands was conducted after adsorption of the precursor. The change in the Gibbs energy was calculated as a measure of the spontaneity of the reaction. Current work elucidates the adsorption process of a new ALD surface chemistry via molecular level theoretical investigations.

REFERENCES

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Oral Lecture

Session Time: October 19 15:15-15:30 Location: Meeting room C

Zhiwen Chen

Zhiwen Chen obtained her Bachelor's degree in Applied Chemistry in 2016 and her Master's degree in Chemistry in 2019 from the China University of Geosciences, Wuhan. Her graduate research concentrated on liquid organic hydrogen storage carriers and high-efficiency hydrogenation/dehydrogenation catalysts. She has published three academic papers and was awarded the National Scholarship. In 2021, she commenced her doctoral studies at the College of Chemical and Biological Engineering, Zhejiang University. Her current research focuses on covalent organic framework membranes and atomic layer deposition (ALD). And this work has been submitted to Angewandte Chemie International Edition and is currently under revision.

TOPIC

Shielding CO_2-Philic Sites in Trimmed Covalent Organic Framework Pores by Atomic Layer Deposition

Zhiwen Chen,[a,b] Ming Zhang,[a,b] Yubin Hu,[a,b] Yingwu Luo,[a] Zheng Yang,[b] Junjie Zhao*[a,b]
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[b] Institute of Zhejiang University-Quzhou 99 Zheda Rd, Quzhou, Zhejiang 324000, China

ABSTRACT

Strong adsorptive sites towards unwanted gas molecules in porous framework materials often lead to reversed sorption selectivity, creating tremendous challenges for enhancing the diffusion-driven membrane separations targeted at the weakly adsorbed species in the gas pair. While post synthetic modification methods have been reported to downsize the pores in covalent organic frameworks (COFs), effective approaches to shield the highly adsorptive sites within the pores are rarely explored. Here, we developed a solvent-less pore modification strategy using atomic layer deposition (ALD). We show that controlled amounts of ZnO can be uniformly deposited into the COF pores, offering the ability to fine tune the pore dimensions. Moreover, the Zn-O moieties grown into the COF pore were found to interact with the CO_2-philic ketoenamine groups, and substantially reduced the CO_2 solubility by 262% in the COF membrane. Accordingly, the simultaneously increased diffusion selectivity and sorption selectivity for H_2/CO_2 led to a 430% improvement of the permselectivity in membrane separation, demonstrating the efficacy of our strategy for pore engineering in COFs.

Keynote Lecture

Session Time:October 19 15:50-16:20 Location:Meeting room A

Prof. Yi Zhao

Yi Zhao (SM'08) received his B.S. degree from Nanjing University of Astronautics and Aeronautics, Nanjing, China, in 2000, his M.S. degree from Zhejiang University, Hangzhou, China, in 2003, and his Ph.D. degree from the University of Tokyo, Tokyo, Japan, in 2007. In 2011, he worked as a Technology Development Engineer with Global foundries/IBM Alliance, Fishkill, NY, USA. He has also served as a Professor at Zhejiang University and is currently a Professor at East China Normal University. His current research interests include advanced CMOS devices featuring new channel materials and novel structures, as well as device and chip architectures for in-memory computing.

TOPIC

Atomic Layer Deposition of $Hf_{1-x}Zr_xO_2$ Anti-ferroelectric Films for Advanced Memory Devices

Zeping Weng[1], Jianguo Li[1], Fan Wu[2], Junliang Zhou[2], Wenchao Yan[2, 3] and Yi Zhao[1*]
[1]College of Information Science and Electronic Engineering, Zhejiang University, Hangzhou, Zhejiang, 310027
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[3]Zhejiang Liryder Technologies Co., LTD, Hangzhou, Zhejiang, 311305

ABSTRACT

This study focuses on the atomic layer deposition (ALD) of Hf1-xZrxO2 (HZO) anti-ferroelectric (AFE) films for advanced memory device applications. Through a systematic investigation of HZO films, we found that variations in thickness and Zr concentration significantly affect the phase composition, thereby influencing the AFE characteristics of the films. Specifically, the orthorhombic-I (o-I) phase has been identified as the fundamental source of the AFE behavior in HZO films. Additionally, the reversible transformation between the tetragonal (t-) phase and the o-I phase also contributes to AFE behavior and enhances the endurance of the films. However, incomplete transformation from the t-phase to the o-I phase may occur, potentially leading to a reduction in polarization. To balance endurance and polarization, we propose adjusting the Zr content based on different thicknesses to achieve a complete reversible transformation between the t-phase and o-I phase, thereby maximizing device performance. Finally, using an ultra-fast testing system, we demonstrated that an HZO film with a thickness of 6 nm and an Hf/Zr atomic ratio of 1:4 exhibits endurance exceeding 1014 cycles. This work highlights the potential of ALD for producing high-quality AFE HZO films, paving the way for the development of embedded DRAM and next-generation memory technologies.

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[2]Z. Weng, Z. Lan, Y. Ding, Y. Qu, Y. Zhao. Orthorhombic-I Phase and Related Phase Transitions: Mechanism of Superior Endurance ($>10^{14}$) of HfZrO Anti-ferroelectrics for DRAM Applications. IEEE IRPS, 2024, p. P11.EM-1 – P11.EM-6.

Invited Lecture

Session Time:October 19 16:20-16:40 Location:Meeting room A

Prof. Zhigang Ji

Ji Zhigang obtained a Bachelor's degree in Electrical Engineering from Tsinghua University in 2003/2006/2010, a Master's degree in Microelectronics and Solid State Electronics from Peking University, and a PhD in Nanoelectronic Devices from Liverpool John Moores University in the UK. Since 2010, I have been teaching at the Department of Electronic Engineering at John Moores University in Liverpool, UK, in collaboration with J F. Professor Zhang co leads the Device Reliability Laboratory. In 2014, he was appointed as a visiting professor at the European Microelectronics Center in Belgium. Appointed as a Reader in 2018, leading the research direction of micro nano electronics. In 2020, he joined Shanghai Jiao Tong University as a professor of micro nano electronics at the School of Electronic Information and Electrical Engineering, and established a micro nano electronic device laboratory.

TOPIC

ALD-based Memcapacitor for Efficient Computing

Xuepei Wang、Sheng Ye、Zhigang Ji*
School of Integrated Circuits， Shanghai Jiaotong University， 200240

ABSTRACT

Recent advancements in neuromorphic computing hardware have achieved significant progress in image classification, speech recognition, and fuzzy computing, surpassing traditional von Neumann computing paradigms. However, memristor-based neuromorphic hardware continues to face challenges such as high write/read currents, severe variability issues, and sneak path problems, leading to high power consumption and complex peripheral circuit designs. Memcapacitors shows promise in alleviating these issues, yet limited memory window and durability hinder practical applications. This paper proposes an atomic layer deposition-based memcapacitor, achieving a storage window of up to 78 fF/μm², excellent durability (>10^9 cycles), retention characteristics (>10 years), dynamic energy consumption (6.2 fJ $bit^{-1}μm^{-2}$), and nearly zero standby static power. The fabricated array exhibits high linearity and inter-device consistency, enabling complete multiply-accumulate operations. The constructed artificial neural network (ANN) achieves 93.6% accuracy on the MNIST dataset after 200 epochs.

REFERENCES

[1] Ishisaki Y, Oshio R, Kuwahara T, et al. Analog Memcapacitor by Ferroelectric Capacitor and Its Application to Spiking Neuromorphic System[J]. IEEE Transactions on Electron Devices, 2024.
[2] Lee M, Narayan D M, Kim J H, et al. Hafnium Oxide-Based Ferroelectric Devices for In-Memory Computing: Resistive and Capacitive Approaches[J]. ACS Applied Electronic Materials, 2024.

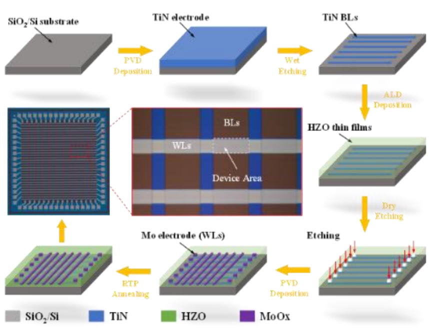

Fig. 1 Procedure for ALD-based memcapacitor

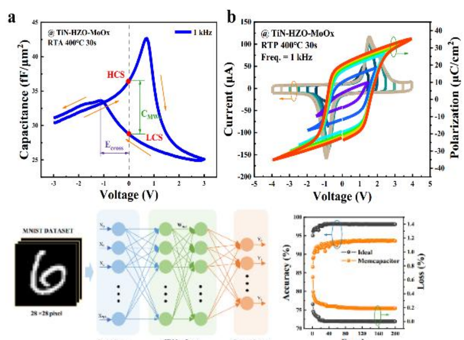

Fig.2 Performance and recognition task

Invited Lecture

Session Time:October 19 16:40-17:00 Location:Meeting room A

Prof. Jeong Hwan Han

Dr. Jeong Hwan Han has been a professor in the Department of Materials Science and Engineering at Seoul National University of Science and Technology (SEOULTECH) since 2017. His research focuses on DRAM electrode and dielectric materials, next-generation low resistance interconnect materials, high-mobility p-type/n-type oxide semiconductors, and tandem perovskite solar cells. Before joining Seoul National University of Science and Technology, he was a senior researcher at the Thin Film Materials Research Center of the Korea Research Institute of Chemical Technology (KRICT) from 2013 to 2017, where he conducted research on ALD precursors and process development. He also worked as a postdoctoral researcher at the IMEC Thin Films Scientific Group from 2012 to 2013, where he focused on in-situ process analysis of ALD rare-earth high-k oxides. Dr. Han received his Bachelor's, Master's, and Ph.D. degrees from the Department of Materials Science and Engineering at Seoul National University, with his doctoral research focusing on MIM capacitors using ruthenium-based electrodes. Throughout his research career, he has published over 100 SCI papers.

TOPIC

Recent Advances in ALD of Mo-Based Electrodes for High-Performance DRAM Capacitors

Jeong Hwan Han
Department of Materials Science and Engineering, Seoul National University of Science and Technology (Seoultech), Seoul 01811, Republic of Korea

ABSTRACT

As the miniaturization of metal-insulator-metal (MIM) and metal-ferroelectric-metal (MFM) cell capacitors advances, there's a growing need for novel electrode materials possessing low resistivity, high work function, and exceptional mechanical properties. Molybdenum (Mo)-based conducting films are gaining attention as next-generation electrodes to replace conventional TiN films due to their excellent properties, including elevated work function (>5 eV) and high mechanical strength. In this presentation, we will report on the atomic layer deposition (ALD) of various Mo-based films, including MoN_x and MoO_2, for next-generation MIM capacitor applications. Firstly, conductive MoNx films were grown by ALD, and MIM capacitors were constructed using a MoN_x layer in combination with $HfZrO_x$ (HZO) films. Despite the excellent electrical properties of the PEALD Mo_2N films, severe interfacial reactions between MoN_x and HZO occurred. A bilayer electrode structure comprising ALD TiN and Mo_2N was introduced to effectively regulate the interfacial reaction, aiming to enhance both the interface property and electrical performance of the capacitors. Secondly, a new strategy to grow monoclinic MoO_2 films by ALD was investigated. It was found that the metastable MoO_2 phase was stabilized by SnO_x doping in MoO_x thanks to the template effect between SnO_2 and MoO_2. ALD TiO_2 films grown on Sn-doped MoO_2 electrodes demonstrated remarkably high dielectric constants of 100–136, indicating that rutile structure TiO_2 was grown. These findings indicate that ALD Sn-doped MoO_2 films are promising electrodes for use in TiO_2 based MIM capacitor.

Oral Lecture

Session Time: October 19 17:00-17:15 Location: Meeting room A

Zhenhai Li

The author focused on the low-power storage and computing, successfully developed novel memory devices. These advancements overcame fast erase-write cycles, low power consumption, and non-volatile memory challenges, elucidating the physical mechanisms behind device performance improvements and providing alternative options for base devices in non-von Neumann architecture. (The power consumption of the devices was reduced to the attojoule level, a 10-layer 3D structure was created, device endurance reached 10^{12} cycles.) The specific research content is as follows:
Addressing the unclear polarization mechanisms and switching dynamics in hafnium-based ferroelectric devices, as well as the optimization of nanoscale high-quality hafnium-based ferroelectric storage units and foundational issues in three-dimensional integration structures and process technologies, the applicant conducted systematic research.
A high-speed, low-power nanoscale hafnium-based ferroelectric memory was constructed. By reducing oxygen vacancies in hafnium-based ferroelectric thin films, low-power devices were achieved, with power consumption as low as 71.5 attojoules, achieving ultra-fast response within 100 nanoseconds.
Three-dimensional integration and memory-computation integration technologies for hafnium-based ferroelectric memory were realized. A 10-layer hafnium-based ferroelectric 3D device array was constructed, featuring excellent cycle endurance ($>10^{12}$ cycles) and thermal stability (withstanding up to 10^{11} cycles at 85 ℃). In addition, based on the storage characteristics of hafnium-based ferroelectric 3D devices, logical operations such as IMP and NAND were implemented. The applicant also constructed hafnium-based ferroelectric flexible devices, explored the potential of hafnium-based wearable devices. Furthermore, using hafnium-based ferroelectric flexible devices, artificial synaptic characteristics were simulated, and an artificial neural network was built upon the long-term potentiation plasticity of the devices, achieving up to 99% accuracy in image recognition.

TOPIC

Optimization and Application Study of the Device based on Hafnium oxide Ferroelectric Thin Films

Li zhenhai[1*], Li Qingxuan[1], and Chen lin[2, 3*]
[1]School of integrated Circuits, Anhui University, Anhui 230601.
[2]School of Microelelctronics, Fudan University, Shanghai 200433. [3]Zhangjiang Fudan International Innovation Center, Shanghai 201203.

Invited Lecture

Session Time:October 19 15:50-16:10 Location:Meeting room B

Prof. Hao Van Bui

Dr. Hao Van Bui obtained his PhD degree in Electrical Engineering at the University of Twente, the Netherlands in 2013. He worked as a postdoctoral researcher at the NanoElectronics Group, University of Twente (2012 - 2014) and at the Process and Product Engineering, TU Delft (2014 - 2017). Since 2018, he works as a PI, leading the ALD Research Group at Phenikaa University, Hanoi, Vietnam.

TOPIC

Multi-Scale Fluidized Bed Reactor for Surface Coating and Modification of Powder-Based Materials

Phuong Cao, Kim-Hue Dinh, Phi Bui, Thuy Nguyen, Diem-Quyen Nguyen, Manh Nguyen, Truong Dinh, Dieu Nguyen, Anh Nguyen, and Hao Van Bui
Faculty of Materials Science and Engineering, Phenikaa University, Hanoi 12116, Vietnam

ABSTRACT

Powder-based materials are crucial in various industrial and technological applications due to their high surface area, tunable properties, and versatility. They are widely used in catalysis, energy storage, pharmaceuticals, and coatings, where the control of particle morphology and surface characteristics is essential for optimizing performance. Surface passivation and modification play a critical role in enhancing the stability, reactivity, and functional properties of these materials. By preventing oxidation, controlling agglomeration, and introducing specific functional groups, surface engineering can significantly improve the durability and efficiency of materials. This makes surface engineering a vital aspect of material design and application development. In this presentation, we will introduce a scalable ALD technique for surface coating and modification of powder-based materials using our home-built fluidized bed reactors (FBRs) working at atmospheric pressure, which are capable of processing from gram to kilogram scale of materials. We will demonstrate the deposition of ultrathin films and nanoparticles with FBR-ALD technique. Finally, we will discuss the potential applications of FBR-ALD in the synthesis of high-performance catalysts for various catalytic reactions, fuel cells, and batteries, as well as the applications in other fields.

Invited Lecture

Session Time:October 19 16:10-16:30 Location:Meeting room B

Prof. Byung Joon Choi

Prof. Byung Joon Choi received Ph.D. degree from Seoul National University, Seoul, Korea, in 2009. Since then he worked at the University of Pennsylvania as a Postdoctoral Researcher. In 2011, he joined Hewlett-Packard Laboratories. He has been an Assistant/Associate/Full Professor at the Department of Materials Science and Engineering, Seoul National University of Science and Technology (Seoultech) since 2013. His research fields are development of thin film processes majorly including atomic layer deposition technique applying for electronic memory and Neuromorphic devices.

TOPIC

User experience of hollow cathode plasma-assisted atomic layer deposition for various thin films

Byung Joon Choi
The Department of Materials Science and Engineering, Seoul National University of Science and Technology, Seoul 01811, Rep. of Korea

ABSTRACT

Hollow cathode plasma (HCP) has recently attracted significant attention as a new plasma source for plasma-enhanced atomic layer deposition. Unlike conventional plasma sources such as capacitively coupled plasma (CCP), inductively coupled plasma, and microwave plasma, HCP offers the advantage of preventing oxygen contamination due to the etching of dielectric liners within the equipment. This capability leads to critical process outcomes that determine the properties of thin films during the deposition of non-oxide materials. HCP generates plasma using the same principles as CCP but exhibits differences in the direction and density of radicals.

The plasma generation area is composed of stainless steel, eliminating oxygen contamination, minimizing plasma damage, and achieving high growth rates. Due to these advantages, HCP is regarded as a promising alternative to other plasma sources, and active research is being conducted on the deposition of nitride materials. This presentation aims to report on the properties of TiN, TiO_2, and GeTe thin films grown by using the HCP-ALD.

REFERENCES

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resistivity and impurity via hollow cathode plasma atomic layer deposition. Journal of Vacuum Science
& Technology A, 2024, 42, p.022405

Oral Lecture

Session Time:October 19 16:30-16:45 Location:Meeting room B

Mr. Sami Sneck

Mr. Sneck, Vice President, Advanced ALD at Beneq, joined Beneq in 2005. Since then, he has held various positions at Beneq, covering positions in product management, application development, business development, sales and business management. He also spent 2 years in Shanghai, China. He received his MSc degree in Chemical Engineering in 2001 from Helsinki University of Technology. Mr. Sneck has special expertise in Atomic Layer Deposition technology and business development. He has played a vital role in introducing various ALD production concepts and solutions to several industries, including jewelry, photovoltaics, LED, micro-OLED display, night vision, X-ray detection, and semiconductor equipment part coating. Mr. Sneck is a frequent speaker at ALD-related academic and industry events, and he holds several patents related to ALD equipment and applications.

TOPIC

Impact of application requirements on ALD tool design

Sami Sneck
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ABSTRACT

As ALD technology becomes more widely used across various industries and applications, the variety of different types of ALD equipment is expanding rapidly. ALD has been a key process technology in the semiconductor industry for twenty years, but additionally has made its way to photovoltaics, display, lighting, battery and several other industries. This presentation discusses how the requirements set by different industries and applications impact the design of ALD tools. Substrate size and format is one of the most profound factors impacting the tool design. Semiconductor wafers are great examples of well standardized substrates, which makes it easier to design ALD tools for coating wafers. Some of the semiconductor equipment parts are nowadays also ALD coated, and these equipment parts are a good example of substrates that come in various sizes and forms. Substrate size, throughput, film material, film thickness, process temperature, cost, and safety standards are examples of factors that have significant impact on the tool design. These factors are discussed one by one, and several examples of applications and corresponding tool designs are provided. Examples range from semiconductor wafer tools to continuously operating roll-to-roll systems for battery manufacturing, from research scale to high volume manufacturing, and covers thermal ALD and PEALD, temporal ALD and spatial ALD, low and high temperatures, as well as very thin films and thicker film stacks.

Oral Lecture

Session Time:October 19 16:45-17:00 Location:Meeting room B

Xujin Song

Xujin Song received his B.S. degree in microelectronics from Peking University, Beijing, China, in 2021. He is currently a Ph.D. student in School of Integrated Circuits of Peking University, under the supervision of Prof. Jinfeng Kang. His current research interests include fabrication and characterization of TiO_2-channel novel ferroelectric devices.

TOPIC

High Performances of 3D Vertical Ferroelectric NAND FeFETs with HfLaO FE Layer and TiO_2-Channel

Xujin Song, Shangze Li, Dijiang Sun, Chenxi Yu, Xiaoyan Liu, and Jinfeng Kang
School of Integrated Circuits, Peking University, Beijing, 100871

ABSTRACT

HfO_2-based FeFETs are emerging as promising candidates for enhancing the density and energy efficiency of 3D V-NAND technology. In this work, a novel 3D vertical NAND ferroelectric field-effect transistor (FeFET) array with TiO_2 channel and HfLaO ferroelectric layer (FE) has been experimentally demonstrated. The fabricated FeFETs, with ultrathin channel(8 nm)-FE(8 nm) stack, exhibit excellent performances including low write voltage (±2 V) with rapid write speed (<1 μs), high on/off current ratio (>10^6), remarkable endurance (>10^8), and high device-to-device consistency of the stacked cells. Moreover, effective string-level NAND operation of the fabricated V-NAND array has also been demonstrated.

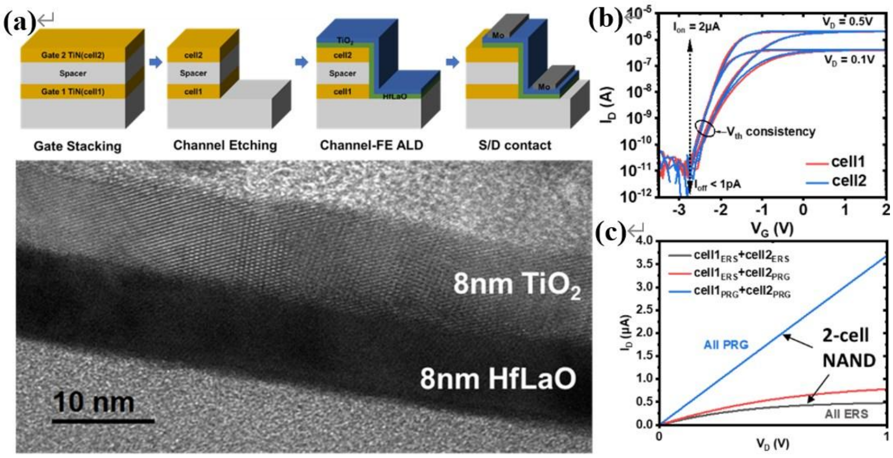


Fig.1 (a) Fabrication process and TEM image of the 3D V-NAND TiO_2 FeFETs array, (b) transfer curves of the stacked cells, (c) string-level NAND operation of fabricated V-NAND array

Oral Lecture

Session Time:October 19 17:00-17:15 Location:Meeting room B

Sujin Kwon

Sujin Kwon is currently a Master of Science (MS) candidate in the Department of Chemical Engineering at Hongik University, where she also received her Bachelor of Science (BS) degree. She has been interested in analyzing the intricate surface chemistry occuring in atomic-level processes such as Atomic Layer Deposition (ALD), Area-Selective ALD (AS-ALD), and Atomic Layer Etching (ALE). She has acquired several skills in analysis using simulation technologies based on computational modeling and molecular dynamics, and has applied these to various surface chemistry examination studies. She had conducted several representative research about the nucleation enhancement using small organometallic molecules during noble metal ALD on oxide substrates, and the differences in substrate selectivity in inherent AS-ALD depending on the type of precursor. She is recently focused on building methodologies for theoretical prediction of the most optimal surface configuration using global optimization method. She is also implementing phase diagrams that allow for the identification of surface geometry under specific process conditions, using thermodynamic analysis for applications in extensive fields. Although, this research focuses only on HfO_2 among metal oxides, she anticipates that such surface configuration prediction algorithms can be applied to a wide range of materials. She is dedicated to continuous study and effort to become a more accomplished researcher and has a strong interest in this field, making the most of her MS study.

TOPIC

Theoretical prediction on the configuration of hydroxyls on the surfaces of HfO_2

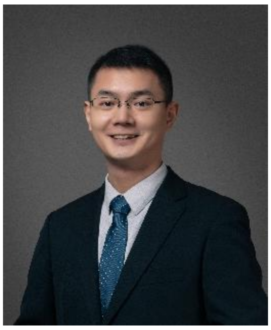
Sujin Kwon and Bonggeun Shong
Chemical Engineering, Hongik University, Seoul, South Korea, 04066

ABSTRACT

It is known that hydroxyls (OH groups) can critically contribute to the chemical interactions occurring on metal oxide surfaces, such as adsorption of precursors during atomic layer deposition (ALD). Furthermore, the configuration of hydroxyls is known to be strongly dependent to external process conditions including temperature and pressure. H_2O molecules in contact with surfaces exhibit various adsorption types, such as dissociative adsorption, molecular adsorption, or forming hydrogen bonds with the surface. Thus, understanding the precise configuration after the hydration process is paramount for the reliable examination of the surface chemistry of oxides. However, accurate estimation on the properties of the hydroxyls on the surfaces of oxides remain vague, partially due to high structural degrees of freedom in atomistic simulations. Recently, theoretical research based on computational chemistry to investigate the properties of metal oxides has consistently developed in various fields. In this work, a global optimization algorithm for prediction of surface hydroxyl configurations of oxides is presented. Machine-learned interatomic potential (MLIP) and the minima hopping (MH) method are coupled to investigate the surfaces of two representative phases of hafnium oxide (HfO_2). The surface structure of each HfO_2 model was globally optimized according to the surface density of H_2O, and the change in the adsorption types of H_2O species was examined with increasing the coverage. For thermodynamic analysis, free energy calculation has performed to construct a phase diagram as functions of temperature and partial pressure of water, illustrating the most stable configuration in each process condition. Our study provides valuable insights into the advancement of theoretical prediction of the surface configuration of solids.

Invited Lecture

Session Time:October 19 15:50-16:10 Location:Meeting room C



Prof. Junjie Zhao

Prof. Junjie Zhao received a B. Eng. in chemical engineering and a B. A. in English from Zhejiang University in 2011. He obtained his Ph.D. degree from North Carolina State University in 2016, and was a postdoctoral associate at Massachusetts Institute of Technology before joining Zhejiang University in 2018. Prof. Zhao's research is focused on the multi-scale structures and patterns of thin film materials. He has published over 40 papers in high-impact journals including Science, J. Am. Chem. Soc., Angew. Chem. Int. Ed., Prog. Polym. Sci, and has been highlighted in the ACS Appl. Mater. Interfaces Early Career Forum. Prof. Zhao is a recipient of the American Vacuum Society Thin Film Division Paul Holloway Young Investigator Award (2023) and the Best Author Award of International Journal of Extreme Manufacturing (2023)

TOPIC

Role of Atomic Layer Deposited ZnO in Confined Interfacial Synthesis of MOF Turing Patterns

Junjie Zhao*
College of Chemical & Biological Engineering, Zhejiang University, Hangzhou, China

ABSTRACT

Turing patterns are widely observed in many biological systems in nature. Attempts to generate Turing patterns have found success in simple reaction systems and synthetic soft materials, but still face difficulty for hard, brittle materials. Recently, we reported a unique confined interfacial synthesis that can form tunable Turing patterns in metal-organic framework (MOF) thin films.[1] In this synthesis, a bilayer structure consisting an atomic layer deposited (ALD) ZnO and a polymer topcoat was exposed to a solution containing the MOF reagents. Driven by the concentration gradient, the MOF reagents diffuse downward in the polymer layer while the hydrolyzed product of ZnO ($ZnOH^+$) diffuses upward. Under specific reaction-diffusion conditions, the resulting traveling chemical waves reach instability, leading to various Turing motifs. In this talk, we will discuss the mechanism of this confined interfacial synthesis and show how we can control the Turing patterns in wrinkled MOF thin films. In addition, we will also demonstrate the flexible integration of these wrinkle MOF thin films for gas separation membranes and soft humidity sensors.

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Oral Lecture

Session Time:October 19 16:10-16:25 Location:Meeting room C

Sojeong Eom

Sojeong Eom received the B.S. degree in chemical engineering from Soongsil University, Seoul, South Korea, in 2023, and she is pursuing the M.S. degree in electrical and electronic engineering from Yonsei University, Seoul, South Korea. Her main research interests include atomic layer deposition (ALD) of SiO_2 oxide and fabrication of nanoscale devices.

TOPIC

High-Temperature Atomic Layer Deposition of SiO_2 using Metal-Organic Si Precursor

Sojeong Eom[1], Sanghun Lee[1], Seonyeong Park[1], Seunggyu Na[1], Jisang Yoo[1], Seung-min Jung[2], Hyungjun Kim[1*]
[1]School of Electrical and Electronic Engineering, Yonsei University, 50 Yonsei-Ro, Seodaemun-Gu, Seoul 03722, Korea
[2]School of Semiconductor and Display, Korea Polytechnics University, 45 Haengmok-Ro, Sinchang-Myeon, Asan 31533, Korea

ABSTRACT

Silicon dioxide (SiO_2) has been widely used in the semiconductor industry due to its good insulation properties. For example, high-quality SiO_2 films have been examined for use as tunneling oxide in NAND flash memory where its performance degrades as device scaling increases. In this regard, vertically stacked NAND (3D V-NAND) was introduced, which could achieve the higher integration density, leading to more complex structures with high aspect ratio trenches. For these reasons, atomic layer deposition (ALD) is conducted for the deposition of the SiO_2 tunneling layer in 3D V-NAND with thermal ALD preferred over plasma-enhanced ALD for its conformal coverage. Consequently, there has been attracted attention to the development of high-temperature thermal ALD to achieve a high-quality SiO_2. For ALD SiO_2, aminosilane has been widely used, but thermal decomposition would occur at high temperatures (>300 °C), while $SiCl_4$ is thermally stable but less reactive. In this manner, we explored high-temperature thermal ALD using ozone and aminosilane, where the Si-H is replaced with the Si-CH_3 ligands, known for better thermal stability. The growth characteristics was investigated at deposition temperature from 100 °C to 700 °C. The saturated GPC was 1.5 Å/cycle at 500 and 600 ℃, while abnormal growth was observed at the 700 °C, revealing the thermal decomposition of Si precursor. We also compared the film quality of SiO_2 deposited at 500 and 600 ℃ by electrical characterization of metal-oxide silicon capacitor.

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Keynote Lecture

Session Time:October 19 16:25-16:55 Location:Meeting room C

Prof. Kwan W. Tan

Dr. Kwan W. Tan is an Assistant Professor in the School of Materials Science and Engineering at Nanyang Technological University, Singapore (NTU). He earned his higher degrees from MIT and Cornell University and conducted his postdoctoral research at both Cornell and with the Singapore-MIT Alliance for Research and Technology. His current research focuses on advanced nanomaterials developed through self-assembly and atomic layer deposition, non-equilibrium phase behaviors, and their applications in clean energy and environmental sustainability.

TOPIC

ALD and Joule Heating-Induced Synthesis of High-Entropy Nano-Alloys for Enhanced Water Electrolysis Performance

Kwan W. Tan
School of Materials Science and Engineering, Nanyang Technological University, Singapore 639798

ABSTRACT

The control of crystal phase, composition, and morphology in multicomponent nanomaterials is a powerful strategy for introducing new, unique physicochemical properties, functionalities, and applications. This contribution details our recent advancements in the rapid non-equilibrium synthesis of functional high-entropy alloy nanocatalysts with enhanced performances in water electrolysis. Precursor noble metal thin layers were deposited sequentially by ALD. Joule heating was then applied in second-range timeframes, promoting atomic diffusion across the individual layers and supercooling kinetics to form homogeneous noble metal high-entropy alloy films. Optimizing precursor film thickness allows control over supercooling kinetics and induces explosive crystallization, forming a multiphasic sub-surface comprising nanocrystalline and amorphous domains through steeper thermal gradients, rapid latent heat release, and quenching dynamics. The resulting noble metal high-entropy alloy thin films demonstrated attractive HER performance with low overpotentials, ranging from 13 to 65 mV at a current density of 10 mA cm^{-2}, and low Tafel slopes from 14 to 78 mV dec^{-1}, indicating fast kinetics across acidic, neutral, and alkaline electrolyte conditions. We further demonstrated the formation of amorphous metal phosphate films that showcased outstanding OER overpotentials as low as 235 mV and Tafel slopes between 30 to 40 mV dec^{-1}, as well as maintaining long-term stability up to 100 hours at a constant current of 10 mA cm^{-2} in an alkaline aqueous medium. Detailed structural analyses using cyclic voltammetry, high-resolution electron microscopy, X-ray-based energy-dispersive spectroscopy and photoelectron spectroscopy, as well as Raman spectroscopy, elucidate how the intrinsic amorphous structure of these materials facilitates rapid charge transfer and surface reconstruction, thereby enhancing HER/OER performance.

REFERENCES

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Oral Lecture

Session Time:October 19 16:55-17:10 Location:Meeting room C

Dr. Weizhen Wang

- BS in Material Science and Engineering at Shanghai Jiaotong University.
- PhD in Material Engineering at McGill University.
- Shenzhen Overseas High-Caliber Personnel.
- 10 year+ thin film deposition experience, application fields including new energy, nanotechnology, medical devices, etc.
- 7 year+ clean-room experience, proficient in nanofabrication.
- Proficient in material characterization, e.g. TEM, SEM, XRD, Ramam spectroscopy, etc.
- Expert at developing new techniques, R&D 100 winner, 5 academic paper, 10+ patents.

TOPIC

Applications of atomic layer deposition in Perovskite Solar Cells

Author Weizhen Wang
Affiliation: Shenzhen Yuansu Optoelectronics Technology CO LTD, Shenzhen

ABSTRACT

Today, silicon solar cell is the mainstream technology in the field of photovoltaic, since it has high efficiency, excellent stability, complete production chain and long lifetime. However, the further improvement of silicon solar cell conversion efficiency has reached the bottleneck. Moreover, the silicon solar modules manufacturing process is relatively expensive and complex(3 days and more than 4 steps), thus not optimized to power grid in terms of $/watt. In order to develop the thrid generation solar cells, people are mainly focusing on novel materials, and perovskite solar cells is one of the most promising techniques. Perovskite tandem cells can achieve a high efficiency of 50% and their fabrication processes are also simple and low-cost. That being said, how to fabricate large-scale perovskite solar cells is still a high technical hurdle.

Atomic layer deposition (ALD), with its unique ability to grow super-uniform, high-density nano-scale films, is now widely used in growing electronic transport layers in pervoskite solar cells to enhance the cell performances. SUPERALD has demonstrated great develpments in ALD techniques, and can provide ALD equipments and technical advice for R&D, pilot plant, 100MW and GW production lines.

Oral Lecture

Session Time:October 19 17:10-17:25 Location:Meeting room C

Seonyeong Park

Seonyeong Park received her B. A. degree from Yonsei University in 2020, and is working on her Ph. D. at the same school under the direction of Hyungjun Kim. Her research interests include ALD process development, and high-k materials.

TOPIC

Effects of Interlayer Formation by Oxidants and Substrates on Properties of ALD ZrO_2 Thin Film

Seonyeong Park[1], Seunggyu Na[1], Yujin Lee[1,2], Seung-min Chung[2], and Hyungjun Kim[1,*]
[1]School of Electrical and Electronic Engineering, Yonsei University, Seodaemun-Gu, Seoul 03722, Korea
[2]Department of Chemical Engineering, Stanford University, Stanford, California 94305, United States

ABSTRACT

Although high integration density and capacitance were obtained by reducing the dielectric SiO_2 thickness in the early stage of DRAM development, SiO_2 reached a fatal limit of physical thickness as it continued to be scaled, which led to an increase in leakage current. To break through this, SiO_2 was replaced by high-k materials. ZrO_2 is attracting attention because of its good thermal stability, high-k value and wide bandgap. However, when high-k film is deposited on widely used TiN electrode, interlayer formed between high-k film and TiN deteriorates the electrical property such as increased leakage current. The interlayer is formed due to the oxidation of the electrode during the film deposition process, which is affected by the potential barrier height (PBH) of the oxidation reaction[1]. Since the PBH depends on the work function of the electrode, proper electrode selection is required. Studies have been reported on Pt, Au, Ag, etc.[1] as electrode, but the high price makes it difficult to apply in real industry. Ru is recognized as a promising material due to its good thermal stability, low resistance, high work function, and relatively inexpensive among noble metals[2]. In this study, we compared effects of bottom electrode on ZrO_2 film properties using Ru and TiN. In addition, O_2 plasma and H_2O_2 were also compared to find proper oxidant that reduces substrate oxidation.

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Sunday, Oct 20th , 2024

09:00-11:00

Shanghai Ballroom

www.ap-ald.org

Invited Lecture

Session Time:October 20 09:00-09:20 Location:Meeting room A

Prof. Gang He

Gang He received the Ph.D. degree from the Institute of Solid State Physics, Chinese Academy of Sciences, Hefei, China, in 2006. He joined Anhui University, Hefei, China, and became a Professor in 2012. His current research interests include III-V-based MOSFET, flexible displays devices, functional oxide-based thin-film transistor and neural synapse device devices.

TOPIC

ALD-Driven Passivation Layer for IGZO-Based TFTs Devices

Yongchun Zhang[1]and Gang He[1*]
School of Materials Science and Engineering, Anhui University, Hefei 230601, China

ABSTRACT

High speed operation and low power consumption requirements have accelerated the development of thin film transistors (TFTs) with exploration of gate dielectrics.[1,2] In this work, the integration of all-sputtering-derived HfGdO high-k gate dielectric with amorphous InGaZnO (a-InGaZnO) films has been reported, yielding significant improvements in the performance of a-InGaZnO TFTs. By adjusting the multilayer dielectric sequence, TFTs device performance can be precisely manipulated. It has been detected that a-InGaZnO TFTs with optimized Al_2O_3/HfGdO dielectric configuration have demonstrated superior electrical performance, including a high field-effect mobility (μ_{FE}) of 23.3 $cm^2 \cdot V^{-1} \cdot S^{-1}$, a large on/off current ratio of 1.2×10^7, a low subthreshold swing of 0.09 V/dec, and good stability under bias stress, respectively. Finally, a low-voltage-operated resistor-loaded unipolar inverter has been assembled on the base of Al_2O_3/HfGdO/a-InGaZnO TFTs, demonstrating full swing characteristics and high gain of ~20. All the experimental results indicate promising potentials for all-sputtering-derived Al_2O_3/HfGdO laminated dielectrics toward the achievement of low-cost, low-power consumption, and large-area all-oxide optoelectronics.

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2,Nomura, K.; Ohta, H.; Takagi, A.; Kamiya, T.; Hirano, M.; Hosono, H. Room-Temperature Fabrication of Transparent Flexible Thin-Film Transistors Using Amorphous Oxide Semiconductors. Nature **2004**, 432, 488−492.

Invited Lecture

Session Time:October 20 09:20-09:40 Location:Meeting room A

Prof. Ai-Dong Li

Professor of College of Engineering and Applied Sciences, Nanjing University. She received B.S. degree in Zhejiang University, M.S. degree in Harbin Institute of Technology, and Ph.D. degree in Nanjing University. Her main researches focus on atomic/molecular layer deposition-fundamental and applications, and information/energy storage/sensor materials and devices. She has published 300 peer-reviewed journal papers and obtained 30 China Patents. She was awarded as second-class prize of National Natural Science of China in 2005.

TOPIC

Optoelectronic Artificial Synaptic Devices Based on ALD/MLD Inorganic-Organic Hybrid Thin Films

Ai-Dong Li*, Song Sun, Lin Zhu, Shuai Zhang and Chen Wang
National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, P. R. China

ABSTRACT

Facing the urgent need of next-generation information technology for brain-like chips beyond von Neumann architecture, the optoelectronic neuromorphic devices combine the advantages of electricity and optics, with wide bandwidth, low RC delay, and low power consumption, showing enormous potentials in brain-inspired artificial neuromorphic computing. Our work focuses on the design, fabrication and characteristics of optoelectronic artificial synaptic devices based on atomic/molecular layer deposited (ALD/MLD) inorganic-organic hybrid thin films, such as ZnO/Zn-HQ and SnO_2/Ti-HQ (hydroquinone). These hybrid devices exhibit improved photoelectric response with obvious current relaxation effect, compared to single metal oxide ones. A series of biological synaptic functions have been confirmed, including transition from short-term plasticity to long-term plasticity, paired-pulse facilitation, conditioning reflexes, and pattern-recognition, especially the ultralow energy consumption of ~1.1 fJ at 0.1 mV and the robustness in ambient. The related mechanism has been proposed. This research paves a way for the ALD/MLD-derived inorganic-organic hybrid optoelectronic synapse applications in energy-efficient neuron network systems.

Oral Lecture

Session Time:October 20 09:40-09:55 Location:Meeting room A

Wei Meng

A Ph.D. candidate at the School of Microelectronics, Fudan University, focusing on research in Atomic Layer Deposition (ALD) processes, oxide semiconductor thin films, and the fabrication and application of hafnia-based ferroelectric materials.

TOPIC

PEALD TiO_2-based FeFET Memory with $Hf_{0.45}Zr_{0.55}O_x$ Ferroelectric Films

Wei Meng, Binbin Luo, Ze Shang, Ming Yang, Bao Zhu, Xiaohan Wu, Shi-Jin Ding*
Affiliation: School of Microelectronics, Fudan University, Shanghai, 200433

ABSTRACT

Ferroelectric transistor memory based on ferroelectric hafnium oxide has attracted significant interest due to its simple structure and excellent compatibility with advanced CMOS fabrication technologies. The application of oxide semiconductor channels can avoid the issue of the low-k interfacial layer that inevitably arises in the process of fabricating FeFETs based on traditional Si-based transistors, while also enabling a lower processing temperature. In this study, PEALD TiO_2 thin films are used both as the channel and the capping layer, effectively promoting the formation of the ferroelectric orthorhombic phase while simplifying the fabrication process. With an optimized TiO_2 thickness of 10 nm, FeFETs annealed at 375 °C demonstrate a memory window of 1.57 V. The devices exhibit an endurance of up to 10^8 cycles and a retention time exceeding 10 years at 85 °C, along with stable 3-bit storage capability. This approach presents a promising candidate for memory cells in three-dimensional integrated circuit applications.

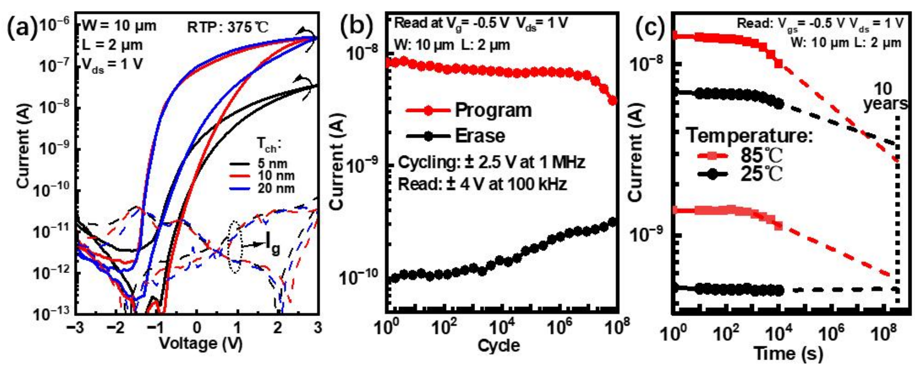

Figure1, (a) Transfer curves of FeFETs with varied TiO_2 thickness, (b) Endurance and (c) Retention characteristics.

Invited Lecture

Session Time:October 20 09:20-09:40 Location:Meeting room B

Prof. Jiaming Sun

Professor Jiaming Sun received his bachelor degree from Department of Physics, Jilin University in 1991. He got his Ph. D from Changchun Institute of Fine optical Mechanics and Physics in 1998. He worked as a post-doctoral fellow in Tokyo University Japan from 2000-2001 and Institute of Ion Beam Physics and Materials, Helmholtz-Zentrum Dresden-Rossendorf in Germany from 2001 to 2006. Then he became a professor in School of Material Science and Engineering Nankai University since 2006. He has worked in different silicon-based light emitting devices for more than 30 years and involving in more than 110 publications. In the past 15 years, he is focused on rare earth doped oxide thin film electroluminescence devices on silicon by atomic layer deposition technology.

TOPIC

Electroluminescence from rare earth doped gallium oxide and gallate films grown by atomic layer deposition

Zhimin Yu, Kang Yuan, Li Yang, Zhiqiang Ma, Yang Yang and Jiaming Sun*
School of Material Science and Engineering, Nankai University, City, Tianjin, 300350,

ABSTRACT

Rare earth doped Ga_2O_3 oxide, Ga_2O_3/Al_2O_3 nanolaminates, $Y_3Ga_5O_{12}$, $Lu_3Ga_5O_{12}$, $Y_3(AlxGa_{1-x})_5O_{12}$ garnet and $MgGa_2O_4$ spinel were deposited by atomic layer deposition (ALD) on silicon. The dependence of the boundary parameters between polycrystalline and amorphous nanofilms are summarized concerning the thickness ratio as well as the composition in the nanolaminates. The optoelectronic performances including the EL intensities, emission efficiencies, conduction mechanism and the operation stability of metal–oxide-semiconductor light-emitting devices (MOSLEDs) based on polycrystalline nanofilms are evaluated according to the different deposition parameters of nanolaminates. Efficient and stable infrared electroluminescence from Er-doped Ga_2O_3 and Ga_2O_3/ Al_2O_3 nanolaminates with external quantum efficiency up to 27% was observed. Bright white electroluminescence was observed from polycrystalline dysprosium-doped yttrium gallium garnet nanofilms with the maximum external quantum efficiency and the optical power density reaching 6.35% and 18.13 mW/cm^{-2}.

REFERENCES

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3. Zhimin Yu, Zejun Ye, Yang Yang and Jiaming Sun, Bright white electroluminescence from polycrystalline dysprosium-doped yttrium gallium garnet nanofilms fabricated by atomic layer deposition on silicon, Nanoscale,2023,15, 9130-9138.

Oral Lecture

Session Time:October 20 09:40-09:55 Location:Meeting room B

Zheng Chen

Zheng Chen, College of Physics, Changchun University of Science and Technology, is engaged in the research of flexible thin film encapsulation of foldable organic light-emitting devices.

TOPIC

Plasma enhanced atomic layer deposition of SiO_2 thin film for efficient encapsulation of organic light-emitting devices

Zheng chen[1,2], Yu Duan[1,2]
[1] College of Physics, Changchun University of Science and Technology, Changchun, Jilin Province;
[2] State Key Laboratory on Integrated Optoelectronics, College of Electronic Science & and Engineering, Jilin University, Changchun, Jilin, China

ABSTRACT

To enable organic light-emitting devices (OLEDs) to be rolled and folded, we need a flexible encapsulation layer that can protect organic materials and metal electrodes that are susceptible to moisture and oxygen. Thin film encapsulation for OLEDs need to have excellent mechanical properties to prevent cracks during bending. Silicon dioxide (SiO_2) films have received great attention as dielectric materials for the gate dielectric of transistors and the insulator of capacitors, and water barrier layers for OLEDs. In this study, we mainly discuss the growth mechanism of SiO_2 thin film for flexible OLED encapsulation using plasma enhanced atomic layer deposition (PEALD). The SiO_2 experiments were conducted using di-(isopropyl amino)-silane (DIPAS) with N_2O plasma as the oxidant. Through the analysis of SiO_2 film forming parameters, such as RF power, pressure, and gas flow, the mechanism of film growth and stress generation was investigated. Stresses were evaluated by UV-Raman spectroscopy, and SiO_2 densities and chemical bonding states were evaluated by X-ray photoelectron spectroscopy and Fourier Transform Infrared Spectroscopy, respectively. It can be controlled by optimizing the process conditions. In addition, the stress stability and the fluctuation of in-plane stress with time are also investigated. In the end, PEALD-SiO_2 thin film has excellent three-dimensional retention to improve the encapsulation stability of flexible OLED. The water vapor transmission rate (WVTR) of the thin film could reach up to 5×10^{-4} $g/m^2\cdot day$.

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Invited Lecture

Session Time:October 20 09:55-10.15 Location:Meeting room A

Prof. Tianyu Wang

Tianyu Wang, researcher at the School of Integrated Circuits, Shandong University, talent under the National Innovation Program, and high-level talent in Shandong Province. He graduated from the School of Microelectronics of Fudan University. Research interests include flexible memristors, low-power in memory-computing electronics. He has published 80 SCI papers and applied 83 patents, including Nature Communications, Nano Letters, Advanced Science, Angew. Chem. Int. Ed., Nano Energy, Materials Horizons, and IEEE Electron Device Letters.

TOPIC

ALD based flexible memristor for low power in-memory computing

Tianyu Wang[1,3], Kangli Xu[2,3], Jialin Meng[2,3], David Wei Zhang[2,3], and Lin Chen[2,3*]
[1]School of Integrated Circuits, Shandong University, Jinan 250100, China
[2]School of Microelectronics, Fudan University, Shanghai 200433, P. R. China
[3]National Integrated Circuit Innovation Center, Shanghai 201203, China

ABSTRACT

The classical von Neumann computing scheme is suffering a bottleneck of complex information processing and storage[1]. In order to improve computing efficiency, In-memory Computing architectures were proposed to complete computing tasks based on storage units, including neuromorphic computing and logic-in-memory. On one hand, neuromorphic computing has become an attractive candidate due to the high efficiency by emulating the computing mode of human brain[2]. Memristors with continuously adjustable conductance induced by voltage stimulation are suitable for simulating the weights update of bio-synapse. The ALD flexible artificial neural network (ANN) based on the integration of three-dimensional (3D) memristors network was proposed. Based on the structure of Pt/HfAlOx/TaN, the 3D ANN exhibits ultralow power synaptic characteristic (4.28 aJ/spike) under spike of 50 ns. The power consumption is 2-4 orders of magnitude lower than that of biological synapses. The 3D ANN has realized the function of information transmission, which could successfully transfer the letters “F”, “F” and “U” between the synapses of multilayer nerves. For the "0-9" digital images (28×28 pixels), the 3D ANN can complete the recognition processing, and the recognition rate can reach 88.8%. This work provides effective guidelines for the development of memristor for low power consumption in-memory computing system.

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Oral Lecture

Session Time:October 20 10:15-10:30 Location:Meeting room A

Binbin Luo

Luo Binbin is a Ph.D. student at the School of Microelectronics, Fudan University. He is also a member of ALD Technology and Functional Device team. His research focuses on ultrathin amorphous oxide semiconductors thin film transistors.

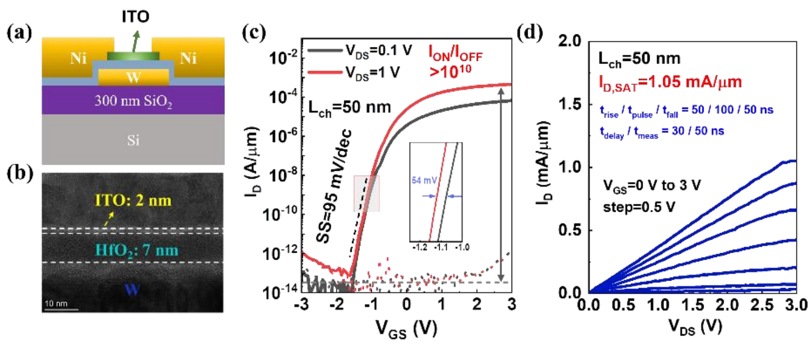
TOPIC

Atomic-Layer-Deposited InSnO Thin-Film Transistors with Scaled Channel Length

Binbin Luo[1] and Shi-jin Ding*
School of Microelectronics, Fudan University, Shanghai 200433, China

ABSTRACT

Indium tin oxide (ITO), known for its high optical transmittance and exceptional electrical conductivity, is widely used as transparent conducting electrodes in display backplanes. Recently, many works have demonstrated the potential of ultrathin ITO thin-film transistors (TFTs) as BEOL-compatible devices, thus prompting intensive research for their future applications in logic and memory devices, including complementary metal-oxide semiconductors (CMOS), dynamic random-access memory (DRAM), and nonvolatile memory. In this work, ultrathin indium tin oxide (ITO) films are investigated for back-end-of-line (BEOL) compatible thin film transistors (TFTs) by plasma-enhanced atomic layer deposition (PEALD). By optimizing the ITO channel composition and thickness, and a novel post-channel annealing process, the resulting TFT exhibits high performance (μ_{FE} = 28.3 cm^2/Vs, V_{th} = -0.29 V, SS = 123 mV/dec), and especially extraordinary thermal stability. Further, a scaled channel length of 50 nm is achieved with outstanding electrical performance, including an I_{ON}/I_{OFF} ~ 10^{10}, an I_{ON} of 1.05 mA/μm, and an Rc of 0.435 Ω·mm. Moreover, the device shows excellent reliability under positive bias temperature instability (PBTI) stress even at 125 °C, V_{stress} of 3 V (E_{ox}= 4.2 MV/cm). Thus, our work provides a promising candidate for BEOL-compatible transistors in monolithic 3D integration.



Oral Lecture

Session Time:October 20 10:30-10:45 Location:Meeting room A

Linlong Yang

Linlong Yang graduated with a bachelor's degree from the School of Materials Science and Engineering at Tongji University. Currently, he is a Ph.D. student in the group of Professor Shi-Jin Ding at the School of Microelectronics at Fudan University. His primary research focus is on top-gate thin-film transistors and memory devices based on oxide semiconductors using atomic layer deposition.

TOPIC

Fluorine-treated top-gate InAlZnO TFT for 2T0C DRAM with >1 ks retention time at V_{hold} = 0 V

Linlong Yang[1], Bao Zhu[1], Xiaohan Wu[1,2*], Shi-Jin Ding[1,2*]
1 School of Microelectronics, Fudan University, Shanghai 200433, China
2 Jiashan Fudan Institute, Jiaxing, Zhejiang 314100, China

ABSTRACT

Recently, amorphous oxide semiconductors have attracted extensive attention in 2T0C DRAM. However, most of the reported AOS TFTs used in 2T0C DRAMs present a negative threshold voltage (V_{th}), and thus a relatively negative hold voltage (V_{hold}) is required to achieve a long retention time. Moreover, the reported 2T0C DRAMs are mainly based on AOS TFTs with structures of bottom-gate, dual-gate, channel-all-around, etc., while the top-gate structure is rather neglected. In fact, the top-gate is a desirable structure because of the excellent scaling and integration capabilities, and thus investigation on 2T0C DRAMs with top-gate AOS TFTs is needed. Our previous work found that 2T0C DRAM cells based on ALD InAlZnO (IAZO) bottom-gate TFTs could achieve a >30 ks retention time, indicating that the ALD IAZO is an excellent channel candidate for the 2T0C DRAMs. In this work, we investigate the effect of F treatment on the performance of top-gate IAZO TFTs with 5-nm channel thickness, and V_{th}, I_{on}, and bias-stress stability of the devices are optimized by modulating the F-treatment parameters and other fabrication processes. Then, 2T0C DRAM cells based on the top-gate IAZO TFTs are fabricated, and the retention characteristics at V_{hold} = 0 V and endurance properties are studied.

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2, C. Gu, et al, High-performance short-channel top-gate indium-tin-oxide transistors by optimized gate dielectric, IEEE Electron Device Lett., 2023, 44(5), 837-840.
3, Q. Hu, et al, Optimized IGZO FETs for capacitorless DRAM with retention of 10 ks at RT and 7 ks at 85 °C at zero V_{hold} with sub-10 ns speed and 3-bit operation, in IEDM Tech. Dig., 2022, 26.26.21-26.26.24.

Oral Lecture

Session Time:October 20 10:45-11:00 Location:Meeting room A

Ming Yang

A Master. candidate at the School of Microelectronics, Fudan University, focusing on research in Atomic Layer Deposition (ALD) processes, oxide semiconductor thin films, and thin film transistor (TFT).

TOPIC

First Demonstration of BEOL-Compatible InMgO Transistor By Atomic-Layer-Deposited

Ming Yang, Binbin Luo, Wei Meng , Bao Zhu, Xiaohan Wu, Shi-Jin Ding*
Affiliation: School of Microelectronics, Fudan University, Shanghai, 200433

ABSTRACT

Since the first report of amorphous IGZO thin-film transistors, amorphous oxide semiconductors have attracted significant interest due to their high electron mobility, low off-state current, low-temperature processing, excellent uniformity, and wide flexibility[1–3]. Among these materials, In_2O_3-based semiconductors stand out as one of the most promising candidates owing to their exceptional carrier mobility. However, the tendency of oxygen atoms to diffuse in In_2O_3-based films creates oxygen-related defect sites, leading to stability challenges[3,4]. Doping strategies are commonly employed to strike a balance between mobility and stability. In this study, we present for the first time the use of ultra-thin atomic layer deposition (ALD) InMgO as a novel back-end-of-line (BEOL) channel material for monolithic 3D integration. By tuning the In/Mg ratio through ALD cycles, devices with a 5 nm channel thickness demonstrate remarkable electrical performance, including a near-zero threshold voltage at 0.11 V, ultra-low subthreshold swing as low as 76 mV/dec, excellent field-effect mobility μ_{FE} = 11 $cm^2/V{\cdot}s$, and a high on/off current ratio up to 10^9.Additionally, through pre-annealing of the channel and optimization of the electrode contacts, the devices exhibit exceptional thermal stability. Following a 30-minute anneal at 300°C in N_2, the threshold voltage shift is limited to just 1 mV. Even after annealing at 400°C in N_2 for 30 minutes, the threshold voltage changes by only -0.13 V

Invited Lecture

Session Time:October 20 09:55-10:15 Location:Meeting room B

Prof. Seong-Yong Cho

Seong-Yong Cho received his BS and PhD in Materials Science and Engineering from Seoul National University in Korea. After working as a postdoctoral research associate at University of Illinois, he began his independent research career at Myongji University. And, now he moved to Hanyang University as an associate Professor. His research background is nanomaterials and research interests are graphene growth mechanism, thin film characterization and nanorod heterostructure light-emitting diode.

TOPIC

Atomic Layer Deposition Approaches for Future Emissive AR/VR Applications

Seong-Yong Cho
Dept. of Photonics and Nanoelectronics, Hanyang University, Ansan 15588, Korea

ABSTRACT

Colloidal quantum dot-based light-emitting diodes (QD-LEDs) are one of the future emissive displays and high-resolution patterning of quantum dot (QD) films is one of the preconditions for the practical use of QD-based emissive display. In this study, we introduce the ZnO interlayer by atomic layer deposition (ALD) to enhance the performance and lifetime of CdZnSeS/ZnS core/shell QD-LEDs. Recently, inkjet and transfer printing have been actively developed; however, high-resolution patterning is still limited owing to nozzle clogging issues and the coffee ring effect and kinetic parameters such as pick-up and peeling speed. Consequently, employing direct optical lithography would be highly beneficial owing to its well-established process in the semiconductor industry. However, exposing the photoresist (PR) on top of the QD film deteriorates the QD film underneath. This is because the majority of the solvents for PR easily dissolve the pre-existing QD films. We present a conventional optical lithography process to obtain solvent resistance by reacting the QD film surface with diethylzinc precursors. It was confirmed that, by simple surface crosslinking of the QD surface and coating of the PR, a typical photolithography process can be performed to generate a red/green/blue pixel of 3000 PPI or more. QD electroluminescence devices were fabricated with all primary colors of QDs; moreover, compared to reference QD-LED devices, the patterned QD-LED devices exhibited enhanced brightness and efficiency.

REFERENCES

1. J. Y. Lee. S.-Y. Cho et al., High-Resolution Multicolor Patterning of InP Quantum Dot Films by Atomic Layer Deposition of ZnO. ACS Photonics, 2023, 10(8), 2598-2607
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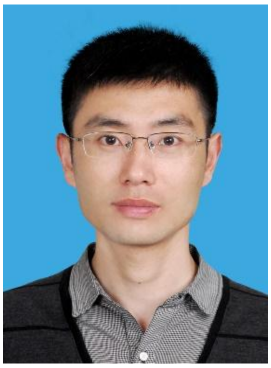
Invited Lecture

Session Time:October 20 10:15-10:35 Location:Meeting room B



Prof. Xingwei Ding

Xingwei Ding, Ph.D., Associate researcher in Shanghai University, has won the Shanghai Youth Science and Technology Talents Sailing Program, the First Prize of Shanghai Science and Technology Progress in 2020, and the 7th Shanghai Vacuum Youth Innovation Award. Dr. Ding presided over one National Natural Science Foundation project, one Youth project, and over 13 company projects focusing on ALD technology. With over a decade of experience in ALD technology, he has published more than 30 SCI papers in esteemed journals such as IEEE EDL, IEEE TED, Science Bulletin, etc. Additionally, he holds two authorized ALD invention patents and two ALD utility model patents. His primary research interests include ALD process development, ALD oxide thin film transistor technology, and ALD equipment development.

TOPIC

Self-developed ALD equipment and its application in high mobility IGZO-TFTs

Luoqiang Wang, Kun Bai, Jun Yang, Xingwei Ding*, Jianhua Zhang
Key Laboratory of Advanced Display and System Application, Ministry of Education, Shanghai University, Shanghai, 200072

ABSTRACT

In recent years, ALD technology has been widely applied in the industry, driven by the rapid development of precursor materials, equipment, and semiconductor technology. Especially for 3D structured microelectronic devices, ALD technology serves as a core solution to achieve uniform film growth in three dimensions. High-mobility IGZO-TFT devices are the core technology for high-resolution displays and 3D NAND/DRAM. In this study, the research group at Shanghai University has developed its own atomic layer deposition equipment and conducted systematic researches on the film process, device, and equipment, successfully achieving the preparation of ultra-high-quality dielectric layers. Furthermore, the study explores the fabrication process and device stability mechanism of high-mobility IGZO-TFT.

REFERENCES

[1] Chuanxin Huang, Dianguo Ma, Zhongkai Guo, Haiyun Yao, Kaikai Lv, Zhongjun Tian, Lanju Liang,Ju Gao, Yunyun Liu , and Xingwei Ding*, Enhanced Stability of SiZTO TFT Under Positive Voltage and Light Negative Voltage Stress and Modified Hysteresis of the CNTs/SiZTO CMOS Inverter by Si Doping, Transactions on Electron Devices, 70 (2023)4213-4219.

[2] Zihui Chen, Jun Yang, Xingwei Ding*, Xifeng Li, and Jianhua Zhang, High-Performance Fully Thermal ALD-Processed IGZO Thin Film Transistors, Transactions on Electron Devices,71(2024) 1963-1968.

Oral Lecture

Session Time:October 20 10:35-10:50 Location:Meeting room B

Guanran Wang

Guanran Wang, male, born in 2000 in Siping City, Jilin Province. 2022, is pursuing his master's degree in Jilin University. Currently, his main research interests are the preparation of ultra-flexible thin film encapsulation film using atomic layer deposition technology, and the improvement of atomic layer deposition process aspects.

TOPIC

Low residual stress flexible thin film encapsulation of 2 mm bending radius based on atomic layer deposition

Guanran Wang, Yu Duan*
Affiliation: Coll Elect Sci & Engn, State Key Lab Integrated Optoelect, Jilin Univ, Changchun, Jilin province, 130012

ABSTRACT

Plasma-enhanced atomic layer deposition (PEALD), is a prevalent preparation method of thin film encapsulation due to its low preparation temperature, excellent densification, and good conformality. However, the film residual stress is large, can't meet the future flexible, wearable organic optoelectronic device encapsulation needs. We obtained a low-stress flexible encapsulation film with a wrinkled morphology by employing polydimethylsiloxane (PDMS) to release residual stress during PEALD. The stress magnitude of the wrinkle film exhibited a reduction from 10^3 to 10^2 in comparison to the conventional Al_2O_3 film. At the same time, due to the strong scattering effect of the wrinkled morphology, more light is scattered from the air-substrate interface, effectively improving the light extraction capability of the device, so that can be used in organic light-emitting diode (OLED) to increase the external quantum efficiency (EQE) of the device by up to 14.12%. The water vapor transmission rate (WVTR) of the wrinkle film prepared at room temperature was 4.49×10^{-5} g/m^2/day, and the mechanical properties of the films retained 92% and more of the initial encapsulation properties after 10000 repetitions at the bending radius of 2 mm.

REFERENCES

1, This article work is in submitting

Oral Lecture

Session Time:October 20 10:50-11:05 Location:Meeting room B

Di Wen

Di Wen is a doctoral student at Huazhong University of Science and Technology in Wuhan, China. Her research focuses on developing flexible ultra-barriers using atomic layer deposition technology for encapsulating flexible electronics in displays and wearables. She has published 11 papers in international journals.

TOPIC

Atomic-Scale Stress Modulation of Nanolaminate for Micro-LED Encapsulation

Di Wen, JiaCheng Hu, Ruige Ruan, Kun Cao, and Rong Chen*
State Key Laboratory of Intelligent Manufacturing Equipment and Technology, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People's Republic of China.

ABSTRACT

Micro/Nano-LEDs for AR and VR applications face the challenge that the edge effect in Micro-LEDs become significant as size of devices shrinks. This issue can be effectively addressed through thin film encapsulation, where the zero stress of the thin film is crucial factor, apart from barrier property. Process optimization effectively controls the residual stress in monolayer films. However, achieving zero stress often leads to a compromise in performance. Herein, a stress modulation strategy is developed through binary-cycle atomic layer deposition (ALD) process combining PEALD SiO_2 (compressive stress) and thermal ALD Al_2O_3 (tensile stress) at the same process window. The hybrid ALD process avoids the extra thermal stress generation and enables precise modulation of atomic-scale thickness, fabricating nanolaminates with modulated stress. The optimal nanolaminate, with near-zero stress, features a high-low refractive index, a tortuous permeation path, and ultra-thin layers, showcasing exceptional barrier properties and an anti-reflection effect. Moreover, micro-LED encapsulated with $SA_{2/1}$ exhibits excellent stability under thermal cycling, damp heat, and applied stress conditions. The mechanical stability of nanolaminate is due to the strong interaction between Si-O and Al-O and an abundance of Si-O-Al bonding in the interface. Overall, the ALD coating process provides a new avenue for accurate controlling of stress on the nanolaminates, and potential application to bolster the reliability of optoelectronic devices.

REFERENCES

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Oral Lecture

Session Time:October 20 10:35-10:50 Location:Meeting room B

Yuhan Wang

Yuhan Wang, male, born in 2002 in Shangrao City, Jiangxi Province, 2024, is pursuing his docter's degree in Jilin University. Currently, his main research interests focuses on the inorganic hybrid film deposited by atomic layer deposition using precursor partial pressure and precursor steric effects, and the area-selective atomic layer deposition.

TOPIC

Future of ultra-flexible thin film encapsulation of optoelectronic devices based on atomic layer deposition

Yuhan Wang, Yu Duan*
Affiliation: Coll Elect Sci & Engn, State Key Lab Integrated Optoelect, Jilin Univ, Changchun, Jilin province, 130012

ABSTRACT

Atomic layer deposition (ALD) offers exceptional film formation densities and encapsulation properties which makes ALD ideally suited for the requirements of thin film encapsulation (TFE). The flexible thin film encapsulation facilitated by ALD has progressed through three stages: initially, the flexible encapsulation of pure inorganic structures; followed by the flexible encapsulation of organic-inorganic composite structures; and currently, the development of organic-inorganic hybrid encapsulation. It is worth noting that flexible encapsulation with pure inorganic structures falls short in terms of mechanical properties due to the excessive Young's modulus of the inorganic material and the presence of residual stresses within the film, although it exhibiting outstanding encapsulation properties. As a result, organic and inorganic composite encapsulation films have been developed using the idea of "division of labour". Their encapsulation feasibility has been verified. However, the "division of labour" will inevitably increase the difficulty of the overall device preparation and application risk, which is not conducive to the future application of ultra flexible encapsulation. We believe that the organic and inorganic films in the encapsulation film as "functional homogenization" or release the excessive residual stress in the inorganic film will be the future direction of the realisation of ultra - flexible encapsulation film.

REFERENCES

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Poster Abstracts

Friday, Oct 18th , 2024

17:15-18:30

Shanghai Ballroom

www.ap-ald.org

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Maksumova Abay Malikovna

Maksumova Abay Malikovna, Bachelor of Chemistry (2018), Master of Chemistry (2020), PhD in Chemistry (2024). Researcher at Dagestan State University. The PhD thesis is devoted to ALD and characterization of thin films of molybdenum oxide and mixed titanium-molybdenum and aluminum-molybdenum oxide films. Research interests: atomic and molecular layer deposition, solid state chemistry, surface physical chemistry, quartz crystal microbalance, thin films, nanomedicine, materials for nanoelectronics.

TOPIC

Atomic Layer Deposition of Aluminum-Molybdenum Oxide Films: Water and Waterless Processes

Abay M. Maksumova, Ilmutdin M. Abdulagatov
Department of Physical and Organic Chemistry, Dagestan State University, Makhachkala, Russian Federation, 367000

ABSTRACT

Aluminum-molybdenum mixed oxides $Al_xMo_yO_z$, their nanolaminates Al_2O_3-MoO_x, aluminum molybdate ($Al_2(MoO_4)_3$) can be use as solid-phase electrolytes, catalysts, photovoltaic cells, dry lubricants, etc. In this work, thin film atomic layer deposition (ALD) of $Al_xMo_yO_z$ was carried out using water as a co-reactant and without (waterless processes). The $Al_xMo_yO_z$ ALD using H_2O was carried out in combination with trimethylaluminum ($Al(CH_3)_3$, TMA) and molybdenum dichloride dioxide (MoO_2Cl_2) [1]. The waterless process was conducted using TMA and MoO_2Cl_2 only. The ALD processes were studied from 120 to 180 °C using in situ quartz crystal microbalance (QCM) and ex situ using number of spectroscopic techniques such as XRR, XPS and ellipsometry. The QCM showed film linear growth with number of ALD cycles and self-limiting surface reactions of the precursors. The film growth rate determined by XRR varied from 3.5 to 5.5 Å/supercycle and the density from 3.4 to 3.7 g/cm³ depending on the surface chemistry used. The obtained films had an amorphous structure. XPS data showed that the films contained some amount of carbon and chlorine impurities (2 - 4 at.%), and Mo had oxidation states of +6, +5 and +4. These data suggested that TMA chemically reduces molybdenum to the lower oxidation states and surface chemistry modification is needed to retain original +6 oxidation. This research also showed that $Al_xMo_yO_z$ thin films can be deposited using oxi groups on molybdenum precursor as an oxygen source.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Byung-ha Kwak

Byung-ha Kwak is in the first semester of his master course in Department of Intelligence Semiconductor Engineering, Ajou University, South Korea, since 2024 fall. The main topic of his research is fabrication of rare-earth transition metal oxide by using vertical controlling method in ALD for device applications. During his master course studies, he works under the supervision of Prof. Il-kwon Oh.

TOPIC

Comparative Study on Lateral and Vertical Controlling of Atomic Arrangement in Multielement Oxides Grown by Atomic Layer Deposition; a Case Study of Dy-Doped HfO_2

Byung-ha Kwak [1], Ngoc Le Trinh[2], Wonjoong Kim[2], Han-Bo-Ram Lee[2] and Il-kwon Oh[1*]
[1] Department of Intelligence Semiconductor Engineering, Ajou University, Suwon, Korea
[2] Department of Materials Science and Engineering, Incheon National University, Incheon, Korea

ABSTRACT

As semiconductor devices continue to scale down, high-k materials face the challenge of a trade-off between band gap and dielectric constant. In this study, we aim to enhance electrical properties by doping Dy into HfO_2 thin film using two methods with different atomic arrangements: lateral controlling (so called as supercycle ALD) and vertical controlling (so called as atomic layer modulation, ALM). The lateral controlling method involves few cycles of Dy_2O_3, followed by multiple HfO_2 cycles. This method can easily control doping concentration of DyHfO films by controlling cycle ratio.[1] But lateral controlling method have limitations when controlling doping concentration films under 5 nm, as it requires a minimum thickness to maintain a consistent concentration across the film. In contrast, the vertical controlling method can control atomic concentration by sequently exposing two precursor(Dy, Hf) in a first-half cycle of ALD process and expose single reactant that react both precursors at the second-half cycle, determined by chemical reactivity and steric hindrance of two precursors.[2] This method allows precise atomic-level doping control even in ultrathin films under 5 nm thickness by controlling individual precursor exposure time. We observed that both Dy doped HfO_2 lateral controlling and vertical controlling thin film showed better performance of devices than single HfO_2 thin film. Interestingly, the better crystallinity was observed for lateral controlling method than vertical controlling. We believe that these approaches will significantly advance the development of high-k materials with optimized properties, supporting the future scaling down of semiconductor devices and enhancing their performance in next-generation electronic applications.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Boxuan Li

Boxuan Li, Enrolled as a graduate student in the School of Materials Science and Engineering at Huazhong University of Science and Technology in 2019. His research interests cover Atomic Layer Deposition (ALD) simulation and Density Functional Theory (DFT) chemical calculations.

TOPIC

Investigating the ALD deposition mechanism of AlO_x barriers in relation to ODT coverage

Boxuan Li[1], Yanwei Wen[2], Bin Shan[2] and Rong Chen[1]*
[1] School of Materials Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.
[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.

ABSTRACT

Self-assembled monolayer (SAM) plays a crucial role to prevent the atomic layer deposition (ALD) on undesired region to achieve high-precisely area-selective deposition in semiconductor manufacturing. The study found that octadecanethiol (ODT) can pack closely on a Cu substrate. Under the close coverage of ODT on Cu, the deposition of DMAI and TEA can be effectively blocked due to the strong repulsion of the two precursors to the interstitial spaces between ODT chains. However, the smaller TMA can diffuse into the SAMs through the interstitial spaces of the ODT chains and come into contact with the Cu substrate. As the coverage of ODT on the Cu substrate decreases, all three precursors can penetrate into the interstitial sites of the SAMs. Our work reveals that the blocking of ALD on SAMs highly depends on the repulsion of the precursors with organic chains rather than that of co-reactant, which implies that the steric effect is of great significance during the area-selective ALD.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Caiyu Shi

Caiyu Shi receives her bachelor's degree from the School of Microelectronics, Shandong University, Jinan, China in 2020. She is currently a Ph.D candidate in Microelectronics and Solid-State Electronics, School of Microelectronics, Fudan University, Shanghai, China. The scope of her research encompasses the growth of Metal oxide thin films based on the ALD process and waveguide integrated nanoscale thin film photodetector .

TOPIC

Voltage shift induced by interfacial dipole in the dielectric stack of atomic-layer deposited Nb_2O_5 ultrathin insertion layer

Caiyu Shi[1] , Lei Shen[1], Ziying Huang[1], Xinbin Ying[1], Xing Yu[1] and Hongliang Lu[1*]
Affiliation: State Key Laboratory of ASIC and System, Shanghai Institute of Intelligent Electronics & Systems, School of Microelectronics, Fudan University, Shanghai, 200433, China.

ABSTRACT

The formation of a dipole insert layer at the high k/SiO_2 interface is now attributed to be the primary reason for the shift in threshold voltage (VTH) in metal-gate CMOS. The flat band voltage (V_{FB}) of MOSCAP can be effectively adjusted by incorporating a thin layer of metal oxide. The insertion layer should possess a thin and uniform nature in order to achieve the desired control effect on VFB, while keeping the oxide equivalent thickness value (EOT) unchanged to some extent. Therefore, the atomic layer deposition (ALD) technique is considered one of the most promising methods for modulating VFB due to its exceptional control over thickness and uniformity. In this study, the ultrathin Nb_2O_5 gate insertion layer with varying thicknesses was grown in-situ on the HfO_2 layer using ALD technology. Subsequently, the Nb_2O_5/HfO_2/SiO_2 gate dielectric stack structure was constructed to modulate V_{FB}. The results indicate that the optimal experimental outcome reveals a thickness of 6 Å for Nb_2O_5, resulting in an increase of the equivalent oxidation thickness (EOT) by no more than 2 Å. In this scenario, the V_{FB} experiences a rightward shift of approximately 280 mV. Consequently, the potential application of Nb_2O_5 as the p-dipole material is evident, thereby offering a novel approach to selecting suitable gate stacks and dielectrics to meet future CMOS device requirements.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Chi Yan

Chi Yan is currently working toward the Ph.D. degree in Materials Science and Engineering with the East China University of Science and Technology. His research direction is the growth and application of atomic layer deposition barrier films on polymer and metal substrates.

TOPIC

Growth and corrosion resistance of ultrathin Al_2O_3/TiO_2 films on polydopamine-modified copper by atomic layer deposition

Chi Yan, Jialin Li, Haobo Wang, CuiLiu and Hongbo Li
East China University of Science and Technology, Shanghai, China, 200237.

ABSTRACT

Metal materials are prone to corrosion in marine environments, which reduces their performance and service life. The anti-corrosion coating prepared by conventional methods has the defects of uneven coating and insufficient density, resulting in excessive coating thickness[1]. We deposited a dense barrier film on the copper surface through atomic layer deposition (ALD) technology to improve its corrosion resistance. In order to better promote the growth and bonding of ALD film on the copper surface. We treated the copper substrate with dopamine self-assembly technology to form an intermediate polydopamine (PDA) adhesion layer on the surface of the copper substrate, and then deposited ALD-Al_2O_3/TiO_2 on the surface of the copper substrate modified by PDA. The presence of PDA coating provides abundant hydroxyl groups as reactive active sites to effectively promote the nucleation growth of ALD film[2]. The PDA coating also has certain corrosion resistance[3], and as an intermediate layer combined with the ALD inorganic coating to form an organic-inorganic hybrid coating, further improving the corrosion resistance of the metal.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Feng Gao

Feng Gao received the B.E. degree in photoelectronics and information engineering from the Shandong, University, China, in 2000, and the M.Sc. degree in micro and nano-technology from the Helsinki University of Technology, Finland, in 2006.
From 2005 to 2021, he worked as research scientist for MEMS device fabrication at the VTT Technical Research Centre of Finland. From 2021, he started working with Chipmetrics as founder and CTO, concentrating on test chip commercialization for the semiconductor industry.

TOPIC

ALD Conformality Analysis Using Lateral High Aspect Ratio Test Structures

Feng Gao[1], Anish Philip[2], Jussi Kinnunen[1], Mikko Utriainen[1]
[1] Chipmetrics Ltd., Joensuu, Finland, 80130
[2] Aalto University, School of Science and Technology, Espoo, Finland, 02150

ABSTRACT

The trend of 3D vertical scaling is revolutionizing the field of nanoelectronics, establishing the need for conformal ultra-thin films in high-aspect ratio (HAR) features for modern semiconductor manufacturing. The PillarHall® Lateral High Aspect Ratio (LHAR) test structure and its measurement methodology bypass the need for destructive cross-sectional analysis, allowing the film penetration depth (PD) profile to be assessed directly from the planner surface. In this study, we concentrated on determining the PD profile and thickness of ultra-thin ALD Al_2O_3 films on the PillarHall LHAR structures. Utilizing both optical and electron microscopy techniques, along with line-scan reflectometry and imaging ellipsometry, we discuss the benefits and limitations of each method. Our results indicate that the high-sensitivity measurement of film penetration depth profiles in LHAR, combined with physical modeling, enables precise quantification and comprehension of conformal film growth. Moreover, we examined wafer-level conformality uniformity, essential for tool qualification and process consistency in manufacturing. The integration of PillarHall test chips on silicon pocket wafers simplifies wafer-level conformality measurements. The innovative Front-End of Line (FEOL) compatible integration of PillarHall test chips with 300 mm pocket wafers presents a promising avenue for 3D thin film characterization. The synergy of PillarHall metrology wafers and imaging ellipsometry introduces a robust new toolkit for monitoring thin film conformality in advanced semiconductor device production.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Geng Ma

Geng Ma, a Master's student at Huazhong University of Science and Technology. Dedicated to exploring the mass transfer and reaction processes during SALD deposition through a combination of CFD simulations and experimental methods.

TOPIC

Analysis of growth rate and consumption under the impact of CVD caused by the substrate move in Spatial ALD

Geng Ma[1], Fan Yang[2], Bin Shan[1], Rong Chen[2*]
[1] School of Materials Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.
[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.

ABSTRACT

Increasing the deposition rate in spatial atomic layer deposition (SALD) can lead to interference from chemical vapor deposition (CVD). We develop a substrate velocity-CVD correlation model using computational fluid dynamics analysis (CFD) and adsorption kinetics theory to investigate CVD as a function of velocity. A low CVD stage with less sensitivity to changes in substrate velocity was found, and expanding this low CVD stage could be achieved by increasing the gas flow rate within the micro-gap. On this basis, CVD, coverage and precursor utilization at different input for atmospheric, low pressure and small gap states, were constructed. Small gap requires less gas and precursor consumption to fulfill the growth requirements compared to atmospheric and low-pressure states. Further exploring the input parameters, we found that decreasing the precursor flow rate input, which is not as effective as simultaneously increasing the isolated N_2 input and precursor concentration input, is conducive to reduced consumption and increased precursor utilization. Under this strategy, we developed an active learning framework that can quickly obtains the process. Experimental results confirmed that these process can deposit films with quality consistent with thermal ALD. This study is applicable to achieving cost-effective SALD processes at higher substrate velocities.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Haobo Wang

Haobo Wang received the B.S. degree in Materials Science and Engineering from East China University of Science and Technology, Shanghai, in 2020. He is currently working toward the Ph.D. degree in Materials Science and Engineering with the same university. His research interests include atomic layer deposition, silicon surface modification and surface-enhanced Raman scattering (SERS) detection.

TOPIC

ALD combined with super hydrophobic modification enhancing the water vapor barrier of PET for photovoltaic

Haobo Wang, Chi Yan, Chengyou Zhang, Hongbo Li and Cui Liu
School of Materials Science and Engineering, East China University of Science and Technology, Shanghai, 200237

ABSTRACT

Polyethylene terephthalate (PET) offers good insulation, dimensional stability, and oxygen barrier properties. Nevertheless, it exhibits limited resistance to moisture and is susceptible to hydrolysis and ultraviolet degradation at high temperatures and humidity levels. To overcome these problems, in this work, we used atomic layer deposition to deposit alumina films on the PET surface to improve the water vapor barrier of PET, and constructed a superhydrophobic structure on the PET surface with alumina by means of the sol-gel method, which effectively prolonged its time-dependent water vapor barrier. In addition, we investigated the wettability, chemical composition, chemical state of PET before and after modification, as well as its light transmittance in the UV-visible band. By adjusting the amount of ammonia and the type of modified silane, PET with superhydrophobic properties was successfully prepared, and it still has high transparency, which is favorable for the development of photovoltaic module. The construction of a superhydrophobic structure on the surface of PET after alumina deposition can effectively reduce the erosion of alumina by water and improve the time efficiency of water vapor barrier. Al_2O_3 by atomic layer deposition effectively improved water vapor barrier of PET and the constructed superhydrophobic layer improves the durability of alumina film in wet environment.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Haojie Li

Haojie Li, a graduate student at Huazhong University of Science and Technology since 2022, specializes in multiscale simulations of atomic layer deposition.

TOPIC

Kinetic Monte Carlo Simulation of the Atomic Layer Deposition of Hafnium Oxide

Haojie Li[1], Yanwei Wen[1], Bin Shan[1] and Rong Chen[2*]
[1] School of Materials Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.
[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Hubei 430074, China.

ABSTRACT

Recent advancements in the semiconductor industry have driven device miniaturization, leading to issues like current leakage and reduced electrical reliability[1]. High-k dielectrics, notably HfO_2 films, are being explored as solutions due to their superior electrical properties, such as low leakage current and high thermal stability. Atomic Layer Deposition (ALD) is essential for depositing HfO_2, offering precise thickness control and excellent conformality, particularly on heat-sensitive substrates. However, its effectiveness is highly dependent on process conditions like temperature and precursor choice. This study uses kinetic Monte Carlo (kMC) simulations, parameterized by density functional theory (DFT) calculations, to investigate the atomistic reaction mechanisms of HfO_2-ALD. Results indicate that $HfCp(NMe_2)_3$ has a lower growth rate than TEMAHf due to greater steric hindrance from the Cp ring. Higher temperatures enhance oxygen migration in the lattice, reducing oxygen vacancies, while nitrogen impurity concentrations remain relatively stable across different temperatures.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Jia-lin Li

I am a graduate student in Materials Science and Engineering at East China University of Science and Technology, specializing in Atomic Layer Deposition (ALD). My research primarily focuses on the development and optimization of ALD processes for thin-film deposition, with an emphasis on improving film uniformity, step coverage, and material properties at the atomic scale. I have hands-on experience with advanced ALD systems, including both experimental and mass production machines.

TOPIC

Atomic layer deposition of nanometric metal oxides for corrosion protection of Al alloy surfaces

Jia-lin Li, Chi Yan, and Cui Liu
East China University of Science and Technology, Shanghai, 200237

ABSTRACT

Atomic layer deposition (ALD) is a well-known technique to fabricate highly conformal barrier on Al alloy for corrosion protection. Ultrathin film of Al_2O_3, TiO_2, SiO_2 and ZnO were deposited on Al alloy using ALD, and their corrosion protection properties were measured using electrochemical impedance spectroscopy (EIS) and Potentiodynamic polarisation tests. Analysis of ~50 nm-thick films of each metal oxide demonstrated low electrochemical porosity, providing enhanced corrosion protection in an aqueous NaCl solution during initial measurements. After 21 days of exposure to a 3.5 wt% NaCl solution, the barrier effect of all coatings failed. However, by adjusting the aluminum-to-titanium ratio, Al-Ti laminated films exhibited the best coating quality after extended exposure.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Jinxiong Li

Jinxiong Li received the B.E. degree from South China University of Technology in 2021. He is currently a Ph.D. student in Materials Physics and Chemistry, Peking University. His research interests include the materials, devices, and integration applications of metal oxide thin-film transistors.

TOPIC

Plasma Fluorination of ALD In_2O_3 for Thin-Film Transistors with Remarkable Stability

Jinxiong Li[1], Shanshan Ju[1], Songjie Yang[1], Xu Tian[1], Lei Lu[2], Shengdong Zhang[2], and Xinwei Wang[1]
[1] School of Advanced Materials, Peking University, Shenzhen 518055, China
[2] School of Electronic and Computer Engineering, Peking University, Shenzhen 518055, China

ABSTRACT

Monolithic 3D (M3D) integration offers a promising solution for the continuation of Moore's Law by vertically stacking devices, which demands oxide semiconductors (OSs) that are suitable for low thermal budget thin-film transistors (TFTs). Among the common OSs, indium oxide (In_2O_3) stands out for its high intrinsic electron mobility. However, the tendency of In_2O_3 to form oxygen vacancies poses challenges to its on-off characteristic and reliability. Herein, we report the high-performance ALD In_2O_3 TFTs by CF_4 plasma fluorination [1]. The afforded In_2O_3:F TFTs exhibited enhanced electrical characteristics, including a high mobility (μ_{FE}) of 35.9 cm²/V·s, a steep subthreshold swing (SS) of 94 mV/dec, and a positive threshold voltage (V_{th}) of 0.36 V. Additionally, the In_2O_3:F TFTs exhibited superior electrical stability, with small V_{th} shifts of -111 mV and 49 mV under negative and positive bias stress conditions, respectively. These results highlight the high promise of the fluorinated In_2O_3:F TFTs for advanced M3D integration and BEOL applications.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Shen Lei

Shen Lei graduates with a bachelor's degree from the School of Electronic Science and Engineering, Jilin University, Jilin, China in 2022. He is currently a Ph.D candidate in the School of Microelectronics, Fudan University, Shanghai, China. His main research direction is wide bandgap oxide semiconductor devices based on ALD technology.

TOPIC

Large Positive V_{FB} Shift in MOS Capacitors Achieved by the Insertion of Ga_2O_3 Dipole Layer

Lei Shen, Xiao-Na Zhu, Yu-Chun Li, Cai-Yu Shi, Zi-Ying Huang, and Hong-Liang Lu*
State Key Laboratory of ASIC and System, Shanghai Institute of Intelligent Electronics & Systems, School of Microelectronics, Fudan University, Shanghai 200433, China

ABSTRACT

The electric dipole layer formed at the high-k/SiO_2 interface has been widely studied as a primary means of adjusting V_{TH} in high-k/metal gate MOS devices. Typically, two types of elements that shift the NMOS V_t negatively or positively are classified as negative dipole (n-dipole) or positive dipole (p-dipole), respectively. However, studies on p-type dipole layers remain limited. Existing p-type dipole material Al_2O_3 faces challenges such as carrier mobility degradation and reliability issues. In this work, a Ga_2O_3 dipole layer (DL) deposited at the SiO_2/HfO_2 interface by in-situ atomic layer deposition (ALD) has been demonstrate to be a great positive dipole. A large positive modulation for the flat-band voltage (V_{FB}) from 1.09 to 1.59 V is achieved, accompanied by a small equivalent oxide thickness (*EOT*) penalty of just 0.05 to 0.36 nm. X-ray photoelectron spectroscopy measurement is empolyed to vertify the modification of the band alignment with the insertion of Ga_2O_3 DL.This work indicates that ALD of Ga_2O_3 is a promising positive dipole candidate for multiple threshold voltage (multi-V_t) technology in advanced process nodes.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Liling Fu

Liling Fu is a direct PhD student in College of Engineering and Applied Sciences, Nanjing University. Her main research interest focus on the application of atomic /molecular layer deposition technology in zinc ion batteries. Currently, she is exploring ALD high- and meso-entropic oxides as surface modification coatings for zinc anode applications.

TOPIC

Construction of amorphous mesentropic oxide protective layer-assisted stable zinc metal anode by ALD

Liling Fu, Shuai Zhang, Shaozhong Chang, Ai-Dong Li*
National Laboratory of Solid-State Microstructure, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Jiangsu Key Laboratory of Artificial Functional Materials, Nanjing University, 210093, P.R China

ABSTRACT

Dendrites and side reactions on the surface of zinc metal anodes greatly limit the cycling stability of aqueous zinc ion batteries. Inspired by the high entropy concept,[1] we constructed amorphous medium entropy oxides (MEOs) of ZrSnTiYO coatings on the surface of zinc anode by atomic layer deposition (ALD). This amorphous medium entropy oxide coating shows excellent corrosion resistance and can promote the rapid transport of Zn^{2+} on the anode surface. As a result, this Zn@MEOs anode exhibits excellent cycling stability more than 1600 h at 5 mA cm^{-2} and 1 mAh cm^{-2}. Compared with the conventional preparation process of medium- and high-entropy oxides, this work combined with ALD technology realizes an amorphous medium-entropy oxide protective coating on the surface of zinc negative electrode at low temperature, which provides a new strategy to realize stable zinc metal negative electrodes.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Lin Zhu

Lin Zhu received B.S. and M.S. in Materials Engineering from College of Engineering and Applied Sciences, Nanjing University. Currently, she is a Ph.D. student in the group of Professor Ai-Dong Li at Nanjing University, focusing on the fabrication, synaptic functions and memristive mechanism of ultrathin memristors by atomic layer deposition.

TOPIC

Structural Optimization and Regulation of Ultrathin Bilayer Organic-Inorganic Hybrid Memristors by Molecular Layer Deposition

Lin Zhu, Shuai Zhang, Chuyi Zhang, Ai-Dong Li*
National Laboratory of Solid State Microstructures, Materials Science and Engineering Department, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, P. R. China

ABSTRACT

The organic-inorganic hybrid materials possess abundant physical/chemical properties and unique merits from combination of both components, enabling great potential in flexible devices due to tunability and versatility in tailoring material structures and properties. In our previous work, amino acids required for humans were considered as the organic component to construct biomimetic hybrid films. By using cysteine (Cys) as organic precursors, Ti-based cysteine hybrid films were deposited by molecular layer deposition (MLD) as a memristor medium. The Pt/Ti-Cys/TiN device exhibits volatile resistive switching (RS) behavior. To further optimize and regulate its performance, the bilayer-structured ultrathin memristor Pt/Al-Cys/Ti-Cys/TiN was prepared. The introduction of Al-Cys improves the device's RS and retention characteristics, showing repeatable nonvolatile bipolar switching with an on/off ratio greater than 10^2. Some crucial bio-synaptic functions, such as long-term potentiation, long-term depression, paired-pulse facilitation, spike rate-dependent plasticity, were also realized in this device. The hybrid bilayer memristors derived by MLD pave a new approach for flexible robust neuroscience applications.

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Ruige Yuan

Ruige Yuan is a Master course of School of Mechanical Science and Engineering, Huazhong University of Science and Technology, expected to receive the degree by June in 2025. She majors in Mechanical Engineering and is devoted to the study on atomic-scale fabrication method and process of the thin film encapsulation layers with high barrier property for bendable electronics.

TOPIC

High-Barrier ultrathin bendable nanolaminate encapsulation with a 1.2 mm bending radius

Ruige Yuan, Di Wen, Fan Yang and Rong Chen
School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074

ABSTRACT

The commercialization of flexible displays has been expanding rapidly due to their adaptability to various form factors, driving the demand for products that can withstand fatigue bending at small radii. The stability of flexible displays in ambient conditions is a major challenge. While inorganic thin film encapsulation can enhance barrier properties, its inherent lack of flexibility limits its suitability for increasingly flexible displays. In this work, a nanolaminate structure has been developed based on a stress compensation strategy involving the low-temperature deposition of ALD-Al_2O_3 with various oxidants in succession, enabling the fine-tuning of residual stress by adjusting the thickness ratio and the number of the Al_2O_3 sublayers. The optimal structure with the aid of finite element analysis, featuring the ultra-thin 10 nm film, achieved exhibits ultra-low internal stress (-7.5 MPa), an extremely low water vapor transmission rate of 2.73×10^{-5} g/m^2/day, and impressive mechanical flexibility, withstanding a bending radius of 1.2 mm for 1000 cycles. The stress compensation strategy at the nanoscale level demonstrates significant potential to deliver robust and flexible nanolaminates for use in flexible electronics with small bending radii.

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Song Sun

Song Sun devoted himself to the research of electrical properties of phase-change storage during his Master's degree. Then he worked as a process engineer in ALD Company for 1.5 years. Currently, he is a Ph.D. student in Nanjing University, focusing on the fabrication, synaptic functions and memristive mechanism of optoelectronic memristors by ALD/MLD.

TOPIC

Optoelectronic artificial synapses based on ZnO nanoporous hybrid thin films by ALD/MLD

Song Sun, Shuai Zhang, Lin Zhu, and Ai-Dong Li*
National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Nanjing University, Nanjing, Jiangsu Province, 210093

ABSTRACT

Neuromorphic computing (NC), by mimicking the connectivity and signal processing of human brain neurons, exhibits superior information processing capabilities with high efficiency and low power consumption. Notably, visual perception accounts for 80% of the external information humans acquire, underscoring its vital role in NC. Study on inorganic-organic hybrid materials for optoelectronic synapses remains scarce. [1] Herein, we present a one-step ALD/MLD process for fabricating ZnO-based inorganic-organic hybrid nanoporous structures. Compared to single ZnO film-based device, these nanoporous structures significantly enhance photoelectric responsivity with obvious current relaxation effect, attributed to their high specific surface area and abundant trap states. ZnO-based nanoporous structural devices demonstrate comprehensive synaptic behaviors, such as short/long-term plasticity, transition from short-term memory to long-term memory, and biological conditioning reflexes. Furthermore, we constructed a three-layer neural network to accomplish MNIST handwritten digit recognition with an impressive accuracy rate of 97.3%, exemplifying the exceptional performance of our devices in neural network applications.

REFERENCES

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Rongli Ye

Rongli Ye obtained her bachelor's degree in Mechanical Engineering from China University of Petroleum in 2022. She is currently a master student in the School of Mechanical Engineering at Huazhong University of Science and Technology. Her research focuses on constructing stable configurations of Pt nanoparticles via atomic layer deposition methods, improving the stability of Pt particles in high temperature oxidizing atmospheres as well as investigating their stabilization mechanisms.

TOPIC

Enhancing the thermal stability of Pt nanoparticles by constructing island-isolated configuration via area selective atomic layer deposition

Rongli Ye, Kun Cao*, and Rong Chen*
School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, People’s Republic of China

ABSTRACT

Platinum nanoparticles are widely used, but problems such as high cost, high demand, and thermal sintering make it necessary to study the reduction, stability strategy, and stability mechanism of platinum. Herein, a highly dispersed, low Pt loading (~0.5 wt%), and ultra-small size (~0.74 nm) island-isolation stable configuration is prepared by area selective atomic layer deposition method. The unsaturated process controlled by atomic layer deposition makes the deposition selectivity up to 95.1%. Before the high-temperature oxidation atmosphere treatment, hydrogen treatment is introduced, and in-situ infrared spectroscopy shows that this treatment can not only reduce PtO_x species that are prone to cause sintering but also maintain the stable adsorption peak of CO on Pt. Meanwhile, XPS characterization discovers that the orbitals of Pt 4d and Co 2p move in opposite directions with similar values, indicating that there is obvious interaction between Pt and Co. This helps to improve the stability of platinum nanoparticles. Due to the difference in metal support interaction, it is found that the treatment under a high-temperature oxidation atmosphere can induce the migration of particles on Al_2O_3 to CoO_x, which further improves the selectivity. Above all, the platinum nanoparticles in this configuration can withstand high-temperature treatment at 600℃ in the oxidizing atmosphere for 4h.

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Weiwei Du

Weiwei Du, a doctoral candidate at Zhejiang University, started her study in 2020. Her current research focuses on the performance control and area-selective deposition of functional polymer films by chemical vapor deposition. She has published 3 papers in the International Journal of Extreme Manufacturing, Progress in Polymer Science, ACS Applied Materials & Interfaces, and were invited to give an invited talk at the 2023 Spring Meeting of the American Chemical Society. She was rewarded the Endeavour Scholarship of China Education Foundation and Kingfa Science and Technology Scholarship.

TOPIC

Nanoscale Surface Strategies for Reducing Foulant Adhesion in Emulsion Polymerization

Weiwei Du and Junjie zhao
State Key Laboratory of Chemical Engineering, College of Chemical and Biological Engineering, Zhejiang University, Hangzhou, China, 310058

ABSTRACT

Emulsion polymerization is extensively utilized for producing sustainable waterborne polymer dispersions across various applications, including paints, adhesives, and synthetic rubbers. Nonetheless, fouling during this process impairs heat transfer, increases reactor downtime, and negatively impacts product quality. While existing research has largely concentrated on suppressing fouling by inhibiting polymerization reactions on reactor surfaces, strategies for mitigating foulant adhesion have not yet been explored. In fact, foulant adhesion is known as one of the primary mechanisms for fouling in emulsion polymerization.

Herein, we developed a series of durable ultrathin copolymer coatings via initiated chemical vapor deposition (iCVD) and examined the relationship between surface properties and latex foulant adhesion. Our findings reveal a transition between two adhesion mechanisms that inform design strategies for anti-fouling coatings: In the dry adhesion regime, reduced surface polarity diminishes adhesion, whereas in the hydration repulsion regime, enhanced hydrophilicity is crucial for minimizing foulant adhesion. The copolymer coatings demonstrated up to 270% lower work of adhesion compared to Fe and 71.8% reduced surface foulant density compared to stainless steel in simulated fouling assessments, indicating promising potential for fouling control in emulsion polymerization.

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Weizhen Wang

Weizhen Wang obtained his master's degree in School of Materials Science and Engineering from Wuhan University of Technology in 2023. He is currently a doctor student in the School of Mechanical Engineering at Huazhong University of Science and Technology. His research focus on redox-coupled inherently selective ALD to propose an anisotropic growth model with the dynamical competition of expansion and dissociation of the nucleus.

TOPIC

Inherently atomic layer deposition of oxides on Cu/SiO_2 with redox-coupled process

Weizhen Wang, Kun Cao, Yicheng Li, Zilian Qi and Rong Chen*
School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, China, 430074

ABSTRACT

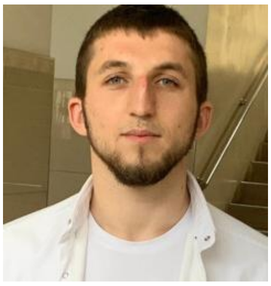
Atomic-scale precision alignment is a bottleneck in the fabrication of next-generation nanoelectronics. And selective atomic layer depositions have unlocked attractive avenues for the development of the device by depositing atoms at desired surface locations. In this talk, a redox-coupled inherently selective atomic layer deposition (ALD) is introduced to tackle this challenge. The redox-coupled inherently selective ALD for self-alignment of tantalum/niobium/molybdenum/tungsten oxide on SiO_2/Cu nanopatterns was studied. The 'reduction-adsorption-oxidation' ALD cycles were designed by adding an in-situ reduction step, effectively inhibiting nucleation of oxide on copper substrate. As a result, oxide exhibits selective deposition on various oxides substrate, with no observable growth on Cu. Self-aligned manufacturing on nanoscale Cu/SiO_2 patterns without excessive mushroom growth at the edge and undesired nucleation defects on the Cu region. The process can be reliably repeated to yield more than 5 nm-thick Ta_2O_5 on the SiO_2 region, while no undesired deposition occurs on Cu patterns. Experiments on Nb/Mo/W with the same ligands as $Ta(NtBu)(NEt_2)_3$ are performed. The redox-coupled ABC-type (EtOH-Nb*/Mo*/W*-H_2O) ALD process has highest selectivity. The results indicated the generality of the redox-coupled ALD method. This method offers a streamlined and highly precise self-aligned manufacturing technique, which is advantageous for the future downscaling of integrated circuits.

REFENENCE

[1] Yicheng Li, Self-aligned patterning of tantalum oxide on Cu/SiO_2 through redox-coupled inherently selective atomic layer deposition. Nature Communications, 2023, 14, 4493.

Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom



Gadjimuradov Sadrutdin Gadjimuradovich

Gadjimuradov Sadrutdin Gadjimuradovich, Bachelor of Chemistry (2020), Master of Chemistry (2022), PhD Student in Chemistry (2023) at Dagestan State University. The PhD thesis is devoted to ALD and characterization of thin films of chromide oxide and mixed titanium-chromide and aluminum-chromide oxide films. Research interests: atomic and molecular layer deposition (theory, modeling and experiment), solid state chemistry, surface physical chemistry, quartz crystal microbalance, thin films, nanomedicine, materials for nanoelectronics, and other industrial applications of the ALD nanomaterials.

TOPIC

Thermodynamic modeling of the processes of molecular layering of MoO_3 on β-cristobalite and monolayers of MoO_x and AlO_x by the DFT method: comparative evaluation of the reactions of $MoOCl_4$, MoO_2Cl_2 and H_2O

S.G. Gadjimuradov[1], S.I. Suleymanov[2], I.M. Abdulagatov[1], A.I. Abdulagatov[1]
[1]Dagestan State University, 43a M. Gadzhiyeva str., 367000, Makhachkala, Russia
[2]Analytical Center for Collective Use of the Institute of Physics of the Dagestan Federal Research Center of the Russian Academy of Sciences, 45 M. Gadzhieva str., 367025, Makhachkala, Russia

ABSTRACT

In this work, quantum chemical modeling was applied to study the surface reactions of atomic layer deposition of molybdenum (VI) oxide on the surface of β-cristobalite and monolayers of MoO_x and AlO_x on β-cristobalite using gaseous $MoOCl_4$, MoO_2Cl_2, and H_2O as reagents. Using the generalized gradient approximation method of density functional theory, the Gibbs energy changes of the ALD reactions (ΔG°) in the temperature range from 273.15 to 650.15 K were calculated. The calculations were carried out considering the aggregate state of the reacting substances - in the approximation of an ideal gas for gaseous substances and excluding the translational and rotational contributions for the solid phase components. According to the obtained data, the highest reactivity of the surface of the aluminum oxide monolayer on β-cristobalite is predicted in the considered temperature range. Additionally, it was found that the $MoOC_{l4}$ compound has greater chemical activity compared to MoO_2Cl_2 towards the studied substrates. Our computational approach can generally aid in understanding the fundamental aspects of nucleation and growth of MoO_3 films and mixed oxide materials like $Al_xMo_yO_z$ on various surfaces. Additionally, the vibrational mode frequencies in molybdenum-containing structures on the substrate surfaces were calculated in the anharmonic approximation: $\nu_{Si\text{-}O\text{-}Mo}$ = 901-1002 cm^{-1}, $\nu_{Al\text{-}O\text{-}Mo}$ = 921-1015 cm^{-1}, $\nu_{Mo\text{-}O\text{-}Mo}$ = 716-889 cm^{-1}, $\nu_{Mo=O}$ = 972-1010 cm^{-1}.

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Yijun Zhang

Yijun Zhang received his doctoral degree from Xi'an Jiaotong University, China, in 2015. He then became an engineer in School of Electronic Science and Engineering, Xi'an Jiaotong University， and was promoted to senior engineer in 2018. His research interest focuses on the deposition of high-k dielectrics thin films by ALD and their integration into MEMS capacitors.

TOPIC

3D HfO_2-Based Capacitor with Superior Energy Storage Properties

Yijun Zhang[1*], Wei Ren[1*], Gang Niu[1], Zenghui Liu[1] and Zuo-Guang Ye[2*]
[1] Electronic Materials Research Laboratory Key Laboratory of the Ministry of Education & International Center for Dielectric Research, School of Electronic Science and Engineering, Xi'an Jiaotong University, Xi'an, Shann Xi, 710049, China
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ABSTRACT

Capacitors are ubiquitous and crucial components in modern electronic technologies. Future microelectronic devices require novel dielectric capacitors with higher energy storage density, higher efficiency, better frequency and temperature stabilities, and compatibility with integrated circuit (IC) processes. Here, in order to overcome these challenges, a novel 3D HfO_2 thin film capacitor is designed and fabricated by ALD in conjunction with an integrated microelectromechanical system (MEMS) process. The energy storage density (ESD) of the capacitor reaches 28.94 J cm^{-3}, and the energy storage efficiency of the capacitor is up to 91.3% under an applied electric field of 3.5 MV cm^{-1}. The ESD can be further improved by reducing the minimum period structure size of the 3D capacitor. Moreover, the 3D capacitor exhibits excellent temperature stability (up to 150 °C) and charge-discharge endurance (10^7 cycles). The results indicate that the 3D HfO_2 thin film MEMS capacitor has enormous potential in energy storage applications in harsh environments, such as pulsed discharge and power conditioning electronics.

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Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Yinchi Liu

Yinchi Liu is a Ph.D. candidate at the School of Microelectronics, Fudan University, specializing in Integrated Circuit Science and Engineering. His research focuses on novel hafnium-based ferroelectric memory devices. To date, Liu has published three papers as the first author in prestigious journals and conferences, including IEEE Electron Device Letters and IEEE ICSICT. His work aims to optimize the memory window and reliability for future non-volatile memory applications.

TOPIC

Improved Ferroelectric Properties in Ultra-Thin Ferroelectric Film Compatible with BEOL via ZrO_2 Middle Layer Strategy

Yinchi Liu[1], Hongliang Lu[1], Lin Chen[1, 2], Shijin Ding[1] and Wenjun Liu[1, 2*]
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ABSTRACT

The Zr-doped HfO_2 ($Hf_{0.5}Zr_{0.5}O_2$, HZO) ferroelectric (FE) thin films have garnered lots of attention in embedded memory toward VLSI integration owing to its high CMOS compatibility as well as scalability. However, the typical thickness of approximately 10 nm results in excessive operating voltages ($V_{op} > 2$ V) for HZO-based FE memories, necessitating further reduction to below 1.2 V for meeting the power driving requirements in advanced process nodes. In this work, the back-end of line (BEOL) compatible sub-6 nm $Hf_{0.5}Zr_{0.5}O_2/ZrO_2/Hf_{0.5}Zr_{0.5}O_2$ (HZO/ZrO_2/HZO) stack and the corresponding capacitors were fabricated. The capacitor with sub-6 nm HZO/ZrO_2/HZO stack annealed at 400 ℃ shows a superior remanent polarization ($2P_r$) of 26.3 μC/cm^2 under only ±1.25 V sweeping, while the conventional HZO film presents non-ferroelectricity. The enhanced ferroelectricity stems from the increased ferroelectric phase proportion by ZrO_2 insertion. Moreover, the capacitor with HZO/ZrO_2/HZO stack also achieved an excellent endurance with a $2P_r$ of 27.1 μC/cm^2 after 10^{11} cycles without breakdown and only ~12% $2P_r$ degradation at 85 ℃. The robust reliability is ascribed to the suppressed generation of defects and domain pinning under the low operating voltage. The sub-6 nm HZO/ZrO_2/HZO stack presents the great potential for BEOL compatible non-volatile memories in advanced process nodes.

Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Yue Huang

Yue Huang received M.Eng. in materials science and engineering from the School of Physics and Electronic Information, Huaibei Normal University, China in 2023. Currently, she is a Ph.D. student in the group of Professor Ai-Dong Li at Nanjing University, focusing on the application of transition metal phosphides in electrocatalytic water splitting.

TOPIC

Atomic Layer Deposition for Surface Modification in Enhancing Electrocatalytic Oxygen Evolution Reaction

Yue Huang, Shuai Zhang, Yu Liu, and Ai-Dong Li*
National Laboratory of Solid State Microstructures, Materials Science and Engineering Department, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, P. R. China

ABSTRACT

Atomic layer deposition (ALD) has garnered significant attention due to its ability to control film thickness at the atomic level with exceptional uniformity and precision[1]. In recent years, ALD has demonstrated considerable potential in the field of electrocatalysis. We employed ALD to uniformly coat a layer of RuO_2 on the surface of Ni_3S_2, enabling precise control over the chemical composition and structure of the electrocatalyst surface. This approach mitigates the corrosion of transition metal sulfides by the electrolyte, preserving crystallinity, maintaining grain size, and stabilizing the active surface area. Under oxygen evolution reaction (OER) conditions, Ni_3S_2 undergoes oxidation to sulfite (SO_3^{2-}) and subsequently to sulfate (SO_4^{2-}). The RuO_2 coating exhibits strong adsorption for SO_4^{2-} so that enriching surface-bound sulfate, not only promoting the activity of OER, but also enhancing the stability of Ni_3S_2 simultaneously. Our findings offer a novel pathway for using ALD to develop efficient and stable electrocatalytic materials.

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Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Yeseul Son

Yeseul Son is in the combined Mater-Doctor course at Ulsan National Institute of Science and Technology (UNIST). Her research interest is the formation of precious metal alloys using atomic layer modulation.

TOPIC

Atomic layer modulation (ALM) process for preparing atomic-scale homogeneous alloy thin films

Yeseul Son[1], Sang-Bok Kim[1], Debananda Mohapatra[1], Taehoon Cheon[2] and Soo-Hyun Kim[1*]
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[2] Center of Core Research Facilities, Daegu 42988, Republic of Korea

ABSTRACT

Precious metals like Ag, Au, Pt, Ru, Rh, Pd, Os, and Ir are valued for their catalytic activity and corrosion resistance. Pt and Ru alloys combine Pt's high catalytic performance with Ru's durability, enhancing their electrochemical properties. This study introduces atomic layer modulation (ALM) technology to address the challenges of non-uniform distribution and nano-laminated structures in multicomponent thin film production via supercycle of ALD. ALM allows the sequential exposure of multiple precursors in one cycle, enabling the fabrication of uniform multicomponent thin films[1]. Using metal-organic precursors—dimethyl-(N, N-dimethyl-3-butene-1-amine-N) platinum ($C_8H_{19}NP_t$) for Pt and tricarbonyl (trimethylenemethane) ruthenium ($Ru(TMM)(CO)_3$) we achieved the atomic-scale homogeneous growth of PtRu alloy thin films with varied compositions by controlling the process variables of ALM process. The films' properties were characterized using TEM, RBS, XPS, XRD, and XRR. The PtRu alloys exhibited superior catalytic performance in OER and HER, outperforming Ru alone. These results highlight the potential of ALM-fabricated noble metal alloys for applications in fuel cells, water decomposition, and other industrial uses.

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ACKNOWLEDGEMENTS

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Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Weike Wang

Weike Wang received his Ph.D. degree in Physics of Nanostructures and Advanced Materials from CIC nanoGUNE/University of the Basque Country (Spain) in 2017. Now he is an Associate Professor in School of Materials Science and Engineering at Shaanxi University of Science and Technology, China (since November, 2018). His current research interests are in the area of the modification of the various polymer thin films and nanofibers by ALD and VPI process, the preparation of conductive MOF thin films, and the preparation of solar-thermal conversion materials for solar steam generation.

TOPIC

Efficiently Tuning the Electrical Performance of PBTTT-C14 Thin Film via in-situ Controllable Multiple Precursors (Al_2O_3: ZnO) Vapor Phase Infiltration

Zhen Jia, Xueyang Mu, and Weike Wang*
School of Materials Science and Engineering, Shaanxi University of Science & Technology, Xi'an, Shaanxi 710021, China

ABSTRACT

Conjugated polymer-based organic/inorganic hybrid materials become the current research frontier and show great potential to integrate flexible polymers and rigid solid materials, which have been widely used in the field of various flexible electronics and optical devices. In this study, based on the multiple vapor phase infiltration (VPI) process, various precursor molecules (DEZ, TMA, H_2O) are applied for the in situ modification of PBTTT-C14 films. The conductivity of the PBTTT-C14/Al_2O_3:ZnO (AZO) film is significantly enhanced, and the maximum value of conductivity is 1.16 S cm^{-1}, which is eight orders of magnitude higher than the undoped PBTTT-C14 thin film. During the AZO VPI process, the formation of new ZnS matrix in the polymer subsurface can generate new additional electron conduction pathways through the crosslinking of polymer chains with inorganic materials, and the addition of Al_2O_3 can bring about the increase of average grain size of ZnO crystals, which is also benefit to the conductivity increase of PBTTT-C14 thin film. Generally, the synergistic effect between the inorganic and polymer constituents results in the significantly enhancement of the conductivity of PBTTT-C14/AZO thin films.

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3, Xueyang Mu, Weike Wang*, Greatly increased electrical conductivity of PBTTT-C14 thin film via controllable single precursor vaporphase infiltration, Nanotechnology, 2023, 34, 015709.

Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Minjeong Kweon

Minjeong Kweon is a graduate student at UNIST, Ulsan, Republic of Korea. Her primary research focus is on the deposition and characterization of transition metal carbides using PEALD.

TOPIC

Zirconium Carbide (ZrCx) Thin Films Prepared by Plasma-Enhanced Atomic Layer Deposition as a diffusion barrier for Ru & Cu metallization

Minjeong Kweon, Chaehyun Park, Sang Bok Kim, and Soo-Hyun Kim*
Graduate School of Semiconductor Materials and Devices Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan, Republic of Korea

ABSTRACT

Zirconium-based materials, known for their high melting points (Zr: 1850 °C, ZrC: ~3420 °C, ZrN: ~2980 °C) and low resistivities (Zr: ~42, ZrC: ~43, ZrN: ~12 μΩcm), are being extensively explored for semiconductor applications, including diffusion barriers, gate electrodes, and high-temperature electronics. While zirconium nitride has been widely studied in ALD processes, a research on the ALD process of zirconium carbide (ZrC_x) remains largely unexplored. In this study, we investigated ZrC_x ALD using a nitrogen-free Zr precursor. ZrC_x films were deposited on thermally grown SiO_2, Si, and TiN substrates utilizing a showerhead-type PEALD reactor (IOV dX1 PEALD reactor, ISAC Research, Korea), with bis (cyclopentadienyl) dimethyl zirconium and H_2 plasma serving as the precursor and reactant, respectively. Deposition was carried out at temperatures ranging from 150 to 450 °C under a chamber pressure of ~1 Torr. Self-limited growth behavior, the key characteristic of the ALD process, was first investigated at a deposition temperature of 300 °C. The properties of PEALD-ZrC_x films under optimized deposition condition were analyzed using various tools, including XRD, XRR, XPS, 4-point probe, SIMS, RBS, and TEM. The results of this study highlight the potential of ZrC_x thin films for advanced technology applications and lay the foundation for further research into future applications.

ACKNOWLEDGEMENTS

This work was supported by the the Technology Innovation Program (No. 20024909, Development of Carbon-based Multi-Layer Thin Film Materials and Films for Protection of EUV Circuit Patterns based on ALD) funded By the Ministry of Trade, Industry & Energy (MOTIE, Korea). This work was also supported by Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (P0023703, HRD Program for Industrial Innovation). This work also was supported by the the Technology Innovation Program (RS-2024-00443038, CMP for 10nm DRAM/3nm logic advanced semiconductors Development of process equipment technology) funded By the Ministry of Trade, Industry & Energy (MOTIE, Korea).

Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Shuai Zhang

Shuai Zhang received the M.S. degree in materials and chemical engineering from University of Jinan, Jinan, China, in 2023. Currently, he is a Ph.D. student in the group of Professor Ai-Dong Li at Nanjing University, focusing on the preparation and properties of semiconductor metal oxide thin film gas sensor with atomic layer deposition (ALD).

TOPIC

Ultra-Fast Hydrogen Detection with SnO_2/In_2O_3 Thin Film Sensors Fabricated by Atomic Layer Deposition

Shuai Zhang, Chen Wang, and Ai-Dong Li*
National Laboratory of Solid State Microstructures, Materials Science and Engineering Department, College of Engineering and Applied Sciences, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, P. R. China

ABSTRACT

Atomic Layer Deposition (ALD), as a novel material preparation technique, has high compatibility with MEMS processes and offers significant advantages in the fabrication of thin-film gas sensors.[1] Here, a hydrogen sensor based on the SnO_2/In_2O_3 thin films (~20 nm) was prepared on the SiO_2/Si substrate by ALD. By constructing the SnO_2/In_2O_3 heterostructure thin films as hydrogen sensing material, the resulting noble metal-free SnO_2/In_2O_3 sensor exhibits high sensitivity, ultra-fast response (0.4 s), low detection limit (1 ppm) towards H_2 at 150 ℃, and excellent selectivity. The outstanding performance of the SnO_2/In_2O_3 sensor may be due to the presence of 2D electrons gas at the heterojunction interface, which significantly enhances the carrier mobility. Our research lays the foundation for the application of ALD-fabricated metal oxide-based thin film hydrogen sensors in a range of fields that require real-time monitoring and precise detection of hydrogen.

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Poster Session

Session Time: October 18 17:15-18:30 Location: Shanghai Ballroom Anteroom

Yan Xu

A master expected to receive the degree by June in 2025 in Huazhong University of science and technology, who majors in Mechanical Engineering and is devoted to “Atomic layer deposition of indium-based oxide thin films and their electrical properties” study for master degree.

TOPIC

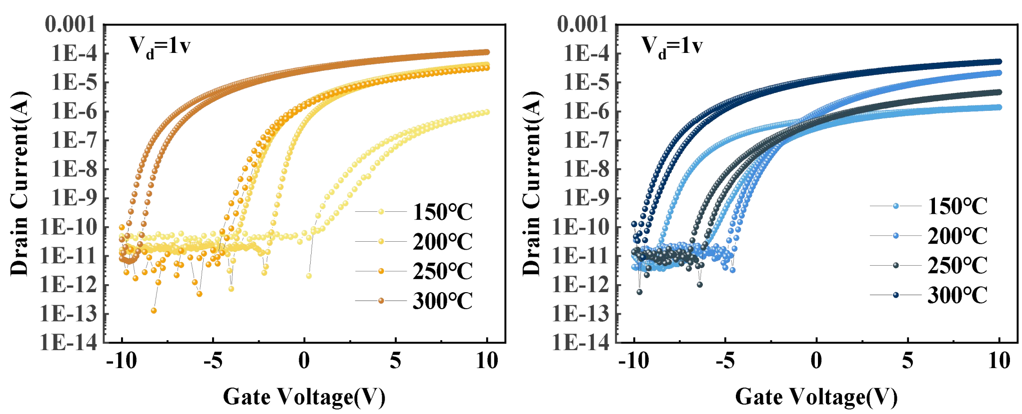
3 nm Thin In_2O_3 Channel via Different Precursor Recipe Comparison for Bottom Gate Thin Film Transistor

Yan Xu[1], Xuewei Jiang[2], Fan Yang[2]* and Rong Chen[2]*
[1] School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, People’s Republic of China
[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China

ABSTRACT

Oxide semiconductors have been widely studied for commercial applications, including thin-film transistors (TFTs) for display backplanes and semiconductor memories. In this study, we demonstrate 2 completely opposite tendencies of carrier concentration that are dependent on specific ALD recipe (InCp and DADI). And a 3 nm In_2O_3 channel is used to overcome the challenge of switching off without post-deposition process. We investigate the electron transport in mechanism in perspective of oxygen vacancy, near band trap and crystallinity by XPS, Photoluminescence and XRD et.al. The transition from amorphous phase to crystalline and from semiconductor to “metal-like” conductor are demonstrated. Process temperature and precursor selection play a role in carrier concentration of which a high level contributes to a depletion mode operation in 3 nm channel TFT and of which a low level contributes to an enhancement mode operation. In addition, TFTs of high mobility and on current are achieved when the deposition temperature exceed 275 ℃ for both recipe. These findings highlight the capability of controlling the growth and properties of In_2O_3 films by process modulation and precursor selection, emphasizing the potential of pure In_2O_3 by ALD in TFT fabrication without post-deposition technology.

Fig. 1. Comparison between InCp and DADI recipes to fabricate 3 nm TFT.



Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Xuewei Jiang

Xuewei Jiang is a Ph.D. student in Materials Engineering at Huazhong University of Science and Technology, class of 2022. Specializing in the atomic layer deposition of semiconductor oxide thin films and their electrical properties, she has published two papers in SCI journals.

TOPIC

Scalable Deposition of SnO_2 ETL via SALD for Large-Area Inverted Perovskite Solar Modules

Xuewei Jiang[1], Bin Shan[1]*, Fan Yang[2]*, Rong Chen[2]
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[2] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China

ABSTRACT

Tin dioxide (SnO_2) stands out as a promising candidate for the electron transport layer (ETL) in perovskite solar cells (PSCs) due to its remarkable conductivity. As PSCs progress towards commercialization, the scalability of deposition methods, cost-effectiveness, and the seamless integration of various material layers become increasingly crucial, alongside the fundamental efficiency requirements. In this study, we demonstrate large-scale deposition of SnO_2 film with low thickness non-uniformity of 2.36% via Spatial Atomic Layer Deposition (SALD), offering a significant advantage by enabling high-throughput production of large-area films at atmospheric pressure. By exploiting the varying reactivity of oxygen precursors and modulating the flow to control oxygen vacancy defects, SnO_2 film, deposited at 100 ℃ with Tetrakis(dimethylamino)tin (TDMASn) and H_2O_2, achieved a high mobility of 19.4 cm2 V^{-1} s^{-1}. The 400 cm^2 perovskite solar modules (PSMs) with optimized SnO_2 ETL achieved high power conversion efficiency (PCE) of 19.35%, marking a notably high PCE of inverted PSCs with such a large area to date. This exceptional performance stems from the excellent uniformity and mobility of the SALD-deposited SnO_2 ETL, highlighting the potential of SALD in future PSM fabrication.

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Poster Session

Session Time:October 18 17:15-18:30 Location:Shanghai Ballroom Anteroom

Sujuan Ding

Sujuan Ding is a doctoral student at the School of Materials Science and Engineering at Zhejiang University. Her research focuses on the nucleation and growth mechanism of ALD high-κ dielectrics on carbon nanotubes.

TOPIC

Sujuan Ding1, Yifan Liu2, Qian Shang3, Bing Gao1, Fenfa Yao1, Bo Wang1, Xiaoming Ma1, Zhiyong Zhang2, Chuanhong Jin1*
1 State Key Laboratory of Silicon and Advanced Semiconductor Materials, School of Materials Science and Engineering, Zhejiang University, Hangzhou, Zhejiang 310027, China
2 Key Laboratory for the Physics and Chemistry of Nanodevices and Center for Carbon-based Electronics, School of Electronics, Peking University, Beijing 100871, China
3 Hunan Institute of Advanced Sensing and Information Technology, Xiangtan University, Xiangtan, Hunan 411105, China

ABSTRACT

Microscopic study on the nucleation and growth of atomic layer deposition (ALD) dielectrics onto carbon nanotubes (CNTs) is an essential while challenging task towards high-performance devices. Here, we capture the morphological evolution and growth behaviors of ALD-HfO2 onto SiO2/Si-supported aligned CNT array (A-CNTs) under three ALD recipes via cross-sectional high-resolution scanning transmission electron microscopy. The HfO2 in ALD I (200℃) preferentially nucleates on SiO2 substrate in heterogeneous growth mode, resulting in films with considerable pinholes. While ALD II (90℃) and III (90℃ and extra H2O presoak) exhibit homogeneous growth with nucleation on both SiO2 and CNTs, yielding uniform films. Arrangement defects in A-CNTs exacerbate non-uniformity of HfO2 and tube-tube separation plays deterministic roles affecting the HfO2-CNT interfacial morphology. Electrical measurements from A-CNT metal-oxide-semiconductor devices validate these findings. Our investigation contributes valuable insights for optimizing ALD processes for enhanced dielectric integration on A-CNTs in next-generation electronics.

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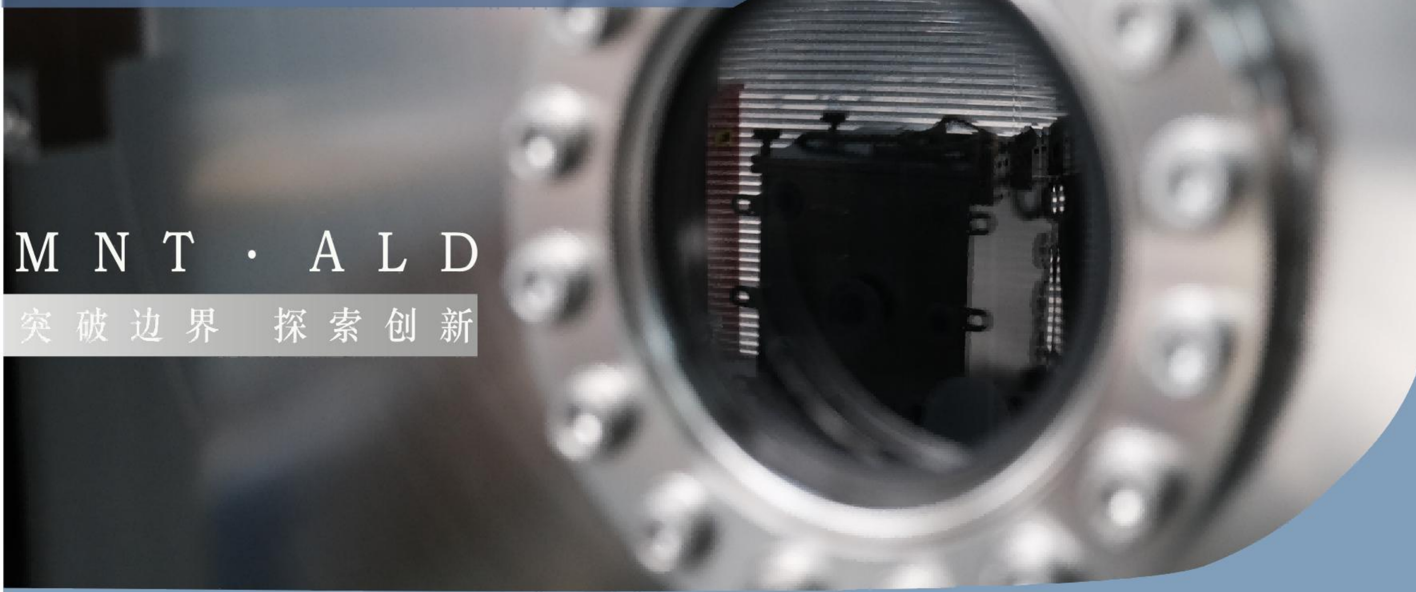
ATOMIC LAYER DEPOSITION (ALD)

原子层沉积（ALD）



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