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## Voltage and Thermally Driven High Current RolltoRoll Printed Transistors

Pastorelli, Francesco

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# Symposium EM6 : Thin-Film Transistors—New Materials and Device Concepts

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## Symposium Organizers

C. Daniel Frisbie, Univ of Minnesota  
Moon Sung Kang, Soongsil University  
Karl Leo, Dresden Integrated Center for Applied Physics and Photonic Materials  
Takao Someya, University of Tokyo

## Symposium Support

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### EM6.6: Novel TFT Structuring and Deposition Techniques

#### Session Chairs

Moon Sung Kang

Wednesday AM, November 30, 2016  
Hynes, Level 3, Room 312

#### 8:45 AM - EM6.6.01

Voltage and Thermally Driven High Current Roll-to-Roll Printed Transistors

[Francesco Pastorelli](#)<sup>1</sup><sup>1</sup> DTU Roskilde Denmark [Hide Abstract](#)

Organic thin film transistors (OTFT) offer great potential for use in flexible electronics. Much of this potential lies in the solution processability of the organic polymers enabling both roll coating and printing on flexible substrates and thus greatly reducing the material and fabrication costs. We have fabricated an OTFT in ambient air, on a PET flexible substrate. The printing technique is very similar to the one used for printing newspapers and has low environmental impact in comparison with traditional electronics. This is because it is made at lower temperature than you would normally use for baking a cake. After implementing the transistor we build a small demonstrator circuit to operate a printed electrochromic surface powered by an organic solar cell all realized with the same technique.

The footprint of organic electronic technologies is important when united in complex circuitry. We present flexible organic power transistors prepared by fast (20 m min<sup>-1</sup>) roll-to-roll flexographic printing of the drain and source electrode structures, with an interspace below 50 μm, directly on polyester foil[1]. The devices have top gate architecture and were completed by slot-die coating of the organic semiconductor poly-3-hexylthiophene and the dielectric material polyvinylphenol before the gate was applied by screen printing. We

explore the footprint and the practically accessible geometry of such devices with a special view toward being able to drive large currents while handling the thermal aspects in operation together with other organic printed electronics technologies such as large area organic photovoltaics (OPV) and large area electrochromic displays (EC). We find especially that an elevated operational temperature is beneficial with respect to both transconductance and on/off ratio. We achieve high currents of up to 45 mA at a temperature of 80 °C with an on/off ratio of 100 which is sufficient to drive large area organic electronics such as an EC device powered by OPV devices that we also demonstrate. Finally, we observe a significant temperature dependence of the performance which can be explored further in sensing applications.

[1] Francesco Pastorelli, Thomas M. Schmidt, Markus Hösel, Roar R. Søndergaard, Mikkel Jørgensen and Frederik C. Krebs, " The Organic Power Transistor: Roll-to-Roll Manufacture, Thermal Behavior, and Power Handling When Driving Printed Electronics", Volume 18, Issue 1, pages 51–55, January 2016, doi: 10.1002/adem.201500348

### 9:00 AM - EM6.6.02

Silicon and Dopant Ink-Based CMOS TFTs on Flexible Steel Foils

Aditi Chandra<sup>1</sup>, Mao Takashima<sup>1</sup>, Arvind Kamath<sup>1</sup>

<sup>1</sup> Thinfilm Electronics San Jose United States

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### 9:15 AM - EM6.6.03

Photonic Curing of Printed Metal Oxide Field-Effect Transistors

Suresh Garlapati<sup>1,2</sup>, Julia Gebauer<sup>3</sup>, Simone Dehm<sup>1</sup>, Michael Bruns<sup>4,5</sup>, Markus Winterer<sup>3</sup>, Horst Hahn<sup>1,2</sup>, Subho Dasgupta<sup>1</sup>

<sup>1</sup> Institute of Nanotechnology Karlsruhe Institute of Technology Eggenstein-Leopoldshafen Germany, <sup>2</sup> KIT-TUD Joint Research Laboratory Nanomaterials Technische Universität Darmstadt Darmstadt Germany, <sup>3</sup> Faculty of Engineering University of Duisburg-Essen Duisburg Germany, <sup>4</sup> Institute for Applied Materials Karlsruhe Institute of Technology Eggenstein-Leopoldshafen Germany, <sup>5</sup> Karlsruhe Nano Micro Facility Karlsruhe Institute of Technology Eggenstein-Leopoldshafen Germany

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### 9:30 AM - EM6.6.04

Full Printing of All Layers in Carbon Nanotube Thin-Film Transistors

Changyong Cao<sup>1</sup>, Joseph Andrews<sup>1</sup>, Aaron Franklin<sup>1</sup>

<sup>1</sup> Duke University Durham United States

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**9:45 AM -**  
BREAK

**10:15 AM - \*EM6.6.05**  
Device Physics of Organic Field Effect Transistors

Henning Sirringhaus<sup>1</sup>

<sup>1</sup> Cavendish Laboratory University of Cambridge Cambridge United Kingdom

 Show Abstract

**10:45 AM - EM6.6.06**  
Solvent-Induced Effects in Polymer-Wrapped s-SWNTs Based Ink-Jet Printed Field-Effect Transistors

Isis Maqueira-Albo<sup>1</sup>, Francesca Scuratti<sup>1</sup>, Giorgio Dell'Erba<sup>1</sup>, Mario Caironi<sup>1</sup>

<sup>1</sup> Istituto Italiano di Tecnologia Milano Italy

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**11:00 AM - EM6.6.07**  
Improved Structure for Patterned Source Electrode Vertical Organic Field Effect Transistor

Michael Greenman<sup>1</sup>, Nir Tessler<sup>1</sup>

<sup>1</sup> Technion Haifa Israel

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**11:15 AM - EM6.6.08**  
Utilizing Marangoni Effect to Assist Bar Coating Method for High Quality Organic Crystals Active Layer

Zhichao Zhang<sup>1</sup>, Paddy K. L. Chan<sup>1</sup>

<sup>1</sup> University of Hong Kong Hong Kong Hong Kong

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**11:30 AM - EM6.6.09**

Room Temperature Fabrication and Patterning of Highly Conductive Silver Features Using In Situ Reactive Inks by Microreactor-Assisted Printing

Elizabeth Allan-Cole<sup>1</sup>, Changho Choi<sup>1</sup>, Chih-Hung Chang<sup>1</sup>

<sup>1</sup> Oregon State University Corvallis United States

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**EM6.7: TFT Circuits, Applications and Lifetime****Session Chairs**

Sigurd Wagner

Wednesday PM, November 30, 2016

Hynes, Level 3, Room 312

**1:30 PM - \*EM6.7.01**

Micro V-Signal Amplification Circuits Based on Organic Thin-Film Transistors

Tsuyoshi Sekitani<sup>1</sup>, Shusuke Yoshimoto<sup>1</sup>, Teppei Araki<sup>1</sup>, Takafumi Uemura<sup>1</sup>

<sup>1</sup> The Institute of Scientific and Industrial Research Osaka University Osaka Japan

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**2:00 PM - EM6.7.02**

Flexible Organic Physically Unclonable Function for 2-V Operation Security Tag

Kazunori Kuribara<sup>1</sup>, Yohei Hori<sup>2</sup>, Toshihiro Katashita<sup>2</sup>, Kazuaki Kakita<sup>3</sup>, Yasuhiro Tanaka<sup>3</sup>, Taiki Nobeshima<sup>1</sup>, Sei Uemura<sup>1</sup>, Takehito Kozasa<sup>1</sup>, Manabu Yoshida<sup>1</sup>

<sup>1</sup> Flexible Electronics Research Center National Institute of Advanced Industrial Science and Technology Tsukuba Japan, <sup>2</sup> Nanoelectronics Research Institute National Institute of Advanced Industrial Science and Technology Tsukuba Japan, <sup>3</sup> Organic Specialty Materials Research Laboratory Ube Industries, Ltd. Ichihara Japan

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**2:15 PM - EM6.7.03**

Effect of Mechanical Strain on the Flexible Complementary Oxide-Semiconductor-Based Circuits Composed of N-Channel ZnO and P-Channel SnO Thin-Film Transistors

Yun-Shiuan Li<sup>1</sup>, Shu-Ming Hsu<sup>1</sup>, I-Chun Cheng<sup>1</sup>

<sup>1</sup> Graduate Institute of Photonics and Optoelectronics, National Taiwan University Taipei Taiwan

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**2:30 PM -**  
BREAK

**3:30 PM - \*EM6.7.04**

Impact of TFT Technologies on Self-powered Hybrid Large-Area /CMOS Systems for Human-Machine Interfaces

James Sturm<sup>1</sup>, Naveen Verma<sup>1</sup>, Sigurd Wagner<sup>1</sup>

<sup>1</sup> Department of Electrical Engineering/PRISM Princeton University Princeton United States

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**4:00 PM - EM6.7.05**

Three-Dimensional Vertically Stacked Complementary Organic Field-Effect Transistors and Logic Circuits

Sungjune Jung<sup>1</sup>, Jimin Kwon<sup>1</sup>, Sujeong Kyung<sup>1</sup>

<sup>1</sup> Pohang University of Science and Technology Pohang Korea (the Republic of)

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**4:15 PM - EM6.7.06**

Bias-Stress-Induced Charge Trapping in Organic Transistor

Kilwon Cho<sup>1</sup>, Boseok Kang<sup>1</sup>, Byung Ho Moon<sup>1</sup>

<sup>1</sup> Chemical Engineering Pohang University of Science and Technology Pohang Korea (the Republic of)

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**4:30 PM - EM6.7.07**

Degradation Process in Pentacene-Based Organic Field-Effect Transistors Evaluated by Three-Terminal Capacitance-Voltage Measurements

Yuya Tanaka<sup>1</sup>, Kohei Yamamoto<sup>2</sup>, Yutaka Noguchi<sup>3</sup>, Hisao Ishii<sup>1 2 4</sup>

<sup>1</sup> Center for Frontier Science Chiba University Chiba Japan, <sup>2</sup> Graduate School of Advanced Integration Science Chiba University Chiba Japan, <sup>3</sup> Department of Electronics and Bioinformatics, School of Science and Technology Meiji University Chiba Japan, <sup>4</sup> Molecular Chirality Research Center Chiba University Chiba Japan

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#### 4:45 PM - EM6.7.08

Flexible Low-Voltage Transistor with Remarkable Stability under Extreme Conditions and Its Application on Biological Sensing

Xudong Ji<sup>1</sup>, Paddy K. L. Chan<sup>1</sup>

<sup>1</sup> University of Hong Kong Hong Kong Hong Kong

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### EM6.8: Poster Session II

#### Session Chairs

Wednesday PM, November 30, 2016  
Hynes, Level 1, Hall B

#### 8:00 PM - EM6.8.03

High-Performance Stretchable Semiconducting Polymer via Dynamic Bonding for Stretchable Organic Transistors

Jinyoung Oh<sup>1</sup>, Simon Rondeau-Gagne<sup>1</sup>, Yu-Cheng Chiu<sup>1</sup>, Zhenan Bao<sup>1</sup>

<sup>1</sup> Stanford University Stanford United States

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#### 8:00 PM - EM6.8.04

Rapid Micron-Scale Imprinting of Graphene Electrodes for Transistors

Aditi Naik<sup>1</sup>, Jae Joon Kim<sup>1</sup>, Mark Hersam<sup>2</sup>, Alejandro Briseno<sup>1</sup>, James Watkins<sup>1</sup>

<sup>1</sup> University of Massachusetts at Amherst Amherst United States, <sup>2</sup> Northwestern University Evanston United States

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#### 8:00 PM - EM6.8.05

## Optimization of Pen Printing Technique for Scale Down of Printed Organic Electronics

Singu Han<sup>1</sup>, Heejeong Jeong<sup>1</sup>, Hwasung Lee<sup>1</sup>

<sup>1</sup> Chemical and Biological Engineering Hanbat National University Daejeon Korea (the Republic of)

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### 8:00 PM - EM6.8.24

Nitrocellulose Passivation Layer for Improving Electrical Characteristics and Stability of Indium-Gallium-Zinc Oxide Thin-Film Transistors

Kwan Yup Shin<sup>1</sup>, Young Jun Tak<sup>1</sup>, Won-Gi Kim<sup>1</sup>, Seonghwan Hong<sup>1</sup>, Naomi S. Kim<sup>2</sup>, Hyun Jae Kim<sup>1</sup>

<sup>1</sup> Yonsei University Seoul Korea (the Republic of), <sup>2</sup> The Bishop's School La Jolla United States

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### 8:00 PM - EM6.8.15

Gate Current and Potential Barrier Height at Defective Metal-Oxide—First Principles Study of H Atom Impurity and Oxygen Vacancy at Al/SiO<sub>2</sub> Interfaces

Jianqiu Huang<sup>1</sup>, Eric Tea<sup>1</sup>, Celine Hin<sup>1</sup>

<sup>1</sup> Virginia Tech Blacksburg United States

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### 8:00 PM - EM6.8.17

Pulsed Laser Annealing for Non-Thermal Equilibrium GeSn (Sn>10%) on Insulating Substrate

Kenta Moto<sup>1</sup>, Ryo Matsumura<sup>1</sup>, Taizoh Sadoh<sup>1</sup>, Hiroshi Ikenoue<sup>1</sup>, Masanobu Miyao<sup>1</sup>

<sup>1</sup> Kyushu University Fukuoka Japan

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### 8:00 PM - EM6.8.10

Analysis of Electronic Subgap States in Amorphous Semiconductor Oxides on the Example of Zn-Sn-O (ZTO) and In-Ga-Zn-O (IGZO) Systems

Wolfgang Koerner<sup>1</sup>, Daniel F. Urban<sup>1</sup>, Christian Elsaesser<sup>1,2</sup>



<sup>1</sup> Fraunhofer IWM Freiburg Germany, <sup>2</sup> FMF University of Freiburg Freiburg Germany

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### 8:00 PM - EM6.8.01

Reduced Water Vapor Transmission Rates of Low-Temperature-Processed and Sol-Gel-Derived Titanium Oxide Thin Films on Polymeric Substrates for Flexible Electronic Devices

Min Park<sup>1</sup>, Eui Hyun Suh<sup>1</sup>, Seonuk Park<sup>2</sup>, Chan Eon Park<sup>2</sup>, Jaeyoung Jang<sup>1</sup>

<sup>1</sup> Department of Energy Engineering Hanyang University Seoul Korea (the Republic of), <sup>2</sup> Department of Chemical Engineering Pohang University of Science and Technology Pohang Korea (the Republic of)

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### 8:00 PM - EM6.8.02

Photo-Patternable High- $k$  ZrO<sub>x</sub> Dielectrics Prepared Using Zirconium Acrylate for Low-Voltage-Operating Organic Complementary Inverters

Eui Hyun Suh<sup>1</sup>, Min Park<sup>1</sup>, Yong Jin Jeong<sup>2</sup>, Chan Eon Park<sup>2</sup>, Jaeyoung Jang<sup>1</sup>

<sup>1</sup> Energy Engineering Hanyang University Seoul Korea (the Republic of), <sup>2</sup> Chemical Engineering Pohang University of Science and Technology Pohang Korea (the Republic of)

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### 8:00 PM - EM6.8.06

High-Performance, Solution-Processed In-Ga-Zn-O Thin-Film Transistors Annealed by Rapid Flash Lamp Annealing

Chan-mo Kang<sup>1</sup>, Hoon Kim<sup>1</sup>, Yeon-Wha Oh<sup>1</sup>, Kyu-Ha Baek<sup>1</sup>, Lee-Mi Do<sup>1</sup>

<sup>1</sup> Electronics and Telecommunications Research Institute Daejeon Korea (the Republic of)

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### 8:00 PM - EM6.8.08

Device Characteristics of Indium Oxide TFTs Fabricated by Atomic Layer Deposition Using Oxygen Plasma and Ozone as a Reactant

Hwanjae Lee<sup>1,2</sup>, Jeongmu Lee<sup>1,3</sup>, Seong-Deok Ahn<sup>1</sup>, Seungyoul Kang<sup>1</sup>, Jin-Seong Park<sup>2</sup>

<sup>1</sup> Electronic Telecommunication Research Institute Daejeon Korea (the Republic of), <sup>2</sup> Materials and Science Hanyang University Seoul Korea (the Republic of), <sup>3</sup> Korea University of Science and Technology Daejeon Korea (the Republic of)

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#### 8:00 PM - EM6.8.09

Performance Enhancement of Pentacene Based Field Effect Transistors Using Glyoxal Crosslinked Polyvinyl Alcohol Gate Dielectric

Debdatta Panigrahi<sup>1</sup>, Sujit Kumar<sup>1</sup>, Achintya Dhar<sup>1</sup>

<sup>1</sup> Indian Institute of Technology Kharagpur Kharagpur India

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#### 8:00 PM - EM6.8.07

Rapid Activation Solution-Processed Aluminium Oxide Gate Dielectric Using Flash Lamp Annealing

Yeon-Wha Oh<sup>1,2</sup>, Chan-mo Kang<sup>1</sup>, Hoon Kim<sup>1</sup>, Lee-Mi Do<sup>1</sup>, Kyu-Ha Baek<sup>1</sup>

<sup>1</sup> IoT Convergence Research Department Electronics and Telecommunications Research Institute Daejeon Korea (the Republic of), <sup>2</sup> Chungnam National University Daejeon Korea (the Republic of)

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#### 8:00 PM - EM6.8.20

Low-Temperature Processed High-Performance N-Channel SnO<sub>x</sub> Thin-Film Transistors by Oxidation Effect from ZrO<sub>2</sub> Capping Layer

Wen-Liang Huang<sup>1</sup>, Yi-An Shih<sup>1</sup>, Shu-Ming Hsu<sup>1</sup>, Yun-Shiuan Li<sup>1</sup>, I-Chun Cheng<sup>1</sup>

<sup>1</sup> Graduate Institute of Photonics and Optoelectronics National Taiwan University Taipei Taiwan

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#### 8:00 PM - EM6.8.21

Influence of Mechanical Tensile Strain on the Performance of SnO Thin-Film Transistors on Plastic Substrates

Shu-Ming Hsu<sup>1</sup>, Jyun-Ci He<sup>1</sup>, Yun-Shiuan Li<sup>1</sup>, Dung-Yue Su<sup>2</sup>, I-Chun Cheng<sup>1</sup>

<sup>1</sup> Graduate Institute of Photonics and Optoelectronics, National Taiwan University Taipei Taiwan, <sup>2</sup> Department of Materials Science and Engineering, National Taiwan University Taipei Taiwan

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#### 8:00 PM - EM6.8.22

Transport Mechanism of Pentacene Organic Thin-Film Transistors with Graphene Oxide as Gate Dielectric

Kalyan Jyoti Sarkar<sup>1</sup>, Biswajit Pal<sup>2</sup>, Pallab Banerji<sup>3</sup>

<sup>1</sup> Advanced Technology Development Centre Indian Institute of Technology, Kharagpur Kharagpur India, <sup>2</sup> Materials Science Centre Indian Institute of Technology, Kharagpur Kharagpur India, <sup>3</sup> Materials Science Centre Indian Institute of Technology, Kharagpur Kharagpur India

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#### 8:00 PM - EM6.8.23

Repair Techniques for Indium-Gallium-Zinc-Oxide Thin-film Transistors—A Comparison between Vacuum and Solution Processes

Byung Ha Kang<sup>1</sup>, Si Joon Kim<sup>2</sup>, Young Jun Tak<sup>1</sup>, Hyun Jae Kim<sup>1</sup>

<sup>1</sup> Yonsei University Seoul Korea (the Republic of), <sup>2</sup> The University of Texas at Dallas Dallas United States

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#### 8:00 PM - EM6.8.13

Growth and Characterization of Ultrathin Conformal Nickel Films by Plasma-Enhanced Atomic Layer Deposition

Pouyan Motamedi<sup>1</sup>, Ken Bosnick<sup>1</sup>, Kenneth Cadien<sup>2</sup>

<sup>1</sup> National Institute for Nanotechnology National Research Council Edmonton Canada, <sup>2</sup> Chemical and Materials Engineering University of Alberta Edmonton Canada

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#### 8:00 PM - EM6.8.11

Encapsulation and Transport Properties of Quantum Dot Thin-Film Transistors Using Scanning Kelvin Probe Force Microscopy

Syed Ali Moeed Tirmzi<sup>1</sup>, Ryan Dwyer<sup>1</sup>, Tobias Hanrath<sup>2</sup>, John Marohn<sup>1</sup>

<sup>1</sup> Chemistry and Chemical Biology Cornell University Ithaca United States, <sup>2</sup> School of Chemical and Biomolecular Engineering Cornell University Ithaca United States

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**8:00 PM - EM6.8.12**

Growth and Characterization of In<sub>2</sub>O<sub>3</sub> on Various Substrates by Mist CVD

Takuya Kobayashi<sup>1</sup>, Keisuke Tanuma<sup>1</sup>, Tomohiro Yamaguchi<sup>1</sup>, Takeyoshi Onuma<sup>1</sup>,  
Tohru Honda<sup>1</sup>

<sup>1</sup> Kogakuin University Tokyo Japan

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**8:00 PM - EM6.8.14**

Epitaxy and Topotaxy of Vanadium Oxide Semiconductor Thin Films by Solid Phase Crystallization under Uniaxial Compression

Akifumi Matsuda<sup>1</sup>, Yasuhisa Nozawa<sup>1</sup>, Ryotaro Namba<sup>1</sup>, Satoru Kaneko<sup>2 1</sup>, Mamoru Yoshimoto<sup>1</sup>

<sup>1</sup> Tokyo Institute of Technology Yokohama Japan, <sup>2</sup> Kanagawa Industrial Technology Center Ebina Japan

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**8:00 PM - EM6.8.18**

Low-Temperature ( $\leq 250^\circ\text{C}$ ) Lateral Crystallization of Sn-Doped Ge-on-Insulator Enhanced by Au Catalysis

Takatsugu Sakai<sup>1</sup>, Taizoh Sadoh<sup>1</sup>, Ryo Matsumura<sup>1</sup>, Masanobu Miyao<sup>1</sup>

<sup>1</sup> Kyushu University Fukuoka Japan

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