# International Workshop
**Pioneers in Soft Matter Science**

**DATE** Jun 18 (Mon) ~ 20 (Wed) 2012  
**PLACE** Rm. 101A, Bldg. E11 (Changeui Learning Cntr.), KAIST

## INVITED SPEAKERS

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<td>Opening Remarks: Mohin Won Kim</td>
<td>Paul Chalikin (NYU)</td>
<td>Fred MacKintosh (Vrije Univ., Netherlands)</td>
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<td>Sung-Min Choi (KAIST)</td>
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<td>Min-Kyo Seo (KAIST)</td>
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**Organizers:** Mohin Won Kim, Yong-Hee Lee, Hee-Tae Jung, Jung H. Shin, Sung-Min Choi, YongKeun Park, Myung Chul Choi (KAIST)  
**Host:** Brain Korea 21 World Class University, Basic Research Lab, KAIST Research Groups, Advanced Research Center for Nuclear Excellence, Department of Bio and Brain Engineering, Department of Physics, Graduate School of Nanosciences (KAIST), Korea Atomic Energy Research Institute.

**Home Page:** [http://softmatt.wordpress.com](http://softmatt.wordpress.com)

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Workshop “Pioneers in Soft Matter Science”

Date: June 18 – 20, 2012

Place:
Rm. #101A, Changeui Learning Cntr. (Bldg. E11), KAIST
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Republic of Korea

Organizers:
Mahn Won Kim (Department of Physics, KAIST)
Yong-Hee Lee (Department of Physics, KAIST)
Hee-Tae Jung (KAIST)
Jung Hoon Shin (KAIST)
Sung-Min Choi (KAIST)
YongKeun Park (KAIST)
Myung Chul Choi (KAIST)

Sponsors:
World Class University (WCU), KAIST
Brain Korea 21 (BK 21), KAIST
Basic Research Laboratory (BRL), KAIST
KAIST Research Group, KAIST
Department of Bio and Brain Engineering, KAIST
Department of Physics, KAIST
Graduate School of Nanoscience, KAIST
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Invited Speakers:
David Pine (NYU)
Hee-Tae Jung (KAIST)
Dov Levine (Technion, Israel)
Wokyung Sung (POSTECH)
Sung-Min Choi (KAIST)
Miriam Rafailovich (SUNY Stony Brook)
Seok-Cheol Hong (Korea University)
Dong June Ahn (Korea University)
Theo Rasing (Radboud University, Netherlands)
Min-Kyo Seo (KAIST)
Paul Chaikin (NYU)
Jooyoung Lee (KIAS)  
Yong-Hee Lee (KAIST)  
Chwee Teck Lim (National University of Singapore)  
Daniel Ou-Yang (Lehigh University)  
Hyuk Kyu Pak (Pusan National University)  
Je-Kyun Park (KAIST)  
Doseok Kim (Sogang University)  
Vinothan N. Manoharan (Harvard University)  
Wonhee Lee (KAIST)  
Fred MacKintosh (Vrije University, Netherlands)  
Yong-Hyun Kim (KAIST)  
Mohan Srinivarao (Georgia Tech.)  
YongKeun Park (KAIST)  
Yoon Sung Nam (KAIST)  
Philip Pincus (UCSB)
Location:

KAIST is located in Daedeok Science Town, the home to more than 60 government-supported and private research institutes, 4 universities, and numerous venture businesses. The Science Town is situated in the northern part of Daejeon, which is approximately 150 km south of Seoul. Daejeon has a population of over 1.3 million citizens. Taking advantage of its geographical location, KAIST provides abundant opportunities for research and learning through collaboration and exchanges with institutions and organizations in the immediate vicinity. Also, KAIST has the College of Business, which is located in Seoul. It provides education programs related to management practice and technology policy.

Access:

From Incheon International Airport to Daejeon

There is Airport Limousine bus from and to International airport. The bus leaves the airport at regular intervals and arrives in Daejeon first at Lotte Hotel, then near the Government Complex Building as the second stop before terminating at the Daejeon Eastern Express Bus Terminal. There will be a short break at a highway resting area before getting to Daejeon. Once the bus exits from the high way, prepare to get off at the second stop "Government Complex Building" where is the convenient stop to take a taxi to KAIST campus. (cost for the taxi ride is around $4 or 4,000 won)
From Daejeon to Incheon International Airport

Bus boarding place in Daejeon: bus stop near Daejeon Government Complex Building.
For more information, please contact:
http://tour.daejeon.go.kr/english/tourguide/transportation/airportlimousine.jsp

Program:

June 17 (Sun)

June 18 (Mon)
8:30–8:50 SANDWICH
8:50–9:00 Opening Remark: Mahn Won Kim (KAIST)
9:00–9:45 David Pine (NYU) “Colloids with directional interactions”
9:45–10:30 Hee-Tae Jung (KAIST) “Liquid Crystals and Nanotechnology: From Display Materials to Graphene Applications”
10:30–10:45 BREAK
10:45–11:30 Dov Levine (Technion, Israel) TBA
11:30–12:15 Wookyung Sung (POSTECH) “Stochastic Resonance in a Stretched Biopolymer”
12:15–1:15 LUNCH
2:00–2:45 Miriam Rafailovich (SUNY Stony Brook) “Polymers Confined at Interfaces: Their Role as Mediators of Cell-Surface Interactions”
2:45–3:00 BREAK
3:00–3:45 Seok-Cheol Hong (Korea University) “Single-Molecule Biophysical Studies of Non-Canonical DNA Structures”
3:45–4:30 Dong June Ahn (Korea Univ.) “Interfacial Design of Sensory Conjugated Polymers”
4:30–4:45 BREAK
4:45–5:30 Theo Rasing (Radboud Univ. Nijmegen, Netherlands) “Probing and Controlling Matter by light”
5:30–6:15 Min-Kyo Seo (KAIST) “Plasmonic Antenna based Optical Vortex Trapping and Full-Visible Range Plasmonic Nano-Antenna”

June 19 (Tue)
8:30–9:00 SANDWICH
9:00–9:45 Paul Chaikin (NYU) “‘Living’ Crystals from Light Activated Artificial Surfers”
9:45–10:30 Jooyoung Lee (KIAS) “Enhanced Protein Function Prediction by Improved Community Detection”
10:30–10:45 BREAK
10:45–11:30 Yong-Hee Lee (KAIST) “Quest for the Smallest Possible Laser”
12:15–1:15 LUNCH
2:00–2:45 Hyuk Kyu Pak (Pusan National Univ.) “AC Electric Current Generation by Mechanically Modulating Electrical Double Layers”
2:45–3:0 BREAK
3:45–4:30 Doseok Kim (Sogang Univ.) “Correlation Analysis on the Single-Molecule FRET Experiment”
4:30–4:45 BREAK
4:45–5:30 P. Pincus (UCSB) “Instability of Polyion Suspensions”
5:30–6:15 Wonhee Lee (KAIST) “High-sensitivity Microfluidic Calorimeters for Bioapplications”

June 20 (Wed)
8:30–9:00 SANDWICH
9:00–9:45 Fred MacKintosh (Vrije Univ. Netherlands) “Elasticity on the edge of stability: soft matter physics inspired by the cell”
10:30–10:45 BREAK
10:45–11:30 Mohan Srinivarao (Georgia Tech.) TBA
12:15–1:15 LUNCH
1:15–2:00 Yoon Sung Nam (KAIST) “Genetic Engineering for the Assembly of Molecules and Materials”
2:00–2:45 Vinothan N. Monoharan (Harvard Univ.) “Dynamics and Transition States of Colloidal Molecules”
We have developed new kinds of colloidal particles with either geometrical or chemical patches that give rise to directional interactions. These interactions allow colloids to interact with each other more like atoms, which in turn is used to build up structures that are not possible with isotropic interactions. These directional interactions are being developed to make self-replicating colloidal motifs and new colloidal crystals.
June 18 (Mon) 9:45 – 10:30

Liquid Crystals and Nanotechnology: From Display Materials to Graphene Applications

Hee-Tae Jung
Dept. of Chemical and Biomolecular Engineering, KAIST, Daejeon 305-701, Korea

Recently, smectic liquid crystal (LC) structures have been suggested as a new class of soft self-assembly building blocks that form an ordered, periodic array of LC defects array. Unlike previously reported self-assembling materials such as blockcopolymer, colloid particle, surfactant etc., the defect ordering of the LC self-assemblies takes advantage of the ability to achieve fast stabilization of molecular ordering and structure due to the reversible and noncovalent interactions of the LC molecules. In this presentation, fabrication and fundamental studies of the periodic smectic LC defect structures based on focal conic domains (FCDs), including toric FCD (TFCD), parabolic FCD (PFCD) and oily streak (OS), are briefly reviewed. Then, in particular, the controlling of regular domain size as well as arrangement and the large area patterning methods of TFCDs are discussed.

In addition, a simple method has been developed to macroscopically visualize graphene domains and their boundaries by using nematic liquid crystals (LCs) on the graphene surface. The results show that nematic LC molecules, containing aromatic and alkyl chains, orient with respect to the domain orientation of graphenes. Thus, the sizes of graphene domains and their boundaries can be simply observed by changes in the birefringences that arise from variations of the director field of the LC molecules. This method should significantly aid the control of domain, boundary structure and properties of graphene.


Hee-Tae Jung received his Ph.D. degree in Macromolecular Science & Engineering from Case Western Reserve University in 1998. He was a postdoctoral fellow at the University of California, Santa Barbara. Following this, he joined the KAIST in Chemical & Biomolecular Engineering. He received many awards including “Top 10 research award” and “Academic Award of Year”. Currently, Prof. Jung is KAIST Chair Professor. He leads the World Class University Program and the National Research Lab. Program for Nanostructure based Opto-electronic Devices. His research interests include creation of nanostructures and organic opto-electronic devices.
June 18 (Mon) 10:45 – 11:30

Dov Levine
Technion, Israel

TBA
Stochastic Resonance in a Stretched Biopolymer

Wokyung Sung
Department of Physics and PCTP, POSTECH, Pohang 790-784, South Korea

The biopolymers are often situated in constrained, fluid environments, e.g., cytoskeletal networks, stretched DNAs in chromatin. It is important to understand how they respond to a minute signal, which is, in general, temporally fluctuating far away from equilibrium. We study dynamics of semiflexible polymer extension in response to a small oscillatory perturbation added to a static force or field. Including hydrodynamic interactions between the polymer segments, we analytically evaluate the extension and associated stochastic resonance (SR). We find a new type of the entropic SR in this system, which is turn out to be an unusual nonlinear monostable system. The power amplification factor is optimized by not only noise strength (temperature) but also polymer contour length as well as the oscillation frequency. The hydrodynamic interaction is found to enhance the SR, representing unique polymer cooperativity which the fluid background can induce despite its overdamping nature.

Also, we studied how a small oscillatory force affects the thermally induced folding and unfolding transition of an RNA hairpin under a constant tension. Strikingly, our molecular simulations performed under overdamped condition show that even at a high (low) tension that renders the hairpin (un)folding improbable, a weak external oscillatory force at a certain frequency can synchronously enhance the transition dynamics of RNA hairpin and increase the mean transition rate. Our study, amenable to experimental tests using optical tweezers, is of great significance to the folding of biopolymers in vivo that are subject to the broad spectrum of cellular noises.
Hierarchical self-assembly of 1D nanoparticles such as carbon nanotubes into highly ordered superstructures in soft matter has been of great interest as a route toward materials with new functionalities. Soft matter including block copolymers, surfactants, and lipids exhibit rich phase behaviors and have been extensively used as excellent templates for highly ordered nanostructure materials with various architectures. Therefore, utilization of the rich phase behavior of soft matter may provide a general and inexpensive way for fabricating a large variety of self-assembled and highly ordered arrays of 1D nanoparticles without going through complicated preparative procedures. In this talk, I will discuss the cooperative self-assembling behavior of functionalized isolated SWNTs in Pluronic block copolymer, lipid and surfactant systems which show highly ordered superstructures of SWNTs with different symmetries depending composition and temperature.
June 18 (Mon) 2:00 – 2:45

Polymers Confined at Interfaces: Their Role as Mediators of Cell-Surface Interactions

Miriam Rafailovich
Department of Materials Science, Stony Brook University, Stony Brook, NY 11794-2275

Polymer thin films have been shown to play determinant roles in stem cell differentiation (1), biomineralization (2), and thrombosis (3). In each case, it was demonstrated that the cell/surface interactions were in fact mediated by the morphology of the underlying extra cellular matrix (ECM) proteins, which in turn was controlled by their interactions with the underlying polymer thin films. The complexity of protein structure allows for functional domains to remain cryptic till exposed under enzymatic control, whose expression in turn depends on multiple external triggers. Here we show that when polymer/protein interactions induce specific protein conformations, cellular response can be initiated in the absence of other enzymatic triggers. Hence our ability to control polymer structure at the nanoscale, via surface confinement, is now shown to affect macro-scale order in complex biological systems.

1. Dental pulp stem cell differentiation on poly-4-vinyl-pyridine surfaces, Suarato, Giulia; Bherwani, Aneel; Chang, Chung-Chueh; Rafailovich, Miriam; Simon, Marcia, American Physical Society, APS March Meeting 2012, February 27-March 2, 2012, abstract #W39.006
2. The role of moderate static magnetic fields on biomineralization of osteoblasts on sulfonated polystyrene films, Xiaolan Ba, Hadjiargyrou, Michael, DiMasi, Elaine, Meng, Yizhi, Simon, Marcia, Tan, Zhongkui, Tan, Zhongkui, Rafailovich. Miriam, Biomaterials, 2011, 32, 7831-7838
June 18 (Mon) 3:00 – 3:45

**Single-Molecule Biophysical Studies of Non-Canonical DNA Structures**

Seok-Cheol Hong  
*Department of Physics, Korea University, Seoul, Korea*

A variety of non-canonical DNA structures are known to exist and some of them exist even *in vivo*. Examples of such structures are left-handed Z-DNA, triple helical H-DNA, and intercalated i-motif to name a few. Over recent years, biological roles of such DNA structures have been suggested and mainly implicated in transcription. Moreover, various disease-related genetic loci are found to have the potential to form such non-B structures. Although there is ample evidence for the significance of those structures in numerous biological processes, fundamental understandings of the structures are far from complete. The kinetics of the structures has not been measured straightforwardly and the effects of physical factors such as tension and torsion on the conformational transitions have been rarely addressed. Here, we used single-molecule biophysical methods to observe conformational dynamics of the aforementioned non-B structures occurring at the nanometer-scale and to study the effects of physical and chemical factors on their formation. From the studies, we found that those structures are highly dynamic and the mechanical factors are critical in the transition. Biological significance of the results will be discussed as well.
Interfacial Design of Sensory Conjugated Polymers

D. H. Yang, C. Cui, J.H. Park, Y.K. Choi, H. Choi, G.S. Lee, and D.J. Ahn*
Department of Chemical & Biological Engineering, Korea University, Seoul 136-701, Korea
Email: ahn@korea.ac.kr

Conjugated polymer nanoarchitectures based on polydiacetylene materials are interesting biomimetic materials in view of application to chemical and biological sensors. These conjugated materials are unique in changing color from blue to red and/or in altering fluorescence emission, caused by perturbation of materials’ electronic state and energy transfer upon specific binding events. Based on these optical characteristics, we can utilize the conjugated polymers as label-free detection agents for chemical and biological targets. In this presentation, we demonstrate strategy of interfacial design of soft nanoarchitectures achieving the label-free and/or rapid detection capability. Their sensitivity and specificity were analyzed in the range of nM to sub-fM depending on the kind of target species. The printed array patterns, characters, and images were found to detect the target substances successfully out of mixture samples. In addition, a strikingly rapid detection of biological targets within ca. 10 min. was also enabled by designing 3-dimensional architectures involving columnar and/or porous interfaces showing higher surface area that enhanced the accessibility and the mass transfer rate of the target molecules.
Probing and Controlling Matter by light

Theo Rasing
Radboud University Nijmegen, Institute for Molecules and Materials, Nijmegen, The Netherlands

The interaction of light with matter is well known: who has not used lenses and prisms to play with intensity and frequencies? Or for the more advanced: magneto optical effects like Faraday or Kerr effect to manipulate the polarisation of light? We often use light to investigate matter, like nonlinear optics to study molecular monolayers at air-water interfaces (T. Rasing, M.W. Kim et al, Phys.Rev.Lett.55,2903(1985)).

The inverse effects are less known but certainly as fascinating: with light one can for example cool atoms to extremely low temperatures or orient their spins. Using circularly polarized femtosecond laser pulses we have generated ultrashort and very strong magnetic field pulses (~Tesla’s or a hundred-thousand times the earth magnetic field) that provide unprecedented means for the generation, manipulation and coherent control of magnetic order on very short time scales (A. Kimel et al, Nature 435 (2005), 655-657). Would this also work for (soft) molecular matter?

Recently we used circularly polarized light to direct the chirality of molecular crystals, grown from a racemic mixture, which may be an explanation of the single chirality found in nature. In this talk some of these “old” and “inverse” optical effects will be introduced and illustrated.

Demonstration of all-optical manipulation of magnetic bits by femtosecond laser pulses. This was achieved by scanning a circularly polarized laser beam across the sample and simultaneously modulating the polarization of the beam between left and right circular. White and black areas correspond to ‘up’ and ‘down’ magnetic domains, respectively. (C.D.Stanciu et al, Phys.Rev.Lett.99, 047601 (2007))

Circularly polarized light emitted from star-forming regions is an attractive candidate as a cause of single chirality in nature. (W.L.Noorduin et al Nature Chemistry 1, 729 (2009))
Plasmonic Antenna based Optical Vortex Trapping and Full-Visible Range Plasmonic Nano-Antenna

Min-Kyo Seo
Dept. of Physics, KAIST, Daejeon 305-701, Korea

Nano-optical trapping techniques, which employ strongly enhanced and localized near-fields in metallic/dielectric nanostructures, can allow the capture and manipulation of nanometer-sized particles. Optical vortex trapping is more attractive because damageable biological particles or particles with a refractive index lower than surrounding material can be captured efficiently. Here we demonstrate the first experimental implementation of low-power nano-optical vortex trapping using plamonic resonance in gold diabolo nanoantennas. The vortex potential formed with minima at 170 nm distant from the antenna center traps polystyrene nanoparticles strongly at the boundary of the nanoantenna. Furthermore, a large radial trapping stiffness, \(~0.69\ \text{pN nm}^{-1} \text{ W}^{-1}\), was measured, showing good agreement with the numerical simulations. This subwavelength-scale nanoantenna system capable of low-power trapping represents a significant step toward versatile, efficient nano-optical manipulations in lab-on-a-chip devices.

We also investigated the experimental implementation of an optical antenna operating in the full visible range via surface plasmon currents induced in a defect-free single-crystalline Ag nanowire. Multi-wavelength channels are frequently required in broadband nano-optical spectroscopy as well as in biochemical sensing employing multiple emitters operating at different colors. Thus, development of plasmonic nanoantennas reliably operating at multiple resonances in the full visible range is a challenging but much desired task. With its atomically flat surface, the long Ag nanowire reliably establishes multiple plasmonic resonances and produces a unique rainbow antenna radiation in the Fresnel region. Detailed antenna radiation properties, such as radiating near-field patterns and polarization states, were experimentally examined and precisely analyzed by numerical simulations and antenna theory.
June 19 (Tue) 9:00 – 9:45

‘Living’ Crystals from Light Activated Artificial Surfers*

Paul Chaikin
NYU

We have made novel self-propelled particles consisting of a hematite cube partially protruding from a polymer sphere and immersed in a dilute \( \text{H}_2\text{O}_2 \) solution. Under blue light illumination the catalyzed decomposition of \( \text{H}_2\text{O}_2 \) sets up concentration gradients activating particle motion and interactions. This system demonstrates a new form of self-assembly from non-equilibrium driving forces leading to living crystals which form, break, explode and reform elsewhere. The dynamic assembly results from a competition between self-propulsion of particles and an attractive interaction induced respectively by, osmotic and phoretic effects. Switching off the light stops the system from all but thermal diffusion. Light controlled active systems open new perspectives in materials design and auto-organization.

*With Jeremie Palacci, Stefano Sacanna, David J. Pine
Enhanced Protein Function Prediction by Improved Community Detection

Jooyoung Lee
School of Computational Sciences, Korea Institute for Advanced Study, Seoul, Korea

In the post-genomic era, we are overwhelmed by a deluge of experimental data, and network science has the potential to become an invaluable method to increase our understanding of large interacting datasets. However, this potential is often unrealized for two reasons: uncovering the hidden community structure of a network—known as community detection—is difficult, and further, even if one has an idea of this community structure, it is not a priori obvious how to efficiently use this information. Here, within the context of protein function prediction, we address both these issues. First, we present a new community detection method that is faster than the current state of the art, and generates better solutions, allowing extraction of additional hidden information. Second, we develop a better approach to use this community information to predict proteins’ functions: we determine when and why this community information is important. We show that some classes of prediction benefit from relatively simple local community information, but that others with longer-range interactions benefit from very careful determination of community structure. In such cases, our community-based approach uncovers hidden non-local information allowing improved prediction of protein function. Thus, for the first time, using community information we can predict function better than methods that only use local information.
June 19 (Tue) 10:45 – 11:30

**Quest for the Smallest Possible Laser**

Yong-Hee Lee  
*Department of Physics, KAIST, 373-1 Kusung-dong, Yusung-gu, Daejon 305-701, Korea*  
*Email: yhlee@kaist.ac.kr*

The long-standing quest for the smaller and faster microlaser has been attracting scientists and engineers in the semiconductor laser community. The evolution from VCSEL → Photonic Crystal Laser → 1-D Nanobeam Laser will be revisited with historical perspectives. And our recent efforts on the nanobeam lasers and smaller plasmonic lasers will be discussed in more detail.
Human diseases can affect our health and well-being by impairing our bodily structures and functions. In particular at the cell level, some diseases are known to give rise to or arise from mechanical and structural property changes in the cells. Such changes have been known to manifest in several human diseases such as malaria, sickle cell anemia and cancer. These abnormal cellular mechanical property changes have also been known to disrupt normal physiological functions, which will eventually give rise to the pathophysiology of diseases (also termed “mechanopathology”).

Several physical changes such as size, deformability and adhesion at the cell level are known to occur and they often reflect the molecular and structural reorganization of the cell. As these changes occur at the micro and nanoscale, advanced micro- and nanotechnological tools are needed to probe such minute changes in the cell. State-of-the-art tools such as optical traps, atomic force microscope and microfluidics have been used to quantitatively probe the deformability and adhesion changes of diseased cells with resolutions of forces and displacements down to piconewton and nanometer scale, respectively.

Here, we will examine the mechanopathology of human diseases such as malaria and cancer, and the accompanying cellular structure-mechanical property-function relationship changes from the molecule to cell levels using such tools. It is hope that we will not only better understand the pathology of these diseases, but also explore their cellular mechanical property changes as possible biomarkers in their detection and diagnosis. Finally, we will briefly showcase a number of mechanics based microfluidic devices that we have developed that make use of such biomarkers for detection and diagnosis.
Who Cares about $B_2$: a Thermodynamic View of Colloidal Interactions

H. Daniel Ou-Yang
*Lehigh University*

Colloidal suspensions are interesting because they can serve as models for understanding condensed matters, and they are ubiquitous in industrial processes. Many-body interactions in such systems create richness and complexity in their phase, structural and mechanical properties. Despite the advancement in our understanding of the two-body interactions between colloidal particles, there have been relatively few studies on interactions beyond three-body interactions, without which it is difficult to make connections between the microscopic and macroscopic behaviors of colloidal suspensions, and many intriguing phenomena, such as like-charge attraction, still lack a satisfactory explanation. This talk attempts to make such connections by experiments that measure Virial coefficients beyond $B_2$ in concentrated colloids.
June 19 (Tue) 2:00 – 2:45

AC Electric Current Generation by Mechanically Modulating Electrical Double Layers

Jong Kyun Moon, Jaeki Jeong, Dongyun Lee and Hyuk Kyu Pak*
Department of Physics, Pusan National University, Busan 609-735, Korea
*Email: hpak@pusan.ac.kr

Many objects in contact with a liquid acquire some electronic charges on their surfaces. These charges on the surface attract counter ions from the liquid. This complex system is called electrical double layer (EDL). Since its geometry and structure are similar to an electric capacitor, it is also called an electrical double layer capacitor (EDLC). Here we proposed a new method of AC electrical power generation by mechanically modulating the EDLs at the interfacial areas of a liquid bridge between two conducting plates without any external bias-voltage source. We found that when the height of the liquid bridge was mechanically modulated, each EDLC formed on two interfacial areas was continuously charged and discharged with a different phase each other generating an AC electric current across the plates. We used RC circuit model to analyze the experiment result. This new phenomena can be useful for constructing a micro-fluidic power generation in future.
Droplet-based microfluidics has recently been applied to a wide range of applications, including biological assay, combinatorial synthesis, and high-throughput screening. In particular, microdroplets of pico- to nanolitre volumes are capable of enclosing various biological soft matter. Unlike solid wells, they are a more active system, and can move or stop, split or merge with others, and select different paths for sorting at timed intervals. A precise temporal control of microdroplets such as synchronization and combinatorial pairing of droplets is also required to achieve a variety range of chemical and biochemical reactions inside microfluidic networks. Here, I will present a single-cell-based assay using a mesh-integrated microwell array which enables easy trapping and consistent addition of droplets in a high-throughput manner. The mesh-integrated droplet array provides a microfluidic platform for simple storage and on-demand merging of droplets. The openness of the system allows easy access to individual droplets and variable integration with other functional modules. By integrating the single-cell droplet-generating channel, the mesh-integrated microarray allows immediate confinement of single cells and total isolation of each chamber throughout the entire droplet manipulation process. With further development, this device may provide a novel screening platform, especially for various microbes directly harvested from a natural environment.

Je-Kyun Park is a Professor of Bio and Brain Engineering at the Korea Advanced Institute of Science and Technology (KAIST). He also holds joint positions as an Affiliated Professor of Biological Sciences and KAIST Institute for the NanoCentury. He obtained his PhD degree in biotechnology from the KAIST in 1992. Prior to joining KAIST, he worked as a Postdoctoral Fellow in the Department of Biomedical Engineering at the Johns Hopkins University School of Medicine in the USA (1996–1997) and a Chief Research Engineer at the LG Electronics Institute of Technology in Korea (1992–2002). He joined the Department of BioSystems at the KAIST as an Associate Professor in 2002 and served as the Department Head of Bio and Brain Engineering (2006–2009). His expertise spans interdisciplinary fields of biotechnology, bioelectronics and bioMEMS, with special emphasis on biomolecular diagnostics, micro total analysis systems (μTAS), cell-based screening platforms, and nanobio devices. He has been an editorial board member of several international journals, including Lab on a Chip, Biosensors and Bioelectronics, and BioChip Journal. From 2011, he has served as an Executive Technical Program Committee Member of the International Conference on Miniaturized Systems for Chemistry and Life Sciences (μTAS Conference) and a Vice President of the Korean BioChip Society. He is the co-author of 8 book chapters, 93 patents, and more than 100 peer-reviewed papers in the field of integrative bioengineering, including microfluidics, lab-on-a-chip, and BioMEMS for cell/tissue engineering.
Correlation Analysis on the Single-Molecule FRET Experiment

SungHyun Kim\textsuperscript{1}, Takkyoon Ahn\textsuperscript{1}, Chirlmin Joo\textsuperscript{2} and Doseok Kim\textsuperscript{1}

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Single-molecule fluorescence resonance energy transfer (smFRET) technique has become one of the popular methods to monitor the dynamics of individual macro-molecules such as protein or DNA. Single-molecule measurement provides information which cannot be obtained by conventional ensemble measurements, such as an identification of a short-lived intermediate in a reaction pathway. However, single-molecule technique has limited detection efficiency and often encounters difficulties in taking out useful information from noisy time traces. Typically Hidden Markov method has been applied to find the most likely FRET time trajectories from a noisy time trace. In this talk, time correlation of the single molecule FRET time traces is introduced as a new analytical method to characterize the underlying kinetics. By applying correlation analysis to the data obtained from the stepwise sliding of RecA nucleoprotein filament, we found that the kinetics does not follow Markovian process. The correlation analysis allowed us to extract out the kinetic rate without presumed kinetic model, and the correlation function was compared with those calculated from various kinetic model simulations.
At low ionic strengths, suspensions of highly charged moieties, e.g. polyelectrolytes, charged colloids, exhibit evidence for *attractive* interactions. A possible theoretical model to explain these observations has been put forth by Patrick Warren, which, however, has been criticized because of some internal inconsistencies. We shall review this situation and report some new simulations which lend some support to the Warren picture.
June 19 (Tue) 5:30 – 6:15

High-sensitivity Microfluidic Calorimeters for Bioapplications

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Microfluidics biosensors have many advantages over their large-scale counterparts, for example, low cost, fast response time, and massive parallelization. Among many biosensor types, calorimetric sensors have not been well-recognized despite of its significance, mainly due to low sensitivity. High-sensitivity microfluidic calorimeters are promising for high-throughput biochemical reaction measurements with minimal sample consumption. Vacuum Insulated Microfluidics (VIM) technique enables calorimeters that overcome difficulties of thermal sensing incorporated with microfluidic channels. VIM calorimeters have demonstrated the unprecedented high-sensitivity which enabled measurements of heat of reaction from a few nL sample. Parylene-PDMS hybrid microfluidic system provided both physical strength to apply vacuum insulation and freedom in microfluidic flow control. VIM calorimeters are not only useful for sensor applications but also are expected to provide innovative tools for studying cellular metabolism. Especially, the sensitivity of calorimeters can reach ~1pW, which will allow direct measurement of metabolism from single cell.
Elasticity on the edge of stability: soft matter physics inspired by the cell

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Much like the bones in our bodies, the cytoskeleton consisting of stiff protein biopolymers determines the mechanical stability and response of cells. Inspired by such filamentous assemblies, we study disordered fiber networks. We show that these exhibit a unique state of highly responsive matter near the isostatic point first studied by Maxwell in the context of particles interacting via central forces. For fiber networks, this represents a marginal state of matter with exceptional mechanical properties, including a strongly nonlinear elastic response. Surprisingly, these networks exhibit rich zero-temperature critical behavior, including diverging fluctuations, anomalous critical exponents and a breakdown of continuum elasticity. We also show how internal stress generation by molecular motors can drive networks to criticality.
Graphene is super strong within the plane, but very compliant in the out-of-plane direction. Because of the intrinsic two-dimensional anisotropy, a chemical modification of graphene is either very limited or very destructive. Therefore, atomistic control of such a chemical modification and thus its microscopic understanding should be desirable for competitive graphene-based technologies. Recently, we have proposed or analyzed, based on quantum materials simulations, a series of chemical functionalization methods of graphene-based materials such as graphene nanoribbon, carbon nanotube, reduced graphene oxide, fluorinated graphene, hydrogenated graphene, oxidized graphene, etc. Depending on how to modify the graphene in-plane and out-of-plane, graphene functionalities can be dramatically changed such as catalytic activity, electron conductivity, mechanical flexibility, frictional characteristics, band gap, and adhesive property. Such functionalized graphenes can be used for many interdisciplinary R&D projects amongst physics, chemistry, biology, materials science, mechanical engineering, and electrical engineering. In order to promote such an opportunity, we will review in this talk our recent understanding about chemically functionalized graphene-based materials including (1-5).

June 20 (Wed) 10:45 – 11:30

Mohan Srinivarao
*Georgia Tech.*

TBA
Quantitative phase imaging techniques for the study of hematology: red blood cell, malaria, and sickle cell disease

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Abstract:
There is a strong correlation between the membrane fluctuations and the mechanical properties of living cells. The dynamic membrane fluctuation consisting of submicron displacements can be altered by changing the cells’ pathophysiological conditions. We have employed diffraction phase microscopy – a quantitative phase imaging technique to noninvasively quantify membrane fluctuations in red blood cells at the nanometer and millisecond scales (1,2). Integration with the mathematical model provides the biomechanical properties from individual cell membrane fluctuations (3). We have systemically dynamic membrane fluctuations in the cell membrane, which can be altered by various pathophysiological conditions: morphological transition of red blood cell; parasitization by the P. falciparum parasites (4,5); metabolic remodeling of the membrane driven by Adenosine-5’-triphosphate (ATP) (6); and sickle cell disease (7,8).

June 20 (Wed) 1:15 – 2:00

**Genetic Engineering for the Assembly of Molecules and Materials**

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In nature we can find a myriad of sophisticated architectures that often exhibit excellent physicochemical properties. Our understanding of the fundamental design principles that nature uses can provide opportunities of developing new techniques to engineer functional materials. In particular, employing nature's strategies we can make use of aqueous processes at low operating temperatures. For industrial applications, this approach inspires 'green chemistry' research by offering environmentally benign synthesis routes for building complex, nanostructured materials under ambient conditions.

One interesting feature of natural processes is the use of organic scaffolds or templates for the assembly of molecules and materials. Biomineralization of, for example, seashells and the bone in mammals is a biologically controlled process for the formation of complex inorganic structures. Further understanding of the interface between inorganic and organic materials can provide a novel engineering tool for synthesizing well-designed functional nanostructures. Natural photosystems are another examples of utilizing protein-lipid scaffolds to achieve the sophisticated self-organization of light-harvesting complexes, electron-transfer mediators and oxygen-evolving complexes.

In this talk, I will talk on the use of virus as a functional platform for the assembly of molecules and materials. By genetically engineering the viral genome a variety of peptides can be expressed on the coat proteins. A phage library technique can be also used to identify peptide motifs that can selectively bind to molecules and materials of interest. The identification of specific peptide building blocks enables us to synthesize novel nanostructures on the surface of genetically engineered viruses. I will discuss how this virus-based strategy can be expanded to various practical applications.
Dynamics and Transition States of Colloidal Molecules

Vinothan N. Monoharan
Harvard University

Colloidal molecules are small clusters of spherical colloidal particles bound to one another through short-range attractive interactions. Previous experimental and theoretical studies have explored the ground states of such systems as well as the self-assembly kinetics of Janus colloids, but few studies have examined the transition states and the dynamics of transitions in clusters of isotropic spherical particles. We use optical tweezers to build clusters of up to 12 particles held together by depletion forces or DNA interactions, and we study their dynamics using optical microscopy and digital holographic microscopy. These techniques allow us to track all the particles in the cluster, on timescales small compared to diffusion. We find that the transition state probabilities agree well with a theoretical model that accounts for the free energy along the entire transition state pathway. The dynamics of the transitions shed some light on how particles roll and slip over one another to form new bonds.