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General Information

The EMN Chengdu Meeting 2019 will take place at Shahe Campus, UESTC from Dec 16 to 20, 2019.

Workshops on selected focus topics will include invited and contributed oral presentations from Tuesday to Wednesday.

Registration Desk Hours

The Meeting registration desk, located at 8 floor Communication Building, will be open during the following hours:

- Monday, December 16 ................................................................. 15:00-17:30
- Tuesday, December 17............................................................... 9:00-17:00
- Wednesday, December 18......................................................... 9:00-17:00
Detailed Meeting Program

EMN Chengdu Meeting 2019

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| 15:00-17:30| Onsite-registration & Sign up 8th floor, Communication Building, Shahe Campus, UESTC  
(电子科技大学沙河校区通信楼 8 楼) |
| Tuesday December 17 | Meeting Room 818 |

**Session: EMN Droplets Session I  Chair: Mingzhe Dong**

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<td>Larisa B. Gulina</td>
<td>Saint Petersburg State University, Russia</td>
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<td>9:25-9:50</td>
<td>A02: Nanowire growth direction control via varying catalyst droplet composition</td>
<td>Nick Sibirev</td>
<td>ITMO University, Russia</td>
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<td>9:50-10:15</td>
<td>A03: Digital Microfluidics for Precision Medicine</td>
<td>Ren Shen</td>
<td>the State Key Laboratory of Analog and Mixed-Signal VLSI, University of Macau, Macau</td>
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<td>10:15-10:45</td>
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<td>10:45-11:10</td>
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<td>A05</td>
<td>Evaporation of complex pendant droplets and the effect of external field stimuli</td>
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<td>11:35-12:00</td>
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<td>Droplet dynamics and condensation in the presence of noncondensable gas using phase-change lattice Boltzmann method</td>
<td>Yu Shi</td>
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<td>14:00-14:25</td>
<td>A07: Molecular Dynamics Simulation on Intergranular Cracking Mechanism of FCC Type High-Entropy Alloys Structural Materials in High-Temperature Pressurized Water Environment</td>
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<td>Chang Liu</td>
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<td>14:25-14:50</td>
<td>A08: Large-Scale Molecular Dynamics Simulations on Friction and Wear Processes of Diamond-like Carbon Materials</td>
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<td>Nobuki Ozawa</td>
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<td>14:50-15:15</td>
<td>A09: Deformation Mechanism of Alumina/Carbon Nanotube Composites by Molecular Dynamics Simulation: How Does Processing Condition Affect Mechanical Properties?</td>
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<td>16:10-16:35</td>
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<td>16:35-17:00</td>
<td>A12: Spintronic Memories</td>
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<td>17:00-20:00</td>
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<td>9:25-9:50</td>
<td>A13: What makes lead-based perovskites incommensurate</td>
<td>Roman Burkovsky (Peter the Great Saint-Petersburg Polytechnic University, Russia)</td>
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<td>9:50-10:15</td>
<td>A14: Perovskite photovoltaic cells for indoor and aerospace applications</td>
<td>Harrison Ka Hin Lee (Swansea University, UK)</td>
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<td>10:45-11:10</td>
<td>A15: Skin-Integrated Sensors and Haptic Interfaces for VR and AR</td>
<td>Xinge Yu (The City of University of Hong Kong, Hong Kong)</td>
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<td>11:10-11:35</td>
<td>A16: Chirality, topology, and hydrodynamics</td>
<td>Yuji Hirono (Asia Pacific Center for Theoretical Physics, Japan)</td>
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## Wednesday December 18

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| 14:25-14:50 | A17: Nanomembrane formed microtubular cavities as a platform for light-matter interactions | Libo Ma  
IFW-Dresden, Germany |
| 14:50-15:15 | A18: Direct-writing 3D superconducting nanostructures                   | Rosa Cordoba Castillo  
University of Valencia, Spain |
| 15:15-15:40 | A19: Nanoengineering hollow structured carbon spheres as nanoreactors for sustainable energy applications | Jian Liu  
State Key Laboratory of Catalysis, Dalian Institute of Chemical Physics, CAS, China |
| 17:00-20:00 |                                                                         | Dinner Social |

Dinner Social
ABSTRACT SESSION

A01: Crystallization on the surface of solution drop as a result of interfacial reaction with gaseous reagent

Larisa B. Gulina, Nadezhda I. Vladimirova, Irina Skvortsova, Vera V. Strykanova, Valeri P. Tolstoy

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It is well-known fact that many different processes are possible to occur in a droplet. A droplet can be a tiny reactor for the formation of micro- and nanostructures. The reactions that proceed in the droplet play paramount role in biochemistry, medical engineering, printing processes, the creation of nano- and microsensors, and other miniature devices. In the contemporary world, a lot of scientific works are dedicated to the study of the evaporation processes of the solutions or suspensions and sedimentation in a droplet, as well as chemical reactions that take place within droplets. In this work, for the first time, the features of the crystallization on the surface of a solution droplet as a result of its interaction with a gaseous reagent are considered.

Recently, a similar Gas-Solution Interface Technique (GSIT) was successfully applied to form a gradient solid layer on the surface of the aqueous solution of salt. The main peculiarity of such layer is not only its nanocrystalline structure, but also the possibility of transformation into microtubes with scrolls morphology. Microtubes of oxides, hydroxides, sulfides, fluorides have been synthesized by GSIT in the last decade. [1-4].
The experimental results of the formation of microstructures of inorganic oxides based on Mn and Fe are discussed in the report. The influence of the synthesis conditions on the morphology, composition, and crystal structure of individual and mixed oxides is investigated. Figure 1 shows the optical and SEM images of oxide structures with Mn and/or Fe content. The possibility of forming ordered honeycomb networks is mentioned [5]. The conclusion is drawn on the role of the curvature of the droplet surface in the formation of a regular structure.

![Fig. 1. Optical image of MnO$_2$ ordered network structure (a); SEM image of MnO$_2$ network (b); optical image of Mn-Fe mixed oxide crystals (c).](image)

A model of the formation of an ordered network of crystals on the surface of a droplet in the process of interaction with a gaseous reagent is proposed.

Authors are grateful resource centers of the SPbSU, namely the X-ray Diffraction Centre and the Nanotechnology Centre.

The work was supported by Russian Science Foundation (grant # 16-13-10223-P).


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**A02: Nanowire growth direction control via varying catalyst droplet composition**

Nickolay V. Sibirev¹,², Yury S. Berdnikov¹

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Semiconductor nanowires (NWs) are widely considered as promising building blocks for novel opto- and nanoelectronic devices [1,2]. However, their use in the device applications usually requires control of the direction of NW growth, which strongly depends on the growth mechanism. The most common approaches to the synthesis of III-V and group IV NWs is the epitaxial growth via the vapor-liquid-solid (VLS) mechanism [1,2].

Here we described the model able to predict NW growth direction. In the present study, we investigate the influence of initial catalyst droplet composition on the growth direction and demonstrate the opportunity to control the growth direction by varying the III/V ratio. We focused on the following aspects of NW growth: sliding down of the droplet sliding down from the NW tip and changing NW growth direction change [1]; detachment of the catalyst from the substrate and stabilization of horizontal growth by nucleation at the nanowire-substrate-liquid line [2]. Therefore, the model allows us to predict whether the VLS growth would preferably result in the formation of in-plane (horizontal) or out-of-plane (vertical or inclined) NWs and the chance of kinks or branch formation during the NW growth.
Our model was applied to the growth of Au and Ga-catalyzed GaAs NWs on the free silicon substrate and covered by graphite nanoplatelets. The model describes four modes of horizontal growth for the NWs contacting barrier on top of GNP. Figure 1 illustrates these growth modes.

![Mode 1 – “Alignment”](image1)
![Mode 2 – “Reflection”](image2)
![Mode 3 – “On-barrier”](image3)
![Mode 4 – “Vertical”](image4)

Fig1. Schematics of horizontal GaAs NW growth modes and corresponding SEM images. The scale bars correspond to 200 nm.


A03: Digital Microfluidics for Precision Medicine

Yanwei Jia

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Faculty of Science and Technology, University of Macau, Macau SAR, China

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With the capability of electronically manipulating individual droplets, digital microfluidics (DMF) has attracted much attention for it removes the burden of pumps and valves for channel microfluidic systems, making it an ideal platform for point-of-care biomedical applications. In this talk, Jia will introduce the updated research progress in her lab on developing portable intelligent digital microfluidic systems for disease diagnostics, especially for precision medicine. An electronic control system with real-time feedback and image processing has been developed for the automated control system. Novel chip design and fabrication combining with specific molecular chemicals have speed up the DNA amplification from hours to minutes and specific pathogen detection from minutes to seconds. Single cell drug screening has been realized on DMF chip with 3D microstructures for precision medicine. A novel pico-pipette on DMF was developed for precise and flexible sample delivery, which significantly simplified the protocol of sample preparation on-chip. All the attempt would pave the way to an automatic DMF device for point-of-care disease diagnostics.

A04: Transport of Oil-in-Water Emulsion Droplets in Porous Media

Mingzhe Dong, Boxin Ding

Department of Chemical and Petroleum Engineering, University of Calgary, Calgary, Alberta, CA

Email: Mingzhe.dong@ucalgary.ca

Injection of oil-in-water (O/W) emulsions could be an innovative conformance control technology in oil sands recovery because of the controllable size and strength of
emulsion droplets.

In this presentation, experimental results in sandpack flood tests are first presented to demonstrate O/W emulsion plugging ability in sandpacks. A model for the pressure drop versus flow rate based on the bi-viscosity model is discussed. This model expresses that the flow of emulsion in porous media has two distinct mobility in porous media demarcated by a critical pressure drop. The inverse of the distinct mobility is determined as consistency parameter and the critical pressure drop as the yield pressure drop. Effects of interfacial tension (IFT), emulsion quality, oil viscosity, droplet size, emulsion slug size, and sandpack permeability on the yield pressure drop and consistency parameter are analyzed.

Second, experimental results of emulsion injection followed by water flooding in sandpack are analyzed. The observed four stages of the plugging process are discussed. Different emulsion properties (emulsion quality, IFT and droplet size), sandpack length, and emulsion slug size are assessed as their impacts on each stage of the plugging process. For a sandpack with specified properties, only injection of an optimal emulsion system can achieve a desired plugging strength and depth. A developed mathematical model can be used to design an optimal emulsion system by fully incorporating emulsion properties, sandpack properties and emulsion slug size.

Third, parallel-sandpack flow tests are analyzed on how emulsion injection achieves the conformance control in both high permeability sandpack and low permeability sandpack. Results indicate that a carefully designed O/W emulsion can selectively flow and block large pore throats in high permeability sandpacks without causing damage in low permeability sandpacks. O/W emulsion also has strong ability to tolerate long-term water flushing to achieve in-depth blockage. Experimental results also show that IFT, emulsion quality, distribution of droplet size, and oil viscosity had a significant effect on the emulsion’s conformance control performance. By adjusting emulsion quality, distribution of droplet size and oil viscosity, conformance control can be achieved in heterogeneous parallel-sandpack models.
A05: Evaporation of complex pendant droplets and the effect of external field stimuli

A R Harikrishnan

1Department of Mechanical Engineering, Birla Institute of Technology and Science Pilani, Pilani, Rajasthan, India.
Email: ar.harikrishnan@pilani.bits-pilani.ac.in, web site: https://www.bits-pilani.ac.in/pilani/arharikrishnan/Profile

Evaporation kinetics of pendant droplets is an area of immense importance in several applications, in addition to possessing rich fluid dynamics and thermal transport physics. This present study experimentally and analytically sheds insight into the evaporation dynamics of ionic as well as colloidal solutions in the presence of external electric and magnetic field stimulus. The literature provides information that solutal advection and the solutal Marangoni effect lead to enhanced evaporation in droplets with solvated ions [1]. Also the previous studies indicate the presence of solute-thermal convection inside the nanocolloidal pendant droplets [2]. The main focus of this article is to understand the thermosolutal advection in the presence of external electric and magnetic fields and comprehend the dynamics of the evaporation process under such complex multiphysics interactions.

An experimental study is performed, where electric and magnetic fields are applied across pendent droplets of salt solutions and colloidal solutions and their internal flow dynamics is observed with the help of an inbuilt flow visualization setup [3, 4]. Flow visualization and velocimetry reveals that the direction of the applied field governs the enhancement or reduction in circulation velocity and the directionality of circulation inside the droplet. Further, it is noted that while magnetic fields augment the circulation velocity (with respect to the solutal advection already present in salt solution droplets at zero field) the electric field leads to deterioration of the same. Experimental observations reveal that the evaporation rate enhances as a direct function of the magnetic moment of the
solvated magnetic element ions, thereby pointing at the magnetophoretic and
magnetosolutal advection. The present study shows experimentally and by
mathematical analysis that the presence of magnetic field improves the evaporation
rates of ferrofluid droplets [4]. The analytical analysis employs a scaling analysis to
evaluate the undelaying mechanism and the extend of contribution of each
mechanism. The stability map is developed to correlate the contributing mechanisms
with the external field condition. The analysis and stability maps reveal that the
magneto-solutal ferroadvection is the more dominant mechanism, and the model is
able to predict the internal advection velocities with accuracy. The present findings
may have strong implications in microscale and interfacial electro- and/or
magnetohydrodynamics.


**A06: Droplet dynamics and condensation in the presence of noncondensable gas using phase-change lattice Boltzmann method**

Yu Shi
*Xi'an University of Science and Technology, China*
shiyu@xust.edu.cn
**A07: Molecular Dynamics Simulation on Intergranular Cracking Mechanism of FCC Type High-Entropy Alloys Structural Materials in High-Temperature Pressurized Water Environment**

Chang Liu¹, Qian Chen¹, Yang Wang¹,², Narumasa Miyazaki¹, Yusuke Ootani¹, Nobuki Ozawa¹, Momoji Kubo¹

¹Institute for Materials Research, Tohoku University, Sendai, Japan

Email: chang.liu@imr.tohoku.ac.jp

²Department of Mechanical Systems Engineering, Tohoku University, Sendai, Japan

High-entropy alloys (HEAs) are formed by mixing equal or relatively large proportions of usually five or more metal elements [1]. HEA indicates the unique mechanical properties such as high oxidation resistance and excellent corrosion resistance which are not found in conventional alloys [2, 3]. Thus, HEA is expected to be applied as structural materials under corrosion conditions. However, the stress corrosion cracking of HEAs occurs in high-temperature corrosion environments leading to the fatal destruction. Consequently, for the improvement of HEAs, it is required to elucidate the stress corrosion cracking mechanism of HEAs in a high-temperature pressurized water environment at the atomic scale. In this research, the tensile test was performed on the models with grain boundary of face-centered cubic structure (FCC) type HEA in both the vacuum and water environments by molecular dynamics simulations with a reactive force field.

Figure 1 shows the atomic structure of Σ37 (610) grain boundary model of FeNiCrCo in (a) vacuum and (b) high-temperature pressurized water environments at the strain of 9.0%. Figure 1(a) shows that in a vacuum environment, the stacking faults via a structural transformation from FCC to hexagonal close-packed structure (HCP) were generated from the grain boundaries and surfaces. However, figure 1(b) shows that in a water environment, the oxide film was generated from the surface because the HEA surface was oxidized by water. Furthermore less stacking faults
were observed in the water environment than that in the vacuum, indicating that the generation of stacking faults is suppressed by oxidation of the HEA surface. Therefore, the relaxation of the strain during the tensile process decreases in the water environment, leading to the cracking along the grain boundary, and the durability of HEA is therefore declined.

Figure 1. Atomic structure of Σ37 (610) grain boundary model of FeNiCrCo in (a) vacuum and (b) high-temperature high-pressure water at strain of 9.0%.

A08: Large-Scale Molecular Dynamics Simulations on Friction and Wear Processes of Diamond-like Carbon Materials

Momoji Kubo¹

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Diamond-like carbon (DLC) and its related materials such as CNx and SiC have gained much attention as super-low friction materials for automotive engines, aerospace equipment, and so on. We have already applied our tight-binding quantum chemical molecular dynamics simulation code “Colors” to investigating the low-friction mechanism of DLC [1,2]. In addition to the super-low friction properties, super-low wear properties are strongly required for industrialization of DLC. Our tight-binding quantum chemical molecular dynamics simulation code is very effective to elucidate the chemical-reaction induced super-low friction mechanism, however it is not effective to investigate the wear process because it can calculate only several thousand atoms. Therefore, we newly developed a reactive molecular dynamics simulation code “LASKYO” for large-scale simulations to clarifying the wear process [3]. This new simulation code has two merits: it is possible (1) to investigate the chemical reaction dynamics during the friction, which cannot be realized by regular classical molecular dynamics method and (2) to calculate large number of atoms, which cannot be realized by quantum chemical molecular dynamics method.

Fig. 1 shows one example of the friction and wear process of hydrogenated DLC at 300 K. It is interesting to see the evaporation of organic molecules such as methane, ethane, and ethylene. This is also observed in the vacuum chamber by the experiments of our collaborator Prof. K. Adachi. Therefore, we confirmed the applicability and effectiveness of our reactive molecular dynamics simulation code. In fig. 1, in addition to the evaporation of organic molecules, carbon clusters are worn and attached on the counter DLC substrate. We propose here that that the evaporation of organic molecules is “Chemical Wear” and the attachment of worn
carbon clusters is “Mechanical Wear”. It means that our reactive molecular dynamics simulation code is very effective to elucidate both “Chemical Wear” and “Mechanical Wear” of DLC, which have not been reported so far, to the best of our knowledge. We also revealed very interesting relationship between “Chemical Wear” and “Mechanical Wear”. First, chemical wear occurs during the friction process and then surface hydrogens are removed by the evaporation of organic molecules and dangling bonds are generated on the surface. Second, these surface dangling bonds connect with those on the counter surface and the interfacial chemical bonds are generated between two DLC substrates. Finally, the interfacial chemical bonds between two DLC substrates induce the mechanical wear. Here, we propose a new wear mechanism of DLC; “Mechanical Wear is induced by Chemical Wear”. To the best of our knowledge, this is the first proposal of the relationship between “Chemical Wear” and “Mechanical Wear”.

Fig1. Friction and Wear Process of DLC

Alumina, like other advanced ceramics materials, have excellent thermo-stability, high stiffness, high biocompatibility and relatively low density. However, its application is limited by the brittleness and unstable mechanical properties. Carbon nanotube (CNT) is supposed to be an excellent reinforcement because of its low density and superior mechanical properties. However, when CNTs are added to alumina, uncertainty in CNTs as toughening agent has been reported because of few interfacial interactions between CNT fibers and alumina matrix [1]. Furthermore, experimental results have shown that the processing conditions especially like annealing could improve mechanical properties of the CNT/alumina composites, although the reinforcing mechanism has not been fully clarified.

In this research, we used reactive molecular dynamics simulations to investigate the reinforcing mechanism of alumina/CNT composites by the annealing. To investigate the effect of annealing, we annealed the alumina/CNT composites at 2000 K then cooled them down to 300 K slowly. Then, we performed a tensile simulation on both the annealed and non-annealed alumina/CNT composite models (Fig. 1a) with various CNT volume fractions. A Nose-Hoover thermostat was used
to control the temperature of the system at 300 K during the tensile simulation. The Young’s modulus was calculated as the slope of the elastic region of the stress-strain curve. The tensile strength was calculated as the max stress of the elastic deformation.

The Young’s modulus and tensile strengths from the tensile simulations are shown in Fig. 1b and 1c, respectively. Without annealing, neither the Young’s modulus nor tensile strength changed with increasing CNT fraction. This is because the slippage at the alumina/CNT interface occurs so that CNT does not bear the load. With annealing, both of Young’s modulus and tensile strength increased as CNT fraction increased because the slippage at the interface is inhibited. We also compared the results with shear-lag prediction, which is a theoretical model to predict the mechanical properties of composites. We find that the mechanical properties of the composite without annealing do not approach the shear-lag predictions, whereas those with annealing do. We reveal that the annealing reinforces the CNT/alumina composite by reducing the slippage at the interface.

![Graph of Young's modulus and tensile strength](image)

Fig. 1 (a) Model of alumina/CNT composite, (b) Young’s modulus with different volume fractions and (c) Tensile strength of CNT with different volume fractions.

A10: High holding voltage SCR for latch-up free ESD protection

Wang Zhuo, Dong Shida, Qi Zhao, Zhang Fabei

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In this paper, the cathode N+ emission area of the traditional lateral SCR device is divided into a certain number of multiple emission N+ regions to improve the holding voltage, as shown in Fig. 1. But the current distribution will be worse due to the different body resistances from P+ anode to N+ regions of cathode. To optimize the current distribution, a series of resistances is fabricated respectively on the electrodes of each cathode N+ emission region to compensate for the aforementioned voltage difference. In this case, the current distribution of device can be optimized and the anti-latch-up capability of the device can be improved due to the high holding voltage, which will significantly improve device performances.

Fig. 1. The proposed structure

Fig. 2. shows the I-V curve of various device with different number of emitter blocks. As the result, the device's holding voltage is 2V at n=1. With the n increases to 4, the device's holding voltage is 8V. Fig. 3(a) shows the current distribution of conventional SCR structure. Fig. 3(b) shows current distribution of the optimized structure. It can be proved that this scheme has the effect of optimizing the current distribution.
Fig. 3. The current distribution of (a) the traditional SCR and (b) the proposed SCR


**A11: Energy Harvesting and Storage Textiles**

Bingang Xu

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Textiles are flexible and versatile materials consisting of natural or synthetic fibers that can be knitted, woven or nonwoven into designable network structures for a quite broad spectrum of applications. Owing to their light-weight, wearability and excellent flexibility, textile-based materials and structures have recently attracted great attention in the development of flexible and wearable devices for energy harvesting and storage. In this talk, our recent works on textile-based wearable energy harvesting and storage technologies and devices will be introduced and discussed in terms of structures, materials and fabrications. Their potential applications in the sustainable development will also be explored.

Figure 1 shows a new kind of 3D textile energy harvesters that is, for the first time, realizing the truly wearable properties of energy devices for harvesting and converting mechanical energy to electricity. The truly wearable energy devices can generate a maximum power density of 1768.2 mW m⁻² and directly light up over 320 LEDs instantaneously by a single impact with an effective area of only 56.7 cm². Figure 2 shows a series of textile-based flexible and wearable supercapacitors (SCs) designed in different dimensions, including 1D fiber-shaped SCs, 2D planar fabric SCs, and 3D porous fiber-network SCs. The as-made SCs have exhibited good electrochemical performance and also excellent flexibility and wearability, demonstrating a promising perspective for the design and development of flexible and multifunctional SCs for wearable energy storage.
Fig1. Truly Wearable Energy Harvesting Devices.

Fig2. Flexible and Wearable Energy Storage Devices.

A12: Spintronic Memories

Viktor Sverdlov\textsuperscript{1} and \textbf{Siegfried Selberherr}\textsuperscript{2}

\textsuperscript{1}Christian Doppler Laboratory for Nonvolatile Magnetoresistive Memory and Logic at the
\textsuperscript{2}Institute for Microelectronics, TU Wien, Gußhausstraße 27-29, 1040 Wien, Austria
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With chips based on the 5nm technology node approaching production, the semiconductor industry is focusing on the 3nm technology node \cite{1}. However, to sustain the growing demand for high performance small area CPUs and high-capacity memory, an introduction of a disruptive technology employing conceptually new computing principles becomes paramount. An attractive solution to significantly reduce the power consumption and eliminate leakage currents in modern integrated circuits is to employ the electron spin. Magnetic tunnel junctions (MTJs) are perfectly suited as key elements of nonvolatile CMOS-compatible magnetoresistive random access memory (MRAM) \cite{2}. The information is encoded into two relative magnetization states with parallel or antiparallel orientation of the MTJ’s magnetic layers. The resistances of the two states are different providing a way to sense the information electrically. The relative magnetization orientation can be switched by means of the spin transfer torque (STT) due to the current, which acts on a free recording layer.

Perpendicular MTJs (p-MTJs) are perfectly suited for high-density memory applications \cite{2}. The discovery of an interface-induced perpendicular anisotropy at the CoFeB/MgO interface \cite{3} enabled p-MTJ based MRAM. Thereby the switching current density is reduced, while the thermal barrier separating the two states - the thermal stability – is increased at the same time \cite{2}. A p-MTJ structure with a composite free layer CoFeB/Ta/CoFeB with two MgO interfaces \cite{4} boosts the thermal stability while reducing the Gilbert damping and the switching current. The use of shape anisotropy allows MTJ diameter scaling beyond 10nm \cite{5}. STT-MRAM is processed on CMOS wafers before the back-end-of-line (BEOL) process \cite{6}. For
embedded applications, a successful implementation of 8Mb 1T-1MTJ STT-MRAM on a 28nm CMOS logic platform [7] was demonstrated. Recently, 128Mb embedded MRAM with 14ns write speed was reported [8]. An embedded MRAM solution compatible with Intel’s 22FFL FinFET technology is available [9].

To further reduce the energy consumption, it is essential to replace the static RAM in modern hierarchical multi-level processor memory caches with a non-volatile memory. Spin-orbit torque (SOT) assisted MRAM is suitable for next-generation SRAM replacement [10]. In this memory cell the MTJ’s free layer is grown on a material with a large spin Hall angle. The SOT acting on the adjacent magnetic layer is generated by passing the current through this material. However, for deterministic SOT-induced switching of a p-MTJ a magnetic field is required. A scheme employing two orthogonal current pulses is suitable for achieving sub-ns deterministic switching without an external magnetic field [11].

The introduction of non-volatility to data processing offers outstanding advantages over standard CMOS-based computing as it paves the way for a new low-power and high-performance computation paradigm based on logic-in-memory and in-memory computing architectures, where the same nonvolatile elements are used to store and to process the information. The availability of high-capacity nonvolatile memory in the proximity to high-performance CMOS circuits allows exploring conceptually new logic-in-memory [12] and computing-in-memory [13], [14] architectures for future artificial intelligence and cognitive computing [15].

A13: What makes lead-based perovskites incommensurate

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Antiferroelectric perovskites are key part in highly pyro- and piezoelectric PZT ceramics. Prospective applications of antiferroelectrics include energy storage due to structural switching and non-volatile memory based on antiferroelectric domain walls. Physics behind antiferroelectric behavior is still puzzling. Why are these materials not ferroelectrics, as BaTiO\textsubscript{3} and PbTiO\textsubscript{3}? This question is fascinating for quite some time.

The defining property of antiferroelectrics, such as PbZrO\textsubscript{3} and PbHfO\textsubscript{3}, is the anti-polar arrangement of Pb\textsuperscript{2+} ion displacements in the low-symmetry phase. On the
other hand, it is known that the dipole-dipole interactions favor polar arrangement, which is why ferroelectricity appears in ferroelectrics. We have shown, that at special circumstances, which are readily expected in lead-based antiferroelectrics, the dipole-dipole interactions favor incommensurate ordering [1], therefore enabling the formation of antiferroelectric phase as a result of lock-in transition. However, these specifics of the Hamiltonian on the harmonic level, although bringing more light on the origin of incommensuration, still do not explain, how incommensurate phases form in the absence of incommensurate soft mode in the cubic phase, as recently observed by us in PbHfO3. To understand that, we have performed a comprehensive spectroscopic scattering study of that crystal and shown that cubic-to-incommensurate transition is driven by antiferrodistortive soft mode, whose condensation leads to the simultaneous formation of incommensurate and antiferrodistortive order parameters [2]. This is the first evidence for a triggered incommensurate transition, which is similar to the triggered ferroelectricity known in BiFeO3. Our high-pressure-high-temperature diffraction and diffuse scattering experiments on PbZrO3 and PbHfO3 further explore the decisive role of antiferrodistortive order parameter in creating incommensuration.

Fig1. Incommensurate phase in PbHfO3 as seen in x-ray diffraction. The numbers indicate the order of incommensurate satellites. The inset shows superstructure reflections due to the antiferrodistortive order parameter.
A14: Perovskite photovoltaic cells for indoor and aerospace applications

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In this presentation, non-AM1.5G applications of perovskite photovoltaic (PPV) cells are explored. PPV cells with three benchmark device architectures – mesoporous PPV (mPPV) and inverted PPV (iPPV) with alternative hole transporting layers (HTLs), and carbon-based PPV (cPPV) are studied under indoor lighting conditions. Although the standard one sun performance is comparable among devices with different device architectures and HTLs, there is substantial difference on the indoor performance depending on the use of the device architectures and HTLs. We found that the variation of the indoor performance correlates to the leakage current in the device. With suitable HTL or device architecture, the indoor performance can be one of the tops among other inorganic PV technologies, generating maximum power density of over 111 μW/cm² under 1000 lux and over 19 μW/cm² under 200 lux.

Besides, PPV cells have high potential for aerospace applications such as satellites or high-altitude pseudo-satellites (HAPS) due to its high specific power. For high altitude pseudo-satellite (HAPS) applications, the PV devices are expected to operate at stratosphere where the temperature and pressure are lower than the earth surface. Performance of PPV cells under AM0 illumination at various temperature were examined. For normal satellite applications, since the presence of
high energy particle, their stability under such condition is studied. We perform high energy proton bombardment to PPV cells with fluence ranged from $10^{12}$ to $10^{15}$ p/cm$^2$. We found that the structural and optical properties of perovskite remain intact up to high fluence levels. Our results highlight the great potential of PPV cells for space applications.

**A15: Skin-Integrated Sensors and Haptic Interfaces for VR and AR**

**Xinge Yu**  
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Technologies for virtual and augmented reality (VR and AR) create human experiences through visual and auditory stimuli that replicate sensations associated with the physical world. The most widespread VR/AR systems use head-mounted displays, accelerometers and speakers as the basis for three-dimensional, computer-generated environments that can exist in isolation or as overlays with actual scenery. By comparison to the eyes and the ears, the skin is a relatively underexplored sensory interface for VR/AR technology that could, nevertheless, greatly enhance experiences, at a qualitative level, with direct relevance in areas ranging from communications and social media, to gaming, entertainment and prosthetics technology. Here we present materials, device structures, power delivery strategies and communication schemes as the basis for a wireless, battery-free platform of electronic systems and haptic interfaces capable of softly laminating onto the skin to communicate information via spatio-temporally programmable patterns of localized mechanical vibrations. The resulting technology, which we refer as epidermal VR, creates many opportunities where the skin provides an electronically programmable communication and sensory input channel to the body, as demonstrated through example applications in social media/personal engagement, prosthetic control/feedback and gaming/entertainment.

Xinge Yu is currently an Assistant Professor of Biomedical Engineering at City University of Hong Kong (CityU), Associate Director of CAS-CityU joint laboratory of
Robotics. He finished his Ph.D. research of printable flexible electronics at Northwestern University (NU) and University of Electronic Science and Technology of China in 2015. From 2015 to 2018, Xinge Yu was a postdoc. in the Center for Bio-Integrated Electronics at NU and an adjunct research assistant professor in the Department of Materials Science and Engineering at the University of Illinois at Urbana-Champaign. His research focus on developing skin-integrated electronics and bio-electronics, and conducts multidisciplinary research addressing challenges in practical applications, such as biomedical electronics with compatible physical and chemical properties, and real-time health monitoring. He has published over 70 papers Nature, Nat. Mater., Nat. Biomed. Eng., PNAS, Sci. Adv., Adv. Mater., etc, and held 15 patents pending or granted. Also, he has been serving as the Associate Editor of IEEE Open Journal of Technology, Vice president/Committee chair of serval international conferences.

The photo of the speaker:

A16: Chirality, topology, and hydrodynamics

Yuji Hirono
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A17: Nanomembrane formed microtubular cavities as a platform for light-matter interactions

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Microtubular cavities, which are self-assembled from prestrained nanomembranes, can support whispering-gallery mode (WGM) resonances. Owing to the subwavelength-thin cavity wall, optical evanescent field greatly extend out of cavity surfaces, allowing for efficient light-matter interactions. By coating plasmonic nanosturctures onto the microcavity surfaces, photon-plasmon coupling are studied relying on the interaction of WGM resonant light and localized surface plasmons. Owing to the ultra-high sensitivity to surface perturbations, the microtube cavities are able to detect surface dynamic process of molecule growth and desorption. In addition, novel types of photonic molecules based on microtube cavities are designed for the study of resonant mode hybridization. Moreover, we have demonstrated the generation of optical Berry phase in microtubular ring cavities. As a novel platform, microtubular cavities imply promising applications for enhanced light-matter interactions, optical tuning, photonic integration and quantum optics.
A18: Direct-writing of 3D superconducting nanostructures
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Nowadays, superconductors are commonly utilized in several applications such as energy generators and storage due to their unique capability of transferring electricity without energy losses. In some applications, their nanoscale patterning enhances their performance and gives rise to new physical phenomena.

Innovative schemes have taken advantage of the third dimension (3D) for the development of advanced superconducting electronics. Thus, 3D nanosuperconductors could promote a change in the next generation of electronic components. Nevertheless, their fabrication and characterization are still challenging and only a few works addressing the growth of real 3D nanosuperconductors have been reported so far [1–4].

In this contribution, we introduce a template-free nano-lithography method to fabricate in a single-step 3D nano-elements on-demand with arbitrary geometry. The fabrication of complex 3D nano-architectures opens fascinating novel routes in the fields of material science, physics and nanotechnology. This specific technique called focused ion beam induced deposition (FIBID) is based on chemical vapour deposition process assisted by a charged particle beam focused to a few nanometers.
As a proof of concept, we report the fabrication of 3D tungsten carbide (WC) nanohelices with on-demand geometries. Our results show the smallest and more-densely-packed nano-helix ever fabricated so far, with dimensions of 100 nm in diameter, and aspect ratio up to 65. These nanohelices become superconducting at 7 K and show large critical magnetic field and critical current density. In addition, given its helical 3D geometry, fingerprints of vortex and phase-slip patterns are experimentally identified and supported by numerical simulations based on the time-dependent Ginzburg-Landau equation [5]. In addition, we report for the first time the fabrication and characterization of 3D superconducting crystalline WC hollow nanowires with outer diameters down to 32 nm and inner ones down to 6 nm [6]. By modifying the ion beam current, hollow nanowires with controllable inner and outer diameters have been achieved [7]. By studying their magnetotransport properties, we have found that nanowires exhibit 1.5 times higher superconducting critical temperatures (6.4 K) as well as

1.5 times higher upper critical magnetic fields (≈14 T) when compared to nanowires grown by a Ga⁺ FIBID.

The fabrication of such nanomaterials with excellent properties makes this technique at the cutting edge of nanofabrication methods based on focused beams of charged particles.

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References


A19: Nanoengineering hollow structured carbon spheres as nanoreactors for sustainable energy applications

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Colloidal carbon sphere nanoreactors have been explored extensively as a class of versatile materials for various applications in energy storage, electrochemical conversion, and catalysis, due to their unique properties such as excellent electrical conductivity, high...
specific surface area, controlled porosity and permeability, and surface functionality. This talk aims to summarize the latest updated research on colloidal carbon sphere nanoreactor, in terms of both their synthesis and applications. Various synthetic strategies are first discussed, including the hard template method, the soft template method, hydrothermal carbonization, the microemulsion polymerization method and extension of the Stöber method. In the following section, the functionalization of hollow structured carbon sphere nanoreactors, including the nanoengineering of compositions and the surface features is then discussed. Afterward, I will present the recent progress in the major applications of hollow structured carbon sphere nanoreactors, in the areas of energy storage, electrochemical conversion and catalysis. Finally, the perspectives and challenges are discussed for future developments in terms of controlled synthesis and functionalization of the hollow structured carbon sphere nanoreactors with tuneable structure, and the composition and properties that are desirable for practical applications.1-7

References
Curriculum Vitae

Dr. Jian Liu is a Professor at Dalian Institute of Chemical Physics, Chinese Academy of Science, China, he also held an adjunct Reader position in Department of Chemical and Process Engineering, University of Surrey, UK. As of November 2019, has published more than 170 peer reviewed journal articles including top ranking journals such as Nature Mater., Nature Commun., Angew. Chem. Int. Ed., Adv. Mater., JACS, Chem. Sci., Chem. Soc. Rev., et al. 1 book, 8 book chapters. A recent search (November 2019) of ISI Web of Science shows his entire publications have been cited for over 13000 times. He has an H-index of 55 and his research has been featured on 21 Cover pages of scientific journals. He was listed as 2018, 2019 Highly Cited Researchers from Clarivate Analytics in Cross-Field. He is the Editor-in-Chief of Materials Today Sustainability (Elsevier), Chief Editor of Frontiers in Nanotechnology. As recognition of his achievements in research, he was honoured with a prestigious UQ Foundation Research Excellence Award, Australian Postdoctoral Fellowship (APD), JSPS Invitation Fellowships, UQ Postdoctoral Research Fellowship, President Award (Chinese Academy of Sciences) and a Young Scientists Award of the 14th International Congress on Catalysis.
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