Nanomaterials
Room: Hau - Session NM-TuM

Nano Devices
Moderator: Joerg Patscheider, Empa, Switzerland

8:20am **NM-TuM2 Molecular- and Polymer-based Electronic Devices on Rigid and Flexible Substrates**, ***Takhee Lee***, Seoul National University, Republic of Korea **INVITED**

Idea of utilizing individual molecules as the electronic components in future ultrahigh-density electronic devices has generated tremendous attention. I will explain recently developed understanding on the electrical transport characteristics through various types of molecular junctions on flat or flexible substrates [1-3]. In particular, obtaining transistor action from molecular orbital control has been the outstanding challenge of the field of molecular electronics nearly since its inception. In this talk, I will demonstrate a direct electrostatic modulation of orbitals in a molecular transistor configuration in electromigration nanogap [1] or in mechanically-controllable break junction (MCBJ) [2]. I will also demonstrate functional devices such as diodes or photoswitches at the molecular-scale on both rigid and flexible substrates [3]

I will also present a brief summary on general characteristics of the materials, device structures, and switching mechanisms used in polymer-based non-volatile memory devices. Strategies for performance enhancement, integration, and advanced architectures in these devices will be presented [4].

References:

[1] Nature 462, 1039 (2009); Adv. Mater. 23, 1583 (2011)-review

[1] Nano Lett. 13, 1822 (2013); Adv. Mater. 25, 4845 (2013)-review.

[3] Nature Nanotech. 7, 438 (2012); Adv. Funct. Mater. 24, 2472 (2014); Adv. Mater. in press (2014). DOI: 10.1002/adma.201306316

[4] Adv. Funct. Mater. 21, 2806 (2011)-review.

9:00am **NM-TuM4 High-Throughput Nanogap Formation by Field-Emission-Induced Electromigration**, ***Mitsuki Ito***, *K. Morihara, T. Toyonaka, K. Takikawa, J. Shirakashi*, Tokyo University of Agriculture & Technology, Japan

High-throughput nanogap formation is reported for simultaneously fabricating arrays of integrated nanogaps. Using this method, series-connected 10 nanogaps with symmetrical and asymmetrical shapes were integrated. The integration was achieved using electromigration (EM) induced by First, series-connected 10 Ni nanogaps having symmetrical shape were fabricated by electron-beam (EB) lithography and lift-off process. After performing the activation with final preset current I_S = 300 nA into the 10 nanogaps, the separation of the gaps was reduced to less than 10 nm. This tendency is quite similar to that of series connected 10 nanogaps having asymmetrical shape. Therefore, it is indicated that integration of nanogaps using activation method hardly depends on the shape of nanogap electrodes. Furthermore, activation method was also applied into 30 nanogaps connected in series, for the mass production of identical nanogaps. As a result, the distance between the Ni nanogap electrodes was totally and completely controlled by performing the activation. These results clearly suggest that the integrated nanogaps can be simultaneously fabricated by the activation procedure.

9:20am **NM-TuM5 *In-Situ* AFM Imaging of Structural Change in Metal Nanowires during Feedback-Controlled Electromigration**, ***Mamiko Yagi***, *T. Saito, J. Shirakashi*, Tokyo University of Agriculture & Technology, Japan

We present real time atomic force microscopy (AFM) imaging of structural changes in gold (Au) nanowires during feedback-controlled electromigration (FCE) process. The resistance increases during the FCE process and is associated with drastic changes of the nanowires morphology, suggesting successful control of electromigration (EM) by FCE scheme. Moreover, we find that the AFM images after performing the FCE indicate a matter redeposition along the nanowire in the direction of the anode side. This grains show faceting structures at the anode side. Furthermore, in order to obtain quantitative information on height of structures, cross sections of the nanowire obtained from the AFM images during FCE was investigated. Height evolution of the narrowest part of the wire perpendicular to the electron flow is obtained, resulting that void nucleation and void growth along the grain boundaries, which are located on the border of the nanowire, start in the vicinity of the nanowire constriction at the cathode side. These results imply that *in-situ* AFM technique provides insight into the behavior of EM-induced voids in nanowires during FCE.

9:40am **NM-TuM6 Single Carbon Nanotube Devices for Integrated Photonics**, ***Yuichiro Kato***, The University of Tokyo, Japan

Single-walled carbon nanotubes have unique optical properties as a result of their one-dimensional structure. Not only do they exhibit strong polarization for both absorption and emission, large exciton binding energies allow for room-temperature excitonic luminescence. Furthermore, their emission is in the telecom-wavelengths and they can be directly synthesized on silicon substrates, providing new opportunities for nanoscale integrated photonics.

Here we discuss the use of individual single-walled carbon nanotubes for optical devices that could be integrated in silicon photonics. Their light emission properties can be controlled by coupling to silicon photonic structures such as photonic crystal microcavities [1,2] and microdisk resonators [3]. With the strong absorption polarization at the nanoscale, they allow for unconventional polarization conversion that results in giant circular dichroism [4]. More recently, we have found that excitons can dissociate spontaneously [5], enabling photodetection at low bias voltages. Ultimately, it should be possible to combine these results to achieve generation, manipulation, and detection of photons on a chip.

Work supported by SCOPE, KAKENHI, The Canon Foundation, The Asahi Glass Foundation, KDDI Foundation, and the Photon Frontier Network Program of MEXT, Japan. The devices were fabricated at the Center for Nano Lithography & Analysis at The University of Tokyo.

[1] R. Watahiki, T. Shimada, P. Zhao, S. Chiashi, S. Iwamoto, Y. Arakawa, S. Maruyama, Y. K. Kato, Appl. Phys. Lett. 101, 141124 (2012).

[2] R. Miura, S. Imamura, R. Ohta, A. Ishii, X. Liu, T. Shimada, S. Iwamoto, Y. Arakawa, Y. K. Kato, submitted.

[3] S. Imamura, R. Watahiki, R. Miura, T. Shimada, Y. K. Kato, Appl. Phys. Lett. 102, 161102 (2013).

[4] A. Yokoyama, M. Yoshida, A. Ishii, Y. K. Kato, Phys. Rev. X 4, 011005 (2014).

[5] Y. Kumamoto, M. Yoshida, A. Yokoyama, T. Shimada, Y. K. Kato, Phys. Rev. Lett. 112, 117401 (2014).

10:20am **NM-TuM8 Large Scale Confinement Induced Alignment of Gold Nanorods**, ***Waqqar Ahmed***, COMSATS Institute of Information Technology, Pakistan, *C. Glass, J.M. van Ruitenbeek*, Leiden University, Netherlands

Gold nanoparticles have attracted enormous attention owing to their interesting optical properties arising from the surface plasmon resonance. The plasmon peaks are very sensitive to the size and shape of the nanoparticles. For anisotropic nanoparticles there are multiple plasmon peaks due to the shape anisotropy. For instant, for a rod-shaped gold nanoparticle, there are two plasmon peaks, owing to the difference in resonance frequencies of electrons along the length and width of nanorods. The relative intensity of these peaks can be controlled by controlling the orientation of nanorods with respect to the incident electromagnetic wave's polarization. Therefore, for application purposes, it is crucial to control the orientation of nanorods.

In this work we describe a simple and elegant method to obtain wafer scale alignment of gold nanorods. We have used hydrophilic-hydrophobic contrast patterned substrates to selectively deposit gold nanorods in desired regions of substrate. The gold nanorods were grown in solution and then deposited on the substrate simply by drop casting. As the nanorods were hydrophilic, they only deposited in hydrophilic regions. When the hydrophilic stripe width becomes comparable to the length of the nanorod, the nanorod aligned along the length of the hydrophilic stripe. The degree of alignment increased with decrease in the stripe width. The alignment is influenced by various entropic and energetic forces such as orientational entropy, excluded volume entropy, van der Waals forces and electrostatic forces [1]. We were able to tune the strength of these forces simply by tuning the concentration of nanorods in solution. Our results agree well with the two dimensional Monte Carlo simulations of confined rectangles.

Ref: [1] W. Ahmed, C. Glass, J. van Ruitenbeek, Nanotechnology 25, 035301, 2014.

11:00am **NM-TuM10 Nanodevices for Molecular Detection based on Nanomaterials and Nanogap**, *D.K. Park*, *C.Y. Lee*, *A. Kang*, Sungkyunkwan University, Korea, ***WanSoo Yun***, Sungkyunkwan University, Korea, Republic of Korea **INVITED**

Singularity dictates a device function at the nanoscale. Dopants or impurities, structural defects, adsorbates, and stray charges can behave as a singularity in certain conditions, either promoting or deteriorating the device function, which frequently is the major concern in the implementation of nanoscale memories and sensors.

In a nanodevice adopting nanomaterials, the control over singular points in the nanomaterials can be regarded as a tuning process of the device property, which may open up a new possibility of its application to the molecular measurements. In the earlier part of this talk, an example of the property-tuned nanodevice for molecular measurements will be discussed after a short introduction of visualizing the singularities in a nanodevice based on the nanomaterials.

An extreme case of the singularity can be found in a nanogap device which has two electrodes separated by a few to a few tens of nanometers. In the later part of this talk, application of nanogap devices in the electric/electrochemical (bio) molecular detection will be discussed with our recent experimental results along with the way of their simple lab-scale mass production.

11:40am **NM-TuM12 Band Offsets at Zincblende-Wurtzite GaAs Nanowire Sidewall Surfaces**, *P. Capiod*, *T. Xu*, *J.P. Nys*, *M. Berthe*, Institut d'Electronique et de Microélectronique et de Nanotechnologies, France, *G. Patriarche*, CNRS-Laboratoire de Photonique et de Nanostructures, France, *L. Lymperakis*, *J. Neugebauer*, Max-Planck Institut für Eisenforschung GmbH, Germany, *P. Caroff*, The Australian National University, Australia, *R.E. Dunin-Borkowski*, ***Philipp Ebert***, Forschungszentrum Jülich GmbH, Germany, *B. Grandidier*, Institut d'Electronique et de Microélectronique et de Nanotechnologies,, France

Recent advances in the growth of nanowires allow the fabrication of complex crystal structures, which otherwise are unstable and hence cannot be achieved in the bulk. In these semiconductor polytype materials, understanding the energetic position of surface states and Fermi level position at the surface is critical, since these parameters might govern the material transport and optical properties. However, the importance of the surface has been put aside so far, due to controversies that already exist for the band alignment in the bulk polytypes. A prototypical material is GaAs, where polytype inclusions consisting of zinc-blende (ZB) and wurtzite (WZ) segments form during the growth of NWs and where the band discontinuities at the interface are strongly debate.

Therefore, we investigated the band structure and the Fermi level pinning at clean and well-ordered sidewall surfaces of zincblende (ZB)-wurtzite (WZ) GaAs nanowires by scanning tunneling spectroscopy and density functional theory calculations. The WZ-ZB phase transition in GaAs nanowires introduces *p-i* junctions at the sidewall surfaces. This is caused by the presence of numerous steps, which induce a Fermi level pinning at different energies on the non-polar WZ and ZB sidewall facets.

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