

Report

The 82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes

Bankoku Shinryokan, Okinawa, Japan,
December 4th - 7th, 2017

Organizing Committee

Satoshi Hamaguchi (Chair), Osaka University, Japan
Timo Gans (Co-Chair), University of York, UK
Keizo Kinoshita (Co-Chair), Petra, Japan
Tetsuya Tatsumi (Co-Chair), Sony Semiconductor Solutions, Japan
Sumit Agarwal, Colorado School of Mines, USA
Masanobu Honda, Tokyo Electron, Japan
Eric Joseph, IBM, USA
Kazuhiro Karahashi, Osaka University, Japan
Erwin Kessels, Eindhoven University of Technology, Netherlands
Shahid Rauf, Applied Materials, USA
Guen Young Yeom, Sungkyunkwan University, Korea

IUVSTA Division: Plasma Science & Technique Division

Website: <http://officepolaris.co.jp/JSPP2017/IUVSTA17Workshop/>

The 82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes was held at Bankoku Shinryokan Convention Center in Nago City, Okinawa, Japan, from December 4th to 7th, 2017. The venue Bankoku Shinryokan is a convention facility owned by Okinawa prefecture and was originally built as a venue for the 26th G8 Summit held in 2000. It is located at the tip of Cape Busena, a remote and rather exclusive resort area in the Okinawa main island, and surrounded by sea on 3 sides. As is the norm for all IUVSTA workshops, the participants were “confined” in the venue and surrounding areas of natural beauty for 4 days discussing science and technologies related to the theme of the Workshop.

The theme of the Workshop was atomic layer processes (ALPs), i.e., etching, deposition, and other surface processes with atomic-scale size control. ALPs include atomic-layer deposition (ALD) and atomic-layer etching (ALE). ALD has been widely used in semiconductor manufacturing processes and is now spreading to other industries that require highly controlled functional material surfaces. ALE is, on the other hand, now entering semiconductor manufacturing processes as new processing technologies for nano-scale devices. What distinguishes an ALP from other surface processes is its self-limiting reactions that limit the surface process only to (nearly) a single atomic layer. Processing with self-limiting reactions

allows not only atomic-scale topography control but also high selectivity and uniformity over a wide surface area of the processed material, less dependent on the structure densities. Many existing ALP technologies do not require the use of plasmas but it has been found recently that a plasma-based ALP significantly enlarges the process window by offering novel radical reactions with new energy sources (e.g., low-energy ion and/or photon irradiation) compared with the conventional ALPs based on thermal processes. Therefore, in this Workshop, the use of plasma for the latest ALP technologies was especially emphasized, with the goal set to explore fundamental science and to clarify the mechanisms of plasma-based ALPs such as plasma-based ALE, ALD, and surface functionalization of various materials. In addition to plasma-based ALPs, novel/conventional ALPs without plasmas as well as other highly controlled plasma surface processing were also presented in the Workshop.

The Workshop was held concurrently with the 10th EU-Japan Joint Symposium on Plasma Processing (JSPP2017). The number of participants, including students, of the 82nd IUVSTA Workshop was 45 and the total number of participants of both the IUVSTA Workshop and JSPP2017 was 141. The registered participants of the IUVSTA Workshop were also allowed to attend the sessions of the JSPP2017 freely. As the JSPP2017 covers a wide range of plasma science and technologies, participants of the IUVSTA Workshop were also able to enjoy presentations on low-temperature plasmas and plasma-surface interaction in general.



Financial Overview

Income	Amount (EUR)
IUVSTA sponsorship	6,000
Registration fees	11,842
Total	17,842

Expenses	Amount (EUR)
Venue	2,373
Invited speaker support	9,398
Administration fee, including website management	2,500
Reception	2,368
Bus transportation between the venue and hotels	1,203
Total	17,842

The 10th EU-Japan Joint Symposium on Plasma Processing

JSPP2017

The 82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes

PROGRAM



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Foreword

On behalf of the organizing committees of both 10th EU-Japan Joint Symposium on Plasma Processing (JSPP) and 82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes, I would like to welcome all participants of both meetings at Bankoku Shinryokan Conference Hall at Okinawa, Japan. The EU-Japan JSPP is an international symposium that covers a broad range of science and technologies related to plasmas processing. This time, in addition to the areas traditionally covered by this Symposium such as basic plasma physics and chemistry, atomic and molecular processes, and plasma-surface interaction, we have organized the Special Sessions on “Plasma-Liquid Interactions” and “Plasma Application to Agriculture.” These two sessions focus on rapidly growing subfields associated with plasma applications in medicine and biology. On the other hand, the 82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes is a focused workshop sponsored by International Union for Vacuum Science, Technique and Applications (IUVSTA) and covers science and technologies of plasma-based atomic layer processes (ALPs), i.e., atomic layer etching (ALE), atomic layer deposition (ALD), and other surface processes with atomic-scale size control. Unlike conventional etching and deposition processes, ALD and ALE characterize themselves as having self-limiting reactions, which allow the processes to proceed (nearly) layer by layer. Plasma-based ALPs have attracted much attention in the semiconductor industry for their great potential in nano-scale device manufacturing.

The organizers believe that having these two rather distinctively different meetings simultaneously and allowing the participants of each meeting to attend sessions of the other freely will benefit all participants in gaining a broader perspective of the technical fields they work on. I hope all participants will enjoy the academic contents of the meetings as well as inspiring discussions with their colleagues in a relaxing atmosphere at Okinawa.

Satoshi Hamaguchi

Chair

10th EU-Japan Joint Symposium on Plasma Processing

82nd IUVSTA Workshop on Plasma-based Atomic Layer Processes

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Shahid Rauf, Applied Materials, USA

Guen Young Yeom, Sungkyunkwan University, Korea

Timetable

Mon (December 4)		Tue (December 5)		Wed (December 6)		Thu (December 7)			
Room A		Room B	Room C	Room B	Room C	Room B	Room C		
8:45-9:00 9:00-9:35	Opening & Introduction (Hamaguchi & Mason)		Eun Ha Choi	Guen Young Yeom	Jean-Michel Pouvesle	David Smith	Seiji Samukawa		
9:35-10:10	Toshiaki Makabe		Alexander Fridman	Yukihiko Shimogaki	Douyan Wang	Peter L. G. Ventzek	HiroYuki Fukumizu		
10:10-10:45	Zoran Lj. Petrović		Uroš Cvelbar	Erwin Kessels	Yuki Yanagawa Kinga Kutasi	Ying Zhang	Shota Nunomura		
10:45-11:00	Mark Kushner		Masaharu Shiratani	Sumit Agarwal	Kiwon Song	Eric A. Joseph	Jozef Brcka Gwerael Fubiani		
11:00-11:35	15 min break		15 min break	15 min break	15 min break	15 min break	15 min break		
11:35-12:10	Jane P. Chang		William Graham	Hae June Lee	Lenka Zajčková	David N. Ruzic	Peter Bruggeman Yoshihide Kihara		
12:30-14:30	Steven M. George		Katsuhisa Kitano	Jan van Dijk	Miran Mozelič	Masaru Hori	Ryo Ono Masaru Izawa		
			Nishtha Gaur	Emilie Desplau-Pujo	Andrei Choukurov	Gilles Cunge	Kenji Miyamoto Masanaga Fukasawa		
			Tomoyuki Murakami		Glenn Látog		Closing (Hamaguchi)		
14:30-16:00	Welcome Lunch (buffet)		Excursion 13:00 - ...		Lunch (with lunch boxes)			(white boxes; talks in EU-Japan JSPP)	
	Poster Session				Kristian Wende	Emil Pinck	(magenta boxes; talks in IUVSTA Workshop)		
					Fumiyoshi Tochikubo	Bert Ellingboe			
					Jun-Seok Oh	Zoltan Donko			
					Endre Szili	Hohyun Song			
						Zoran Petrovic			
16:00-16:30			Ron White	Uwe Czarnetzki					
16:30-17:00			Yong Zhang	Timo Gans					
17:00-17:30	Dajji Kato		Toshiro Kaneko	Jaeho Kim					
17:30-18:00	David Zarzoso		Ladislav Moravsky	Magdaleno Jr. Vasquez					
18:00-18:30	Sadruddin Benkadda								
18:30-20:30	Reception							Banquet 19:00- ...	

<Room D> Sunset Lounge

- Panel Discussion : Mon (December 4)

<Room A> Summit Hall

- Opening & Introduction : Mon (December 4)
- Plenary : Mon (December 4)

Café terrace

- Welcome Lunch : Mon (December 4)

<Room B, C> Ocean Hall

- Invited
- Oral (Contributed)
- Poster Session
- Reception
- Closing

Mon (December 4) – Fri (December 7)



Sh. Takayama

Symposium/Workshop Venue Map

Social Events

Opening & Introduction:

Date: 8:45-9:00, Monday, December 4.

Venue: Summit Hall, Bankoku Shinryokan

Welcome Lunch (buffet):

Date: 12:30-14:30, Monday, December 4.

Venue: Cafe Terrace, Bankoku Shinryokan

Reception (drinks & snack):

Date: 18:30-20:30, Monday, December 4.

Venue: Ocean Hall, Bankoku Shinryokan

Excursion:

Date: 13:00- Tuesday December 5.

Visit to Ocean Expo Park including Okinawa Churaumi Aquarium, and Okinawa-style dinner at Nago city in the evening.

The tour will start after the morning session and return to the hotels by 9PM.

Conference Banquet:

Prior reservation is required.

Date: 19:00-21:00, Wednesday, December 6.

Venue: Function Room, The Busena Terrace
(on Level 4 of the Central Tower)

Fee: 10,000 JPY

A sit-down buffet dinner

Closing:

Date: 12:30-, Thursday, December 7.

Venue: Ocean Hall, Bankoku Shinryokan

General Information

Registration Desks:

- Pre-Registration Desk
- On-Site Registration Desk
- Cashier

Hours of Operation:

December 4	8:00 - 18:30
December 5	8:00 - 12:30
December 6	8:00 - 18:30
December 7	8:00 - 12:30

Lunch:

Welcome Lunch will served on December 4 at Café terrace.

Boxed lunch called “*Bento*” will be served on December 6 and 7 at Ocean Hall.

Wi-Fi Area:

Free Wi-Fi is available in all halls at the venue. SSID: guest

Lost and Found:

If you lose or find an item, please stop by the registration desk.

First Aid:

If you require medical assistance during the Conference, please contact the secretariat office staff immediately.

Cloak Room:

No cloakroom is available. Please note it in advance.

Taxi:

If a taxi is required, please contact the Registration Desk.

Smoking Policy:

Smoking is not permitted in any building. There are some smoking spaces outside the building.

Instructions for Presenters

Oral Presentation

- The presentation time is as follows

(including the time for you to connect your PC to the projector):

- Plenary 35 min (30 min presentation and 5 min discussion)
- Invited 30 min (25 min presentation and 5 min discussion)
- Oral (Contributed) 15 min (12 min presentation and 3 min discussion)

- Equipment

Windows laptop computer for common use will be available for your presentations in the conference room.

Please bring your presentation data saved to a USB storage device.

****Notes when using your own laptop for presentation****

Please bring all required connection cables (with a d-sub 15-pin adapter) for your laptop, and a power adapter, if necessary.

If you wish to use your own Mac computer, you will need the appropriate VGA video adapter.

Poster Presentation

- Poster session is held on Monday, 4 (13:30-14:30)
- Poster board size is 2.1m high and 1.2m wide.

Poster should not be larger than the poster board.

Drawing pins (thumbtacks) for posting will be offered by the organizer.

- Please put up your poster before your poster session starts.
- Please remove your poster by 12:00 on Thursday 7.

Posters left on the board after this time may be removed by the Conference staff.

Plenary Session Program

===== **Monday, December 4, 2017** =====

<Room A> Summit Hall

Opening & Introduction (8:45-9:00)

Satoshi Hamaguchi (Osaka Univ., Japan) & Nigel Mason (Open Univ., UK)

Plenary Sessions (9:00-12:10)

[PL-1] (9:00-9:35) Toshiaki Makabe (Keio University, Japan)

“Development of research over these 70 years on electron velocity distribution in time-varying low-temperature plasmas”

[PL-2] (9:35-10:10) Zoran Lj. Petrović (Institute of Physics, Serbia)

“Physics of Swarms of Charged Particles, as a Foundation for Modeling Non-Equilibrium Collisional Plasmas”

[PL-3] (10:10-10:45) Mark Kushner (University of Michigan, USA)

“From the Plasma to the Surface: Connecting Plasma Kinetics to Atomic Layer Processing”

----- Break (10:45-11:00) -----

[PL-4] (11:00-11:35) Jane P. Chang (UCLA, USA)

“Plasma-Surface Interactions at the Atomic Scale”

[PL-5] (11:35-12:10) Steven M. George (University of Colorado, USA)

“Thermal Atomic Layer Etching Using Sequential, Self-Limiting Surface Reactions”

82nd IUVSTA Workshop Presentations Program

===== **Monday, December 4, 2017** =====

Poster Sessions (14:30-16:00)

Ocean Hall

*Please see page 31 for poster's presenter, title information.

Panel Discussion (16:00-17:30)

<Room D> Sunset Lounge

"Atomic Layer Processes for Future Industries"

Discussion Leaders: Sumit Agarwal and Keizo Kinoshita

===== **Tuesday, December 5, 2017** =====

Invited & Oral Sessions (8:45-12:30)

<Room C> Ocean Hall

[I-1] (8:45-9:15)

Guen Young Yeom (Sungkyunkwan University, Korea)

“Layer control of 2D-MoS₂ by atomic layer etching and its device characteristics”

[I-2] (9:15-9:45)

Yukihiro Shimogaki (The University of Tokyo, Japan)

“CVD/ALD process development for highly-reliable ULSI-Cu interconnect system”

[I-3] (9:45-10:15)

Erwin Kessels (Eindhoven University of Technology, The Netherlands)

“Recent advances in (area-selective) plasma-based atomic layer deposition”

[I-4] (10:15-10:45)

Sumit Agarwal (Colorado School of Mines, USA)

“Plasma-assisted atomic layer deposition and etching of dielectric films studied using in situ infrared spectroscopy and ellipsometry”

----- Break (10:45-11:00) -----

[I-5] (11:00-11:30)

Hae June Lee (Pusan National University, Korea)

“Two-Dimensional Simulations of a Capacitively Coupled Reactor for the Uniformity Control of SiN_xHy films”

[I-6] (11:30-12:00)

Jan van Dijk (Eindhoven University of Technology, The Netherlands)

“On the Management of Input Data for the Modeling and Numerical Simulation of Chemically Complex Plasma Sources”

[I-7] (12:00-12:30)

Emilie Despiaud-Pujo (Grenoble Alpes University (LTM), France)

“Atomic-scale simulations of low-damage plasma etching processes”

===== **Wednesday, December 6, 2017** =====

Invited & Oral Sessions (8:45-17:30)

<Room C> Ocean Hall

[I-8] (8:45-9:15)

David Smith (Lam Research Corporation, USA)

“Atomic Layer Processing of Silicon Dielectrics: Precursors, Processes and Plasmas”

[I-9] (9:15-9:45)

Peter L. G. Ventzek (Tokyo Electron America, USA)

“Fundamentals based studies of plasma surface interactions in plasma enhanced atomic layer etching and deposition”

[I-10] (9:45-10:15)

Ying Zhang (Applied Materials, USA)

“Atomic Layer Etch (ALE) Challenges and Opportunities”

[I-11] (10:15-10:45)

Eric A. Joseph (IBM Research, USA)

“Methods to Enable Plasma Etching with Atomic Scale Precision”

----- Break (10:45-11:00) -----

[I-12] (11:00-11:30)

David N. Ruzic (University of Illinois at Urbana-Champaign, USA)

“Dry Etching Assisted by Lasers -- a new DEAL”

[I-13] (11:30-12:00)

Masaru Hori (Nagoya University, Japan)

“An Atomic Layer Etching of SiO₂ Film Employing Fluorocarbon and O₂ Plasma Chemistry”

[I-14] (12:00-12:30)

Gilles Cunge (LTM-CNRS University of Grenoble Alpes, France)

“Towards atomic scale control of plasma processes: application to graphene”

----- Lunch (12:30-14:00)-----

[I-15] (14:00-14:30)

Emil Pincik (Institute of Physics SAS, Slovak Rep.)

“About plasma anodic oxidation of high-doped GaAs”

[I-16] (14:30-15:00)

Bert Ellingboe (Dublin City University, Ireland)

“rf-frequency effects on power coupling, plasma chemistry, and surface processes”

[I-17] (15:00-15:30)

Zoltan Donko (Wigner Research Centre for Physics, Hungary)

“Customising ion flux-energy distributions in low-pressure capacitive RF discharges”

[O-1] (15:30-15:45)

Hohyun Song (KAIST, Korea)

“Study on the gate sidewall spacer silicon-nitride ALD process at low temperature by high density multiple ICP sources.”

[O-2] (15:45-16:00)

Zoran Petrovic (Institute of Physics University of Belgrade, Serbia)

“RF Breakdown as a Swarm Experiment”

----- Break (16:00-16:30)-----

[I-18] (16:30-17:00)

Uwe Czarnetzkie (Ruhr University Bochum, Germany)

“New Developments in Diagnostics of Charged Particles”

[I-19] (17:00-17:30)

Timo Gans (University of York, UK)

“Monitoring and control of plasma based atomic layer processes”

===== **Thursday, December 7, 2017** =====

Invited & Oral Sessions (8:45-12:30)

<Room C> Ocean Hall

[I-20] (8:45-9:15)

Seiji Samukawa (Tohoku University, Japan)

“Atomic Layer Etching and Deposition Processes for Future Nano-devices”

[I-21] (9:15-9:45)

Hiroyuki Fukumizu (Toshiba Memory Corporation, Japan)

“Investigation of atomic layer etching process for AlGaIn/GaN HEMT”

[I-22] (9:45-10:15)

Shota Nunomura (AIST, Japan)

“Real-time monitoring of defects creation and annealing during plasma processing”

----- Break (10:45-11:00) -----

[I-23] (11:00-11:30)

Yoshihide Kihara (Tokyo Electron Miyagi Limited, Japan)

“New innovative etching approaches by CD controlling at atomic-level”

[I-24] (11:30-12:00)

Masaru Izawa (Hitachi High-Technologies, Japan)

“Rapid Thermal Cyclic ALE for Conformal Removal of Thin Films”

[I-25] (12:00-12:30)

Masanaga Fukasawa (Sony Semiconductor Solutions Corp., Japan)

“Damaged Layer Control for Atomic Level Processes”

Closing (12:30-)

Satoshi Hamaguchi (Osaka Univ., Japan)

Poster Sessions

[P-101] Kazuhiro Karahashi (Osaka University, Japan)

“Surface reactions of nickel by carbon monoxide cluster beams”

[P-102] Yong Sup Choi (National Fusion Research Institute, Korea)

“Polishing of SiC using Plasma Enhanced Atomic Layer Etching”

[P-103] Tomoko Ito (Osaka University, Japan)

“XPS Analysis of Adsorbed Organic Compounds on Magnetic Materials Surfaces”

[P-104] Nicolas Mauchamp (Osaka University, Japan)

“Molecular dynamics simulation of Ni self-sputtering and modeling of interatomic potential functions”

[P-105] Yuki Okada (Osaka University, Japan)

“Molecular dynamics simulations of atomic layer etching (ALE) of SiO₂”

[P-106] Jin Woo Park (Sungkyunkwan University, Korea)

“Controlled Etching of 2D Black Phosphorus”

[P-107] Dong Chan Seok (National Fusion Research Institute, Korea)

“High Precision Sintered SiC Etching with Atmospheric Pressure Plasma”

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Sponsors

International Union for Vacuum Science, Technique and Applications (IUVSTA)



The Vacuum Society of Japan (VSJ)



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