KAIST BrainKorea21 PLUS Engineering for Value Creation

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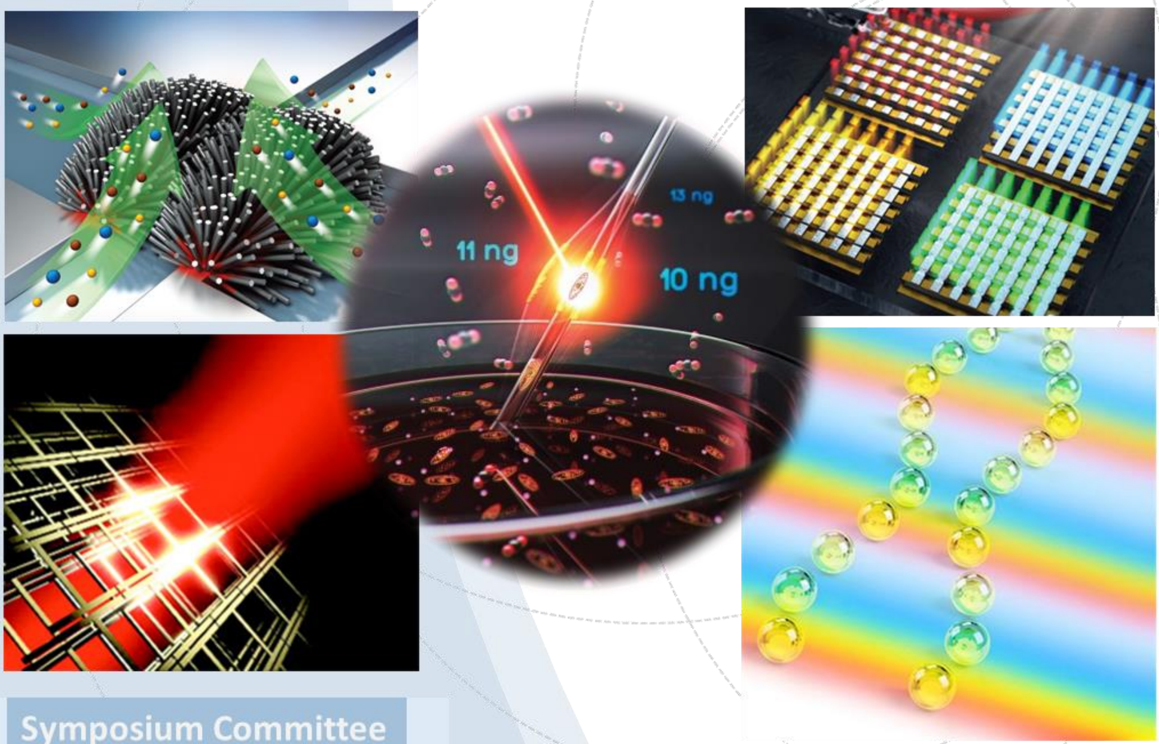
December 2(Thu) - 3(Fri), 2021

KAIST e-Symposium on Emerging Technologies in Mechanical Engineering



Symposium Committee

- Symposium Chairs: Prof. Ki-Uk Kyung (KAIST), Prof. Hongki Yoo (KAIST)
- Program Chairs: Prof. Hyoungsoo Kim (KAIST), Prof. Sanha Kim (KAIST)
- Organizing Chair: Prof. Young-Jin Kim (KAIST)
- Honorary Chairs: Prof. Inkyu Park (KAIST), Prof. Bumki Min (KAIST), Prof. Jungchul Lee (KAIST)

Zoom Link: https://kaist.zoom.us/my/kaistme2 Password: kaistme

Day1) December 2(Thu)
Micro/Nano Transducers and Photonics

Time (KST, GMT+9)	Speakers and Presentation Titles
10:05am	Prof. Jung Kim, Mechanical Engineering Department Head (KAIST) Opening Remarks
10:15am~11:00am	Prof. Sameh Tawfick, University of Illinois Urbana-Champaign (UIUC) (USA) Actuation for Future Automation: Artificial Muscles and Morphing Textures 
11:00am~11:45am	Prof. Hayden Taylor, UC Berkeley (USA) Mechanics and Modeling of Nanoimprint Lithography, and Spatially Multiplexed Mechanical Assembly of Van Der Waals Heterostructures 
11:45am~12:30pm	Prof. Yon Visell, UC Santa Barbara (USA) Haptic and Soft Robotic Engineering 
12:30pm~3:00pm	Break
3:00pm~3:45pm	Prof. Hiroyuki Shinoda, University of Tokyo (Japan) Materialized Graphics as an Extended Robot 
3:45pm~4:30pm	Prof. Ki-Uk Kyung, KAIST (Korea) Challenges in Soft Actuators NOT to be Soft 
4:30pm~5:15pm	Prof. Hongki Yoo, KAIST (Korea) Label-free Assessment of High-risk Plaque by Multi-modal Imaging Catheter 
5:15pm~6:15pm	Prof. Stefan W. Hell, Max Planck Institute (Germany) 'Nobel Prize in Chemistry 2014' MINFLUX Nanoscopy and Related Matters  

Day2) December 3(Fri)
Micro/Nano Optical Measurement and Printing Technologies

Time (KST, GMT+9)	Speakers and Presentation Titles
10:30am~11:15am	Prof. Steven T. Wereley, Purdue University (USA) Particle Diffusometry for Microfluidic Healthcare Applications 
11:15am~3:00pm	Break
3:00pm~3:45pm	Prof. Sanha Kim, KAIST (Korea) Engineered Carbon Nanotube Surfaces for High Resolution Flexographic Printing and Micro/Nano Picking-and-Placing 
3:45pm~4:30pm	Prof. Hyoungsoo Kim, KAIST (Korea) Fluid Mechanics and Coating Technologies 
4:30pm~5:15pm	Prof. Vasilis Ntziachristos, Technical University of Munich (Germany) Optical and Optoacoustic Imaging: The Revolution of Label Free Observations 
5:15pm~6:15pm	Prof. Detlef Lohse, University of Twente (Netherland) Physicochemical Hydrodynamics of Droplets in Inkjet Printing 

Day 1 / Speaker #1

Actuation for Future Automation:

Artificial Muscles and Morphing Textures

Sam Tawfick

University of Illinois at Urbana-Champaign, IL, USA

Abstract

The future of work is shaped by the synergy between ubiquitous automation and artificial intelligence. Today, automation is driven by electric motors, which deliver clean mechanical actuation and are even already replacing engines in transportation, in addition to their role in robotics, prosthetics and energy. In this talk, I will describe a roadmap to replace bulky electric motors and exploit instead bioinspired deformable materials, processes and self-organization phenomena for actuation and morphing.

First, I will describe the design and production of artificial muscles which use electric, thermal, or chemical energy to generate contractile motion. I will demonstrate their use in concert with snapping beams for robotic actuation. Next, I will describe the use of liquid surface energy to manufacture surface textures by self-organization, as well as for actuating morphing surfaces.

These examples shed light on the future of automation propelled by new materials, nonlinear mechanisms and unusual manufacturing processes.

Speaker's Bio

Sam Tawfick is an Associate Professor of Mechanical Science and Engineering and at the Beckman Institute at the University of Illinois Urbana-Champaign. Tawfick obtained his PhD from the University of Michigan and was a Postdoctoral Associate at MIT. He is the recipient of the AFOSR Young Investigator Program, the Chao and Trigger Young Manufacturing Engineer from ASME, the Outstanding Young Manufacturing Engineer by SME, The Everitt Award for Teaching Excellence and the Two-year Alumni Teaching Award from the University of Illinois.

Day 1 / Speaker #2

Mechanics and modeling of nanoimprint lithography, and spatially multiplexed mechanical assembly of van der Waals heterostructures

Hayden Taylor

Department of Mechanical Engineering, University of California, Berkeley, USA

Abstract

Forming semiconductor device geometries by nanoimprint lithography (NIL) requires the control of complex mechanical interactions between viscoelastic deformations of the fluid resist material, elastic deformations of the imprinting stamp and wafer substrate, and the flow and parasitic entrapment of process gases. Numerical modeling plays an important role in process development, but specialized reduced-order methods are crucial for marshalling the extremely complex geometries of practical circuit designs. In this talk I will describe a set of boundary-element simulation methods that we have developed over the past decade to guide NIL process development, encompassing chip-scale, roll-to-roll, and droplet-dispensed variants of NIL.

I will also describe the more recent development of a process chain for mechanically exfoliating and transferring monolayers of van der Waals solids with repeatable shape, size and position. The covalent bond exfoliate–align–release (CoBEARs) process has been used, for example, to build arrays of WS_2–MoS_2 heterostructures. The effects of process variables on functional coupling between the monolayers are explored. Possible future research directions synthesizing NIL with multiplexed exfoliation will be discussed, with a view to highly parallelized mechanical transfer, assembly and patterning of atomically thin materials.

Speaker's Bio

Hayden Taylor is an Associate Professor of Mechanical Engineering at the University of California, Berkeley. His research spans the invention, modeling, and simulation of manufacturing processes. Current work addresses three themes: (A) Contact mechanics in nanomanufacturing, including nanoimprint, 2D material processing, and semiconductor wafer planarization; (B) Multiscale additive manufacturing, including the additive manufacturing process of computed axial lithography which his group co-invented with Lawrence Livermore National Lab; and (C) Surface engineering for heat and mass transfer. He received the B.A. and M.Eng. degrees in Electrical and Electronic Engineering from Cambridge University, and the Ph.D. in Electrical Engineering and Computer Science from MIT.

Haptic and Soft Robotic Engineering

Yon Visell

University of California, Santa Barbara

Abstract

Despite the remarkable advances in many areas of technology that have been realized over the course of the past century, engineering systems by and large fall well short of attaining levels of integration and functionality that are exhibited by myriad biological systems that physically interact with their environments, including the human hand. Some of the challenges involved in engineering such technologies can be traced to the complex mechanics, high dimensionality, uncertainty, and multiple physical regimes that are encountered in even the simplest real-world environments and interactions. I will describe haptics and soft robotics research from my lab that has been informed by properties and capabilities that are prevalent in biology. I will describe how the results can furnish efficient solutions for robotic grasping, haptic interfaces, and wearable technologies.

Speaker's Bio

Visell is Associate Professor at the University of California, Santa Barbara, in the Media Arts & Technology Graduate Program, Department of Electrical and Computer Engineering, and Department of Mechanical Engineering. Trained in engineering and physics, he received the PhD in Electrical and Computer Engineering from McGill University in 2011, working with Prof. Jeremy Cooperstock on haptics and virtual reality technologies. From 2011 to 2012, he was a postdoctoral researcher working on haptics with Prof. Vincent Hayward at Sorbonne University in Paris, France. Prior to joining UCSB, he was Assistant Professor of Electrical and Computer Engineering at Drexel University (2013 to 2015) in Philadelphia, PA. He received MA and BA degrees in Physics from The University of Texas, Austin and Wesleyan University respectively.

Dr. Visell directs the RE Touch Lab, where we pursue fundamental and applied research on the future of interactive technologies, with emphasis on haptics, robotics, and electronics, including emerging opportunities in human-computer interaction, sensorimotor augmentation, soft robotics, and interaction in virtual reality. Our lab is committed to positively impacting the world through its research. Visell currently serves as the General Co-Chair for the 2020 edition of IEEE Haptics Symposium, the premier conference venue for haptics in North America and longest running conference in the field. He also serves on the editorial boards for IEEE Robotics and Automation Letters and ICRA, and previously served as technical Program Chair for IEEE Haptics Symposium and for the EuroHaptics Conference.

Day 1 / Speaker #4

Materialized Graphics as an Extended Robot

Hiroyuki Shinoda

The University of Tokyo

Abstract

In the early stage of the midair ultrasonic tactile display, which started in 2008, it was only able to produce weak, specific, and somewhat strange tactile sensations as a narrow subset of haptic sensations. However, as research progresses, it is becoming a universal tactile display that can freely produce various tactile sensations. The sensations of static pressure and temperature are also covered by ultrasound. As these technologies progress and improve in realism, a virtual object with a 3D image and haptic response will evolve into what should be known as *materialized graphics*, behaving as though possessing a physical entity. Such a sensory substance extends the mechanical robot to fully computational existence, enables the non-invasive and seamless connection between humans and computers.

The significance of materialized graphics can be understood through the analogy of humanoid robots as a multimodal interface with humans. The human-like behavior and shape of humanoid robots enable communication with humans with no special prior knowledge. Materialized graphics provides a natural interface that humans can handle and manipulate using the skills that are inherent in humans. It may embody a passive object or a living being, including a human. They may be used to mediate human–human or human–robot communication, as well as to evaluate the usability of a prototype before it is created. They can change their appearance and shape and even instantly disappear when they are unnecessary. This talk will introduce the latest achievements and challenges of the materialized graphics and discuss the future.

Speaker's Bio

Hiroyuki Shinoda is a professor in the Graduate School of Frontier Sciences, the University of Tokyo. He received Ph.D. in Engineering from the University of Tokyo in 1995 and started his laboratory at the Department of Electrical and Electronic Engineering, Tokyo University of Agriculture and Technology. After a period with UC Berkeley, as a visiting scholar in 1999, he was an Associate Professor with the University of Tokyo from 2000 to 2012. Among research projects on haptic sensors and displays, ultrasound devices, and two-dimensional communication, his group developed the world's first non-contact ultrasound tactile display. He served as the general co-chair of the IEEE World Haptics Conference 2019 and is a member of SICE, IEEJ, RSJ, JSME, VRSJ, ACM, and IEEE.

Day 1 / Speaker #5

Challenges in Soft Actuators NOT to be Soft

Ki-Uk Kyung

Department of Mechanical Engineering

Korea Advanced Institute of Science and Technology (KAIST), South Korea

Abstract

Recently, with the emergence of flexible devices including stretchable/bendable consumer electronic devices, wearable devices and soft electromechanical machines such as soft robots allowing them to be mechanically robust against deformation, user interfaces are also required to be soft to be embedded into the systems. Particularly, in the case of designing an interactive user experience interface responding to user intention, sensing components for detecting user intention and responding components providing user experience need to be considered together with interaction schemes. In the area of sensor development, thin film sensors detecting amounts of strain, bending and contact pressure have been investigated for a long time. However, the stability of sensing response under dynamically deformed conditions still remains a critical issue to be solved, although many flexible tactile sensors have been suggested. The soft tactile sensors, which are stable under conditions of dynamic bending, curvilinear surface and water environment, may to enhance the practical applicability to wearable input interfaces, artificial skin for a robot, input interface of a flexible display and etc. In the area of soft actuators, electroactive polymers (EAPs) have been proposed as one of powerful materials for implementing flexible actuation mechanism. Owing to attractive benefits of light-weight, flexibility, non-geometric constraints, cost effectiveness, and easy miniaturization, the soft EAP actuators configured to a thin film are capable of enlarging their potentials to tactile feedback interfaces for flexible touchscreen, Braille devices, and wearable tactile devices. Recently, with advances of output capability, the soft actuators have contributed to opening up many opportunities in artificial muscles, biomimetic robots, and small mechanical devices as well as tactile interfaces. In addition, soft components have a major advantage in reconfigurability. For example, a soft actuating film can change its form from flat to locally protrusive in order to simulate a physical button. Robotic grippers with deformable fingers have advantages in handling arbitrary shaped objects. In the case of a transparent soft actuator having a shape of a lens, it can be used for varying its focal length by itself for adaptive optical systems. This talk also includes challenges in soft actuators for practical application to innovative soft human-machine interfaces.

Day 1 / Speaker #6

Label-free Assessment of High-risk Plaque by Multi-modal Imaging Catheter

Hongki Yoo

Department of Mechanical Engineering

Korea Advanced Institute of Science and Technology (KAIST), South Korea

Abstract

Recent advances in optical fibers, lasers, and optical imaging technologies have introduced miniaturized fiber-based micro-endoscopy technology for use in a variety of biomedical applications. Especially, miniaturized fiber-based endoscopic imaging probes for optical coherence tomography (OCT) have been successfully translated into clinical diagnostics, including cardiology and gastroenterology. While gray-scale OCT provides only the microstructural information of biological samples, multimodal endoscopic imaging techniques using double-clad fiber can provide comprehensive information on top of the microstructure. In particular, fluorescence lifetime imaging (FLIm) provides biochemical composition, inflammatory activity, and molecular information in a label-free manner. In this talk, we will present the technical advances of fiber-based micro-endoscopy technologies and its application to diagnose coronary artery disease. These newly developed endoscopic imaging technologies can provide an opportunity to investigate a variety of disease, including cardiovascular and gastrointestinal diseases.

Speaker's Bio

Hongki Yoo is an associate professor in the Department of Mechanical Engineering, KAIST, Korea. Professor Yoo received his B.S., M.S., and Ph.D. in Mechanical Engineering from KAIST. He has worked as a postdoctoral research fellow and an instructor in Wellman Center for Photomedicine at Harvard Medical School and Massachusetts General Hospital. He led Biomedical Optics and Photomedicine Lab in the Department of Biomedical Engineering, Hanyang University, 2012-2019. After that, he joined KAIST in 2019 to lead Biomedical Optics and Optical Metrology (BOOM) Lab. His research topics include multimodal optical imaging, endoscopic imaging, optical coherence tomography, confocal microscopy, diagnostics and therapeutics of cardiovascular diasease, and machine leaning in optical imaging. For more information on Professor Yoo's research projects, please visit his website at https://boom.kaist.ac.kr

Day 1 / Speaker #7

MINFLUX nanoscopy and related matters

Stefan W. Hell

Max Planck Institute for Biophysical Chemistry, Göttingen &

Max Planck Institute for Medical Research, Heidelberg

Abstract

I will show how an in-depth description of the basic principles of diffraction-unlimited fluorescence microscopy (nanoscopy) has spawned a powerful superresolution concept, namely MINFLUX nanoscopy. MINFLUX utilizes a local excitation intensity minimum (of a doughnut or a standing wave) that is targeted like a probe in order to localize the fluorescent molecule to be registered. In combination with single-molecule switching, MINFLUX has obtained the ultimate (super)resolution: the size of a molecule. MINFLUX nanoscopy, providing 1–3 nm resolution in cells, is being established for fluorescence imaging at molecular-size resolution. Relying on fewer detected photons than popular camera-based localization, MINFLUX is poised to open a new chapter in the imaging of protein complexes and distributions in fixed and living cells.

Speaker's Bio

Stefan W. Hell is a director at both the Max Planck Institute for Biophysical Chemistry in Göttingen and at the Max Planck Institute for Medical Research in Heidelberg, Germany. He is credited with having conceived, validated and applied the first viable concept for breaking Abbe's diffraction-limited resolution barrier in a light-focusing microscope and has received several awards: he shared the 2014 Kavli Prize in Nanoscience and the 2014 Nobel Prize in Chemistry.

Day 2 / Speaker #1

Particle Diffusometry for Microfluidic Healthcare Applications

Steve Wereley

Mechanical Engineering, Purdue University

Abstract

Leveraging many years of experience in the Particle Image Velocimetry (PIV) technique for measuring small-scale flows, my research group in the Microfluidics Laboratory at Purdue University has developed a related technique called Particle Diffusometry (PD). The underlying principle of PD relies on the Stokes-Einstein diffusion coefficient and the statistics of PIV to measure the diffusive behavior of particle species. PD can measure any of the parameters in the Stokes-Einstein diffusion coefficient (particle diameter, fluid viscosity, temperature) as long as the others are held constant. PD has proved especially useful in healthcare applications where small changes in particle size or viscosity can signify an important change, such as DNA amplification or proteins adhering to a particle. Applications in virus detection, protein degradation and DNA amplification will be discussed. The last technology is core technology in Wereley's healthcare diagnostic start-up OmniVis, Inc.

Speaker's Bio

Professor Wereley completed his masters and doctoral research at Northwestern University. He joined the Purdue University faculty in August of 1999 after a two-year postdoctoral appointment at the University of California Santa Barbara. During his time at UCSB he worked with a group developing, patenting, and licensing to TSI, Inc., the micro-Particle Image Velocimetry technique. His current research interests include designing and testing microfluidic MEMS devices, investigating biological flows at the cellular level, improving micro-scale laminar mixing, and developing new micro/nano flow diagnostic techniques. Although considerably outside the field of microfluidics, Professor Wereley used his flow measurement expertise to analyze the Deepwater Horizon oil spill in the Gulf of Mexico in 2010, serving on the US government's *Flow Rate Technical Group*. His contributions to characterizing the disaster were recognized with the US Geological Survey Director's Award. Professor Wereley is the co-author Particle Image Velocimetry: A Practical Guide, 3rd ed (Springer, 2018). He is on the editorial board of Experiments in Fluids and is an Associate Editor of Springer's Microfluidics and Nanofluidics. Professor Wereley has edited Springer's recent Encyclopedia of Microfluidics and Nanofluidics and Kluwer's BioMEMS and Biomedical Nanotechnology.

Day 2 / Speaker #2

Engineered Carbon Nanotube Surfaces for High Resolution Flexographic Printing and Micro/Nano Picking-and-Placing

Prof. Sanha Kim

Department of Mechanical Engineering, KAIST, South Korea

Abstract

Synthesis and modification of vertically aligned carbon nanotubes (CNTs) provides new opportunities to design materials with novel mechanical behavior and multifunctional performance. In this talk, I discuss the design and fabrication strategies of CNT surface structures with tailored geometry and mechanics, and their applications in advanced manufacturing processes. First, I present how CNT forests can be engineered as nanoporous stamps for flexographic printing of electronically functional inks, which enables combination of high resolution (<10 μm) and throughput (>0.1 m/s) that far surpasses existing printing processes. The CNT microstructures are highly porous (>90 %) and can be infiltrated by colloidal inks, and are used to transfer a thin layer to a target substrate upon brief mechanical contact. Diverse micron-scale patterns of a variety of functional nanoparticle inks, including Ag, ZnO, WO_3, and CdSe/ZnS, have been printed onto both rigid and compliant substrates. The printed patterns have highly uniform nanoscale thickness (5-50 nm), and match the stamp features with high fidelity (edge roughness ~0.2 μm). Here, conditions for uniform printing are derived based on nanoscale contact mechanics. Second, I introduce CNT forests with atomic layer of conformal dielectric coatings that can be configured as electrically switchable dry adhesives, for potential applications in pick-and-place micro-assembly of electronics. The electromechanical contact behavior is enabled by nanocomposite electroadhesive surfaces with new combination of functionalities, including mechanically soft, low intrinsic adhesion, and switching of the surface adhesion in wide range (upto ~100 on/off adhesion ratio) by an external voltage.

Speaker's Bio

Sanha Kim is an assistant professor in the Department of Mechanical Engineering at the Korea Advanced Institute of Science and Technology (KAIST). He earned his Bachelor's and Master's degrees in Mechanical Engineering from Seoul National University, and obtained his PhD degree in Mechanical Engineering from Massachusetts Institute of Technology (MIT). He also worked as a Postdoctoral Associate and a Research Scientist in the Department of Mechanical Engineering and Laboratory for Manufacturing and Productivity at MIT. His focused research areas include chemical-mechanical polishing, contact mechanics & tribology, micro/nano materials synthesis and architecturing, and digital 2D&3D printing technologies.

Day 2 / Speaker #3

Fluid Mechanics and Coating Technologies

Hyoungsoo Kim

Department of Mechanical Engineering

Korea Advanced Institute of Science and Technology (KAIST), South Korea

Abstract

Printing technology has been received considerable attentions in history, and these days. These days, printing technology has been developed for smaller, more complicated, and more flexible structures, such as 3D printing, stretchable and/or transparent electronic device, rollable display, and so on. However, to obtain a uniform coating or to control a coating pattern is still far from complete. Hydrodynamic effects are predominant because solid materials should be transferred by fluid all the time. In this seminar, we will talk about how we can achieve a uniform coating result or control a coating pattern when we use soft matters. The examples include coffee-ring-less QD-LED polygonal patterns and liquid metal coating and its applications. These problems characterize my approach of using optical measurement techniques to explore new questions in multiphase flows and physicochemical hydrodynamics.

Speaker's Bio

Dr. Hyoungsoo Kim is an associate professor in the Department of Mechanical Engineering at the Korea Advanced Institute of Science and Technology (KAIST). He received his B.S. (2006) degree from Kumoh National Institute of Technology and M.S. (2008) degree from KAIST, South Korea. He obtained his PhD degree in Mechanical Engineering from Delft University of Technology (TUDelft) in 2013, the Netherlands. He worked with Prof. Howard Stone as a Postdoctoral Researcher and an Associate Research Scientist in the Department of Aerospace and Mechanical Engineering at Princeton University, US. His research mainly focuses on the development of flow visualization techniques, soft matters, coating and printing technologies, hydrodynamic instabilities, and interfacial flow problems.

Day 2 / Speaker #4

Optical and Optoacoustic Imaging: the Revolution of Label-free Observations

Vasilis Ntziachristos

Professor and Chair of Biological Imaging (Technical University of Munich)
Director, Institute of Biological and Medical Imaging (Helmholtz Zentrum München)
Director of Bioengineering, Helmholtz Pioneer Campus

Abstract

Optical imaging is unequivocally the most versatile and widely used visualization modality in the life sciences. Yet it has been significantly limited by photon scattering, which complicates the visualization of tissue beyond a few hundred microns. Recently, powerful new optical and optoacoustic imaging methods have emerged that offer high resolution imaging beyond the penetration limits of microscopic methods. The talk discusses progress in multi-spectral optoacoustic tomography (MSOT) and mesoscopy (MSOM), which yield unprecedented optical imaging performance in visualizing anatomical, physiological, and molecular biomarkers. Advances in light technology, detection methods, and algorithms allow for high-performance visualization in biology and medicine through several millimetres to centimetres of tissue and real-time imaging. The talk demonstrates implementations in the time and frequency domain, showcases how it is possible to accurately solve fluence and spectral coloring issues for yielding quantitative measurements of tissue oxygenation and hypoxia, and demonstrates quantitative in-vivo measurements of inflammation, metabolism, and angiogenesis in label-free mode. In parallel, progress in clinical systems and the complementarity of ultrasound imaging, fluorescence molecular imaging, and other modalities is discussed. Finally the talk offers insights into new miniaturized detection methods based on ultrasound detection using optical fibers, which could be used for minimally invasive applications.

Speaker's Bio

Vasilis Ntziachristos Ph.D. is Professor of Medicine, Professor of Electrical Engineering and Director of the Chair for Biological Imaging (CBI) at the Technical University of Munich, Director of the Institute for Biological and Medical Imaging (IBMI) at the Helmholtz Zentrum Munchen and Director of Bioengineering at the Helmholtz Pioneer Campus. He has received the Diploma in Electrical Engineering and Computer Science from the Aristotle University of Thessaloniki, Greece and the M.Sc and Ph.D. degrees in Bioengineering from the University of Pennsylvania in Philadelphia PA. Prior to his current appointment he was faculty at Harvard University and the Massachusetts General Hospital. Professor Ntziachristos is the founder of the journal Photoacoustics, regularly Chairs in international meetings and councils and has received numerous awards and distinctions, including the Chaire Blaise Pascal (2019) from the Region Ile-de-France, the Gold Medal from the Society for Molecular Imaging (2015), the Gottfried Leibnitz prize from the German Research Foundation (2013), the Erwin Schrödinger Award (2012) and was named one of the world's top innovators by the Massachusetts Institute of Technology (MIT) Technology Review in 2004.

Day 2 / Speaker #5

Physicochemical hydrodynamics of droplets in inkjet printing

Detlef Lohse

Physics of Fluids Group, University of Twente

Abstract

Inkjet printing is the most widespread technological application of microfluidics. It is characterized by its high drop productivity, small volumes and extreme reproducibility. In this talk I will give a synopsis of the fluid dynamics of inkjet printing and discusses the main challenges for present and future research [1]. These lie both on the printhead side – namely the detailed flow inside the printhead, entrained bubbles, the meniscus dynamics, wetting phenomena at the nozzle plate, and jet formation – and on the receiving substrate side – namely droplet impact, merging, wetting of the substrate, droplet evaporation, and drying. In most cases the droplets are multicomponent, displaying rich physicochemical hydrodynamic phenomena. The challenges on the printhead side and on the receiving substrate side are interwoven, as optimizing the process and the materials with respect to either the printhead side or the substrate side is not enough: As the same ink (or other jetted liquid) is used and as droplet frequency and size matter on both sides, the process must be optimized as a whole. One example for conflicting requirements from the printhead side on the one hand and from the receiving substrate or more specifically the paper side on the other hand is the volatility of the ink: At the nozzle, it would be preferable if the evaporation of ink were avoided to prevent nozzle clogging, but on the paper side, fast evaporation of ink is desirable to enable productive printing and to prevent paper deformation.

Even such a seemingly simple process as the evaporation of multicomponent droplets keeps surprising us through its richness of phenomena. I will show and explain several of such phenomena, namely evaporation-triggered segregation thanks to either weak solutal Marangoni flow or thanks to gravitational effects. The dominance of the latter implies that sessile droplets and pending droplets show very different evaporation behavior, even for Bond number << 1. I will also explain the full phase diagram in the Marangoni number vs Rayleigh number phase space, and show where Rayleigh convections rolls prevail, where Marangoni convection rolls prevail, and where they compete, and why these processes are very important in piezoacoustic inkjet printing. I will also extend these considerations to ternary and colloidal droplets and show and explain the new, fascinating, and often counter-intuitive phenomena which occur for these case of complex ink droplets.

[1] Detlef Lohse, Annu. Rev. Fluid Mech. 54, 349-382 (2022)

Speaker's Bio

Detlef Lohse studied physics at the Universities of Kiel & Bonn (Germany), and got his PhD at Univ. of Marburg (1992). He then joined Univ. of Chicago as postdoc. After his habilitation (Marburg, 1997), in 1998 he became Chair at Univ. of Twente in the Netherlands and built up the Physics of Fluids group. Since 2015 he is also Member of the Max Planck Society and of the Max-Planck Institute in Göttingen.

Lohse's present research interests include turbulence and multiphase flow and micro- and nanofluidics (bubbles, drops, inkjet printing, wetting). He does both fundamental and more applied science and combines experimental, theoretical, and numerical methods.

Lohse is Associate Editor of J. Fluid Mech. (among others journals) and serves as Chair of the Executive Board of the Division of Fluid Dynamics of the American Physical Society and Member of the Executive Board of IUTAM. He is Member of the (American) National Academy of Engineering (2017), of the Dutch Academy of Sciences (KNAW, 2005), the German Academy of Sciences (Leopoldina, 2002) and Fellow of APS (2002). He won various scientific prizes, among which the Spinoza Prize (NWO, 2005), the Simon Stevin Meester Prize (STW, 2009), the Physica Prize of the Dutch Physics Society (2011), the AkzoNobel Science Award (2012), two European Research Council Advanced Grants (2010 & 2017), the George K. Batchelor Prize (IUTAM, 2012), the APS Fluid Dynamics Prize (2017), the Balzan Prize (2018), and the Max Planck Medal (2019). In 2010, he got knighted to become "Ridder in de Orde van de Nederlandse Leeuw".

Website: http://pof.tnw.utwente.nl