International Nanofluidic Symposium Singapore, Jan 18-20 2023

International Nanofluidic Symposium Singapore, Jan 18-20 2023

Organized by

Slaven Garaj, National University of Singapore

Zhang Sui, National University of Singapore

Venue

CREATE tower at University Town National University of Singapore, Singapore

Supported by

Contents

Symposium program

Wednesday, 18 January 2023					
Wednesday 18.01	8:15	**Registration**			
	9:10	**Opening remarks**			
	9:30	Karnik	Rohit	MIT (USA)	Nanofluidic Transport across Nanoporous Atomically Thin Graphene and its Development as a Next-Generation Membrane
	10:00	Mi	Baoxia	UC Berkley (USA)	Exploring the Multifunctionality of 2D Nanomaterials for Novel Membranes and Processes

Break 10:30 - 11:00

Wednesday 18.01	11:00	Kumar	Manish	U. Texas Austin (USA)	A channel-based paradigm for separation membranes
	11:30	Cheng	Chi	U. Melbourne	Move ions and molecules across sheets of atoms: insights and applications
	12:00	Andreeva	Daria	NUS (Singapore)	Artificial ionic channels
12:30 - 14:00		**Lunch and poster session**			

Wednesday 18.01	14:00	Novoselov	Konstantin	NUS (Singapore)	Colloquium
	14:30				
	15:00	Panel Discussion (chair: Rohit Karnik, MIT)		**New-Paradigm Membranes** Konstantin Novoselov, NUS (scientific perspective) David Menzier, Nematiq (startup perspective) Gurdev Singh, PUB (government agency) Neil Hu, Veolia (system integrator) Beth Henderson, Startupbootcamp (VC/accelerators)	

Break 16:00 - 16:30

Wednesday 18.01	16:30	**Industrial forum**	Short 10-minutes presentations from industrial participants.
Leaving room by 17:45			

Thursday, 19 January 2023					
Thursday 19.01	9:00	Leburton	Jean-Pierre	U. Illinois Urbana-Champaign (USA)	Interplay amongst Van der Waals, Electrostatics and Dehydration Energies in Ionic Transport through Charged Sub-Nanometer Pores
	9:30	Agrawal	Kumar	EPFL (Switzerland)	Chemistry of graphene at the Å-scale for efficient molecular manipulation
	10:00	Gundlach	Jens	U.Washington (USA)	Using nanopores as the most precise single-molecule tool
	10:30	Meller	Amit	Technion	Solid-state Nanopores and Nanochannels for single protein molecule counting

Break 11:00 - 11:30

Thursday 19.01	11:30	Han	Jongyoon	MIT (USA)	Enhanced Transport of Molecules into Nanopores – Application to Dentistry
	12:00	Lim	Chwee Teck	NUS (Singapore)	Microfluidic Approaches to Isolating Micro- and Nanoscale Circulating Biomarkers for Disease Diagnosis and Monitoring
	12:30	Doyle	Patrick	MIT (USA)	Probing complex DNA topologies using nanopores

Lunch 13:00 - 14:00

Thursday 19.01	14:00	Strano	Michael	MIT (USA)	*Colloquium*: Understanding Extreme Fluid Confinement in Single Digit Nanopores - the Center for Enhanced Nanofluidic Transport (CENT)
	14:30				
	15:00	Aluru	Narayana	U. Texas Austin (USA)	Nanofluidic Transport in Low-D Materials: Role of Fluctuations and Quantum Effects
	15:30	Majumder	Mainak	Monash U. (Australia)	Realization of the potential of practical Graphene Oxide membranes for molecular separations

Break 16:00 - 16:30

Thursday 19.01	16:30	Joshi	Rakesh	UNSW (Australia)	Graphene oxide membranes for purification and separation
	17:00	Wang	Luda	Peking U (China)	Ionic transport through controllable angstrom- to nanometer-sized pores
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Conference dinner 19:00					

Friday, 20 January 2023					
Friday 20.01	9:00	Zhang	Sui	NUS (Singapore)	2D nanoporous and microporous membranes for challenging separations
	9:30	Vogel	Jörg	Aquaporin (Denmark)	Rethinking water filtration with biotechnology and how to upscale
	10:00	Mirsaidov	Utkur	NUS (Singapore)	Nanoscale elastocapillary forces

Break 10:30 - 11:00

Friday 20.01	11:00	Zhao	Dan	NUS (Singapore)	Porous Cages as Water Channels in Reverse Osmosis Membranes
	11:30	Kidambi	Piran	Vanderbilt U. (USA)	Selective Nanoscale Mass Transport through Atomically Thin 2D Membranes
	12:00	Drndic	Marija	U. Penn. (USA)	Sculpting of 2D Materials: From Pores and Nanoporous Membranes
	12:30	Marion	Sanjin	IMEC (Belgium)	Nanofluidics with ultrathin nanopores

Lunch 13:00 - 14:00

Friday 20.01	14:00	Noy	Aleksandr	LLNL (USA)	Nanofluidics in sub-1-nm carbon nanotube porins
	14:30	Freger	Viatcheslav	Technion (Israel)	Ions in sub-nm carbon nanotubes: charging, transfer and pairing
	15:00	Garaj	Slaven	NUS (Singapore)	Ionic transport through 2D nanochannels and nanopores
Best poster award, symposium closing.					
Post - Symposium activity					

Invited talks

INS2023 - Invited talks – 1

Wednesday, Jan 18, 2023

Rohit Karnik

Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, USA

Prof. Rohit Karnik is Tata Professor and Associate Department Head for Education in Mechanical Engineering at the Massachusetts Institute of Technology, where he leads the Microfluidics and Nanofluidics Research Group. His research focuses on the physics of micro- and nanofluidic flows and the design of micro- and nanofluidic systems for applications in water, healthcare, energy, and environment. He obtained his B. Tech. degree from the Indian Institute of Technology at Bombay in 2002, and his PhD from the University of California at Berkeley in 2006 under the guidance of Prof. Arun Majumdar. After postdoctoral work with Prof. Robert Langer at MIT, he joined the Department of Mechanical Engineering at MIT in 2007. Among other honors, he is a recipient of the Institute Silver Medal (IIT Bombay, 2002), NSF Career Award (2010), Keenan Award for Innovation in Undergraduate Education (2011), DOE Early Career Award (2012), IIT Bombay Young Alumnus Achiever Award (2014), and the Ruth and Joel Spira Award for Distinguished Teaching (2018).

Nanofluidic Transport across Nanoporous Atomically Thin Graphene and its Development as a Next-Generation Membrane

Rohit N. Karnik

Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, USA

Abstract

Nanoporous atomically thin graphene, wherein nanopores in the two-dimensional graphene lattice provide pathways for rapid and selective fluidic transport, constitutes the thinnest possible membrane and has potential for improving the efficiency, selectivity, productivity, versatility, and chemical resistance for a variety of membrane separations. Through controlled nucleation of defects via ion bombardment and oxidative etching, sub-nanometer pores are created in a single layer of graphene placed on a porous support. We discuss strategies for the design of membranes that are tolerant of defects in the graphene layer, and show that appropriate choice of the porous support is critical for exploiting the selectivity of nanoporous graphene. We further demonstrate that the impermeability of graphene can be exploited to selectively seal defects and tighten the pore size distribution to greatly improve its selectivity. Through these developments, we are able to realize centimeter-scale graphene membranes that show high selectivity between ions, molecules, and proteins for nanofiltration and dialysis, and ultrahigh permeance in organic solvent nanofiltration. These studies illustrate the interplay between material structure and transport in nanoporous graphene and demonstrate its potential for the realization of next-generation membranes for addressing emerging needs in water purification, resource recovery and recycling, and energy-efficient separations that demand the ability to operate under harsh conditions.

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Wednesday, Jan 18, 2023

Baoxia Mi

Department of Civil and Environmental Engineering, University of California Berkeley, USA

Prof. Baoxia Mi directs the research and educational activities of the Membrane Innovation Laboratory, studying physicochemical processes with emphases on advanced membrane processes and nanotechnology to address some of the most challenging issues in sustainable water supply (desalination, drinking water purification, wastewater reuse), renewable energy production, and public health protection.

Education

Ph.D. in Environmental Engineering, University of Illinois at Urbana-Champaign, 2006

M.S. in Environmental Engineering, Tianjin University, 2001

B.S. in Civil Engineering, Tianjin University, 1998

Awards

Hellman Fellows Award, 2017

CAPEES/Nanova Young Investigator Award, 2017

Invited Speaker, US Frontiers of Engineering Symposium, 2016

NSF Faculty Early Career Development (CAREER) Award, 2014

Exploring the Multifunctionality of 2D Nanomaterials for Novel Membranes and Processes

Baoxia Mi

Department of Civil and Environmental Engineering, University of California Berkeley, USA

Abstract

Two-dimensional (2D) nanomaterials (e.g., graphene oxide/GO and MoS2) offer a variety of interesting properties that can be potentially used to in water purification and desalination technologies. This talk will focus on exploring some of these properties for membrane filtration, adsorption, and solar evaporation. 2D GO and MoS2 have been widely used as building blocks to make new nanostructured membranes, but their other functionality has often been neglected. Here we would like to use two examples to explain some promising features of multifunctional membranes to enable novel separation processes. First, a layer-stacked MoS2 membrane will be presented as a promising multifunctional platform technology for efficient removal of heavy metal ions and oxyanions with superior selectivity. Next, a GO-enable 3D solar water evaporator will be introduced and its potential for desalination, brine treatment, and zero liquid discharge (ZLD) will be discussed.

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Wednesday, Jan 18, 2023

Manish Kumar

Environmental Engineering and Chemical Engineering, University of Texas at Austin, Austin, TX, USA

Prof. Manish Kumar received his bachelors degree in Chemical Engineering from the National Institute of Technology in Trichy, India in 1998. He received his masters degree in Environmental Engineering from the University of Illinois at Urbana Champaign (UIUC) in 2000. He then worked as a an engineer with NCS, Inc in Phoenix for a year and a half on arsenic treatment and membrane water and wastewater treatment projects. He moved to the Applied Research Department of MWH in 2001 and worked there for 5.5 years on various applied research projects including a range of membrane technologies - microfiltration/ultrafiltration, membrane bioreactors, reverse osmosis (for brackish surface and groundwater, reclaimed water and seawater), and forward osmosis. He also worked on demonstration testing of UV disinfection and Membrane Bioreactors for Water Reclamation and was involved in the City of San Diego Indirect Potable Reuse Study. He returned to UIUC in 2006 to continue his graduate studies. His PhD conducted under the guidance of Dr. Mark Clark and Dr. Julie Zilles resulted in one of the first reports on biomimetic membranes for desalination. He then joined the Walz Laboratory at the Harvard Medical School in Boston as a postdoc to look at structure and function of the eye lens Aquaporin (AQP0) in lipids and block copolymers. He started at Penn State as an Assistant Professor on August 1st, 2011, received tenure in 2017 and moved to UT Austin in 2019.

A channel-based paradigm for separation membranes

Manish Kumar

Environmental Engineering and Chemical Engineering, University of Texas at Austin, Austin, TX, USA

Abstract

Fast and selective water and ion transport across cellular membranes has inspired the development of bioinspired membranes for possible separations applications. An emerging approach is to use artificial channels (ACs) as a key transport element of membranes for aqueous separations such as desalination and ion-ion separations. ACs are synthetic mimics or engineered versions of naturally occurring biological membrane proteins. In this talk, I will provide a brief overview of recent and exciting AC developments with a focus on artificial water channels[2] and discuss emerging paradigms for fast water transport and water/ion selectivity. Following this will be a discussion on the potential of ion selective channels with some examples. I will also provide a perspective on how these novel artificial water and ion channels could be leveraged to create high performance membranes using some proposed general principles for channel-based membranes.

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Wednesday, Jan 18, 2023

Chi Cheng

Department of Chemical Engineering, The University of Melbourne, Australia

Move ions and molecules across sheets of atoms: insights and applications

Chi Cheng

Department of Chemical Engineering, The University of Melbourne, Australia

Abstract

Precisely controlled ionic and molecular transport are key processes governing the performance of a wide range of crucial technologies such as energy-efficient membrane separations, electrochemical energy storage and synthesis. With competing forces, complex structural and chemical interactions in nanosystems, unexpected transport behaviors emerge that present a barrier toward engineering nanofluids with molecular-level precision. In this talk, I will present our work on how we advance our abilities to study, analyze, control and design nanoconfined ionic and molecular transport, by employing graphene materials. I will show the versatility of graphene for fabricating nanopores and nanochannels, while discuss novel transport physics under confinement, namely the correlated ion transport in nanoconfined electrical double layer and sub-continuum fluid permeation across angstrom-sized atomically thin nanopores. I will conclude the talk by showing graphene is a rich materials system for engineering nanofluids that could enable new engineering solutions to address challenges in sustainable energy and manufacturing.

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Wednesday, Jan 18, 2023

Daria Andreeva

Institute for Functional Intelligent Materials, National University of Singapore, Singapore

Materials Science and Engineering Department, National University of Singapore, Singapore

Daria V. Andreeva-Baeumler is an Assoc. Professor in the Institute for Functional Intelligent Materials, the National University of Singapore. She is leading a group on smart membranes with self-adapting and learning capabilities. Daria has authored more than 100 research papers including papers in Nature Nanotechnology, Nature Communication and Advanced Materials and received various fellowships (e.g. Alexander von Humboldt and UNESCO).

She leaded a physical chemistry group in the University of Bayreuth, Germany, and worked on smart anticorrosion coatings in Max Planck Institute of Colloids and Interfaces.

Having finished her habilitation, she joined the Centre for Soft and Living Matter, South Korea. Daria explores electrochemical phenomena in self-assembled stimuli responsive nanostructures for smart membranes and energy harvesting devices. Of particular interest are semiconductors, piezoelectric crystals and stimuli responsive polymers that operate with ionic currents.

Artificial ionic channels

Daria V. Andreeva

Institute for Functional Intelligent Materials, National University of Singapore

Materials Science and Engineering Department, National University of Singapore

Abstract

Although highly selective and permeable ionic channels are main transport pathways in biological membranes, to achieve similar efficiency in artificial membranes is still beyond the wildest dreams of membrane science and technology. To realize high efficiency of protein-based water and ionic transport in artificial materials, we base our technology on the combination of graphene-family, 2D, materials and macromolecules, polymers.

I will talk about our recent innovation: 2D membranes made of graphene-oxide and polyamines (which together form a network of ionic channels) that exhibit regulated permeability of water and ions, like biological membranes. Furthermore, we observed that permeation of some ions can be controlled by the presence of other ions, creating a “transistor effect” for selective ionic transport.

Artificial membranes with intrinsic intelligence are critical not only to cellular functions, but they are also fundamental in many areas of science and technology and used widely in the food, pharmaceutical and energy industries. Such membranes are of great interest for modern technology such as extraction of Li+ for Li-ion batteries and Cs+ removal from radioactive waste. Such membranes can lead to further advances in the formation of super-nanocapacitors, membranes with selective release of ions for biofilm growth for food industry and pharmacy.

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Wednesday, Jan 18, 2023

Konstantin Novoselov

Institute for Functional Intelligent Materials, National University of Singapore, Singapore

Prof Sir Konstantin 'Kostya' Novoselov FRS was born in Russia in August 1974. He has both British and Russian citizenship. He is best known for isolating graphene at The University of Manchester in 2004, and is an expert in condensed matter physics, mesoscopic physics and nanotechnology. Every year since 2014 Kostya Novoselov is included in the list of the most highly cited researchers in the world. He was awarded the Nobel Prize for Physics in 2010 for his achievements with graphene. Kostya holds positions of Langworthy Professor of Physics and the Royal Society Research Professor at The University of Manchester.

He graduated from the Moscow Institute of Physics and Technology, and undertook his PhD studies at the University of Nijmegen in the Netherlands before moving to The University of Manchester in 2001. Professor Novoselov has published more than 250 peer-reviewed research papers. He was awarded with numerous prizes, including Nicholas Kurti Prize (2007), International Union of Pure and Applied Science Prize (2008), MIT Technology Review young innovator (2008), Europhysics Prize (2008), Bragg Lecture Prize from the Union of Crystallography (2011), the Kohn Award Lecture (2012), Leverhulme Medal from the Royal Society (2013), Onsager medal (2014), Carbon medal (2016), Dalton medal (2016) among many others. He was knighted in the 2012 New Year Honours.

Konstantin Novoselov

Institute for Functional Intelligent Materials, National University of Singapore, Singapore

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Thursday, Jan 19, 2023

Jean-Pierre Leburton

Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Illinois 61801, USA

Prof. Jean-Pierre Leburton received his Ph.D. from the University of Liege (Belgium) in 1978. He is a professor in the UIUC Department of Electrical and Computer Engineering and a research professor in the Coordinated Science Laboratory. He is also a full-time faculty member of the Computational Electronics Group in the Beckman Institute.

Professor Leburton's expertise is the theory and simulation of nanoscale semiconductor devices and low-dimensional systems. His research focuses more specifically on transport and optical processes in semiconductor nanostructures such as quantum wells, quantum wires and quantum dots. Current research projects involve electronic properties of self-assembled dots for high performance lasers, single-electron charging and spin effects in quantum dots, modeling of nanocrystal floating gate flash memory devices, nanoscale Si MOSFET's and carbon nanotubes and graphene nanostructures. His research deals also with dissipative mechanisms involving electron-phonon interaction in nanostructures for mid- and far-infrared intra-band lasers. Approaches to these problems involve use of sophisticated numerical techniques such as Monte-Carlo simulation and advanced 3D self-consistent Schroedinger-Poisson model including non-equilibrium transport for full scale nanodevice modeling.In the last 21 years, he turned his interest toward the interaction between living systems and semiconductors to investigate programming and sensing biomolecules with nanoelectronics.

Interplay amongst Van der Waals, Electrostatics and Dehydration Energies in Ionic Transport through Charged Sub-Nanometer Pores

Jean-Pierre Leburton

Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Illinois 61801, USA

Abstract

In this talk, we provide a detailed analysis of various mechanisms at play during ionic transport through the ultra-thin 2D synthetic sub-nanometer pore as a function of discrete charge decorating the pore edge. As expected while the van de Waals and permeation energies remain practically unchanged, electrostatic interaction increase with the number of on-site charges. All-atom molecular dynamics simulation indicates ion trapping from resulting from realistically charged sites in the vicinity of the 2D material sub-nanometer. A transport model based on the thermionic emission-based formalism combined with the permeation free energy barriers displays I-V curves in good agreement well with recent experimental results. Our analysis applied to vertically stacked monolayer MoS_2-hBN nanopore FETs in a multi-sensing electronic scheme indicates improved sensing robustness and noise reduction in detecting biomolecules such as DNA and proteins. The synchronization of electronic sensing current signatures across successive MoS_2 probes achieved by time-lagged cross-correlation (TLCC) enhances the signal-to-noise ratio notably in the lower frequency spectrum, enabling the identification of homopolymers.

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Thursday, Jan 19, 2023

Kumar Varoon Agrawal

Laboratory of Advanced Separations, Institute of Chemical Sciences and Engineering, École Polytechnique Fédérale de Lausanne (EPFL)

Prof. Kumar Varoon Agrawal is an Associate Professor and GAZNAT Chair at the Institute of Chemical Sciences and Engineering (ISIC) at École Polytechnique Fédérale de Lausanne (EPFL) where he heads the laboratory of advanced separations (LAS) since year 2016. He received his undergraduate degree in Chemical Engineering from IIT Bombay (India) in 2005. Following this, he joined the global R&D division of Procter & Gamble in Japan where he worked on product design (2005-2008). He subsequently joined the University of Minnesota for a PhD degree in chemical engineering (2008-2013). His thesis advised by Prof. Michael Tsapatsis and Prof. Lorraine Francis led to the isolation of highly crystalline two-dimensional zeolite nanosheets. He joined Strano group at the Massachusetts Institute of Technology as a postdoctoral researcher where he studied the effect of nanoconfinement on the phase transition of fluids (2014-2016).

At EPFL, his research group is engaged in material chemistry and engineering at the Å-scale for high-performance inorganic and hybrid membranes for energy- and cost-efficient molecular separation. For this, his group is developing synthetic routes for the two-dimensional nanoporous membranes with precise control of nanopore size and functionality. He is the recipient of the American Institute of Chemical Engineers (AIChE) Separation Division FRI/John G. Kunesh Award (2021), North American Membrane Society Young Membrane Scientist Award (2018), European Research Council Starting Grant, Swiss National Science Foundation Assistant Professor Energy Grant, among others.

Chemistry of graphene at the Å-scale for efficient molecular manipulation

Kumar Varoon Agrawal

Laboratory of Advanced Separations, Institute of Chemical Sciences and Engineering, École Polytechnique Fédérale de Lausanne (EPFL)

Abstract

Two-dimensional films hosting molecular sized pores offer a unique untapped opportunity to advance the field of molecular transport with application in selective membrane-based separation, energy storage, energy harvesting, sequencing, etc. We have been interested in incorporating Å-scale pores in graphene with a high degree of control, by developing methods that are sensitive enough to allow one to independently control pore density and pore size with latter in the range of 3-10 Å for application in solute-solute separation, and at the same time, allow uniform lattice engineering over a large area in scale-up friendly manner. For this, we have developed oxidation chemistry of graphene using ozone and CO_2 as chemical reactants. In this presentation, I will highlight the mechanism of pore formation in graphene when it is exposed to ozone, starting from the incorporation of epoxy group in the lattice followed by epoxy cluster formation and finally gasification of cluster. This allows one to design oxidation chemistry where first clusters are formed without forming pores and subsequently pores are incorporated on demand by supplying energy for cluster gasification. I will then discuss controlled pore expansion by CO_2 at the rate of few Å/min where fresh pore nucleation events are eliminated. This toolbox allows one to tune the pore size in the desired size range. I will then discuss specific case studies. First involving CO_2/N_2 separation where incorporation of Å-scale pores and heteroatom doping allows development of membranes which makes graphene membrane extremely attractive for carbon capture application. In this respect, I will highlight recent progress in the laboratory for scaling up membranes for a pilot-plant initiative. Second involving ion-ion separation where pores tuned in the right size range yield extremely large K^+/Mg^{2+} selectivities. I will end the presentation with recent development in direct bottom-up synthesis of nanoporous graphene, and show that control of pore size distribution by this route is also possible by tuning the crystallization pathway.

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Thursday, Jan 19, 2023

Jens Gundlach

Department of physics, University of Washington, Seattle, Washington 98195 USA

Prof. Jens Gundlach is an experimental physicist at the University of Washington. He has two main research interests that are pretty close to the opposite ends of the research spectrum in physics: fundamental physics and biophysics.

Education

Physik-Vordiplom, Johannes Gutenberg Universität, Mainz, Germany, 1982.

Physik-Diplom, Johannes Gutenberg Universität, Mainz, Germany, 1986. Ph.D. (Nuclear Physics), University of Washington, 1990.

Honors and Awards

Deutscher Akademischer Austausch Dienst, Full Scholarship, 1982-83. National Institute of Standards and Technology Precision Measurement Grant, 1997-2000.

Francis M. Pipkin Award of the American Physical Society in 2001.

Royalty Research Fund Award, University of Washington, 2003.

Fellow of the American Physical Society, 2010.

Breakthrough Prize 2021.

Using nanopores as the most precise single-molecule tool

Jens Gundlach

Department of physics, University of Washington, Seattle, Washington 98195 USA

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Thursday, Jan 19, 2023

Amit Meller

Faculty of Biomedical Engineering, Technion - IIT, Israel

Prof. Amit Meller is a Full Professor (tenured), Faculty of Biomedical Engineering, Technion, Haifa, Israel.

Education

1997 PhD Department of Physics, Weizmann Institute of Science, Rehovot, Israel.

1992 MSc Department of Physics, Weizmann Institute of Science, Rehovot, Israel.

1989 BSc Physics and Astronomy (Cum laude), Tel Aviv University, Tel Aviv, Israel.

Research interests

Nanopore sensors for single molecule sensing of genetic and epi-genetic markers in cancer and infectious diseases.

Single molecule protein sensing assisted by deep learning algorithms.

Super-resolution microscopy for following protein translation processes in live cells.

Development of bioensors with plasmonic amplifiers for single-molecule-level separation.

Biomolecule manipulation with micro- and nano-fluidics.

Signal processing and computerized biomedical design for point-of-care-systems.

Solid-state Nanopores and Nanochannels for single protein molecule counting

Amit Meller

Faculty of Biomedical Engineering, Technion - IIT, Israel

Abstract

SARS-CoV-2 outbreak of the coronavirus disease has underlined the acute need for extremely sensitive, accurate, fast, point-of-care mRNA quantification sensors. Here I will show how solid-state nanopores can be used to digitally count target mRNA molecules from both biological and clinical Covid-19 samples surpassing the accuracy and “gold-standard” RT-qPCR. Moving beyond nucleic acids, I will discuss our on-going efforts towards the use of *plasmonic nanopore devices* for the single protein molecules identification. While most protein sequencing/identification technologies to date involve short peptides analyses, our lab research is focused on full-length protein recognition. We computationally showed that full-length proteins analyses greatly simplify whole-proteome profiling, permitting an accurate protein calling based on chemical labelling of only three amino-acids. Towards this goal we evaluated the use of heat denaturation and the anionic surfactant sodium dodecyl sulfate (SDS) to facilitate electrokinetic nanopore sensing of full-length, unfolded, proteins. Specifically, we characterized the voltage dependence translocation dynamics of a wide molecular weight range of proteins through sub-5 nm solid-state nanopores, using a SDS concentration below the critical micelle concentration. In parallel, we developed single-molecule method for electrophoretic protein separation by mass/charge ratio in sub-wavelength, nanometric channels. Two color sensing of dually labelled proteins combined with their in-channel dynamics highly facilitates proteins identification. This method can be integrated upstream of the nanopore sensors for enhanced, high-throughput proteome profiling.

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Thursday, Jan 19, 2023

Jongyoon Han

Department of Electrical Engineering and Computer Science

Department of Biological Engineering

Massachusetts Institute of Technology, Cambridge, MA, USA

Prof. Jongyoon Han is the principal investigator of Micro/Nanofluidic BioMEMS Group in the Research Laboratory of Electronics (RLE) at MIT. He received a B.S. and a M.S. degree from the Department of Physics of Seoul National University, Seoul, Korea. Han received his PhD from the School of Applied and Engineering Physics at Cornell University. Before joining BE, Professor Han was a research scientist at Sandia National Laboratories where he studied protein microfluidic separation systems.

Research Areas

Biomechanics

Nanoscale Engineering

Omics

Systems Biology

Transport Phenomena

Honors & Awards

Principal Investigator, Singapore-MIT Alliance for Research and Technology (SMART) centre

NSF CAREER Award, 2004

VanTassel Career Development Chair in Biomedical Engineering, 2004-2007

Louis D. Smullin (1939) Prize for Teaching Excellence, 2009

Analytical Chemistry Young Innovator Award, American Chemical Society, 2009

Enhanced Transport of Molecules into Nanopores – Application to Dentistry

Jongyoon Han

Department of Electrical Engineering and Computer Science, Department of Biological Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA

Singapore-MIT Alliance for Research and Technology (SMART) Centre

CAMP IRG & AMR IRG, 1 Create Way, CREATE Tower, Singapore

Abstract

Dental enamel is the hardest tissue in the body, and once degraded, it is not regenerated. Enamel is composed of a nanoporous (2-5nm) structure. While highly desirable, the delivery of drugs and other therapeutic materials into the dental enamel tissue has been challenging due to the complexities associated with diffusion in nanopores and nanochannels. In this talk, I will show that a simple electrokinetic transport can deliver various molecules deep into the dental enamel structure, which is otherwise impossible. These results have implications for various dental clinical practices and also for other delivery problems in many human tissues.

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Thursday, Jan 19, 2023

Lim Chwee Teck

NUSS Professor, Mechanobiology Institute, National University of Singapore

Professor Lim is the inaugural NUSS chair Professor at the Department of Biomedical Engineering and Founding Principal Investigator at the Mechanobiology Institute. He is also the Director of the Institute for Health Innovation and Technology (iHealthtech) and Founding Director of the Singapore Health Technologies Consortium. Prof Lim's research interests are interdisciplinary and include human disease mechanobiology, microfluidic biomedical technologies for human disease diagnosis and precision medicine and soft wearable technologies for healthcare applications.

He has authored over 400 peer-reviewed journal papers and delivered more than 390 plenary/keynote/invited talks. He is an elected Fellow of the American Institute for Medical and Biological Engineering (AIMBE), International Academy of Medical and Biological Engineering (IAMBE), Academy of Engineering, Singapore and the Singapore National Academy of Science. He is also an elected member of the World Council of Biomechanics. He currently sits on the editorial boards of more than 20 international journals. Prof Lim has co-founded six startups which are commercializing technologies developed in his lab.

He and his team have garnered close to 100 research awards and honors including Highly Cited Researcher 2019, Winner of IDTechEx Launchpad 2017, International Precision Medicine Conference Prize 2017, ASEAN Outstanding Engineering Achievement Award and Asian Scientists 100 in 2016, Vladimir K. Zworykin Award in 2015, University's Outstanding Researcher Award and Outstanding Innovator Award in 2014, the Credit Suisse Technopreneur of the Year Award, Wall Street Journal Asian Innovation Award (Gold) in 2012, President's Technology Award in 2011 and the IES Prestigious Engineering Achievement Award in 2010 among others. His research was cited by the MIT Technology Review magazine as one of the top ten emerging technologies of 2006 that will "have a significant impact on business, medicine or culture."

Microfluidic Approaches to Isolating Micro- and Nanoscale Circulating Biomarkers for Disease Diagnosis and Monitoring

Chwee Teck Lim

Department of Biomedical Engineering, Institute for Health Innovation & Technology (iHealthtech), National University of Singapore

Abstract

Microfluidics has emerged as a powerful technology not only for biological but also clinical research and applications. For example, the ability to manipulate and analyse minute volume of fluids and samples has led to a wealth of new biological assays which can provide unique approaches for better manipulation and capture of micro- and even nanoscale circulating biomarkers such as cells, extracellular vesicles and exosomes. With these new tools, researchers are not only being led to new questions and discoveries, but also applications in disease diagnosis, monitoring and even therapy. Here, I will present several microfluidic technologies that we have developed for both biological and clinical applications relating to diseases such as cancer. These includes microfluidic chips for rare diseased cell separation, single cell isolation as well as capture of extracellular vesicles and exosomes.

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Patrick Doyle

Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA, 02142, USA

Singapore-MIT Alliance for Research and Technology Centre, 1 CREATE Way, Singapore, 138602, Singapore

The Doyle Research Group focuses on fundamental and applied topics in soft matter. Much of their research is in the realms of micro/nanofluidic technologies, nanoemulsions, DNA biophysics, biosensing, and rheology. They utilize both experimental and computational approaches in our research in order to understand fundamental issues in a wide variety of applications and often collaborate closely with industry. A burgeoning interest is the use of microfluidics to synthesize microparticles for both fundamental colloidal studies and applications, such as multiplexed sensing, pharmaceutical manufacturing, and water purification.

Education

Ph.D., Stanford University, 1997

M.S., Stanford University, 1993

B.S., University of Pennsylvania, 1992

Honors and Awards

AIChE's Alpha Chi Sigma Award for Chemical Engineering Research, 2022

Singapore Research Professorship, 2021

J-WAFS Seed Grant, 2019

Singapore Research Professorship, 2016

Michael Mohr Outstanding Faculty Award, 2013 & 2014

Probing complex DNA topologies using nanopores

Patrick S. Doyle

Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA, 02142, USA

Singapore-MIT Alliance for Research and Technology Centre, 1 CREATE Way, Singapore, 138602, Singapore

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Thursday, Jan 19, 2023

Michael S. Strano

Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139-4307

In order to improve the human condition, **the Strano Research Group** seeks to understand nanometer-scale phenomena using mathematics and chemistry and invent new technologies for health, energy, food production, and materials science.

Research Interests

Transport in nanopores, thermopower waves for energy generation, exciton engineering for solar energy, nanosensors for reaction network analysis

Education

Ph.D., University of Delaware, Newark, DE, 2002

B.S., Polytechnic University, Brooklyn, NY, 1997

Honors and Awards

AIChE's Andreas Acrivos Award for Professional Progress in Chemical Engineering, 2019

Bose Research Grant Award, 2017

Elected to the National Academy of Engineering, 2017

World's Most Influential Scientific Minds list, Thomson Reuters, 2016

Thomson Reuters Highly Cited Researcher, 2015

Understanding Extreme Fluid Confinement in Single Digit Nanopores - the Center for Enhanced Nanofluidic Transport (CENT)

Michael S. Strano

Carbon P. Dubbs Professor, MIT

Abstract

Not all nanopores are created equal. By definition, all have characteristic diameters or conduit widths between approximately 1 and 100 nm. However, the narrowest of such pores, perhaps best called Single Digit Nanopores (SDNs), defined as those with less than 10 nm diameters, have only recently been accessible experimentally for precision transport measurements. What scientists are finding for pores in this size range has been surprising, with many experiments indicating extraordinary transport rates and selectivities. These studies expose critical gaps in our understanding of nanoscale hydrodynamics, molecular sieving, fluidic structure and thermodynamics. These gaps are, in turn, an opportunity to discover and understand fundamentally new mechanisms of molecular transport at the nanometer scale that may inspire a host of new technologies, from novel membranes for separations and water purification to new gas-permeable materials and energy storage devices. To address the challenges of bridging the deficiencies of theory and experiment for fluids confined within the most extreme conduits, we have formed the Center for Enhanced Nanofluidic Transport (CENT) and over the past 4 years have brought together theorists, experimental platforms and new characterization tools. This talk will outline some of the major successes of this collaboration in understanding the thermodynamics and transport through SDN systems, as well as mark the path of our next 4 years of operation to address these questions.

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Thursday, Jan 19, 2023

Narayana Aluru

Department of Mechanical Engineering, Oden Institute for Computational Engineering and Sciences, The University of Texas at Austin, Austin, TX 78712 USA

Prof. Aluru joined the Walker Department of Mechanical Engineering at the University of Texas at Austin in August 2021. He is also a core faculty member in the Oden Institute for Computational Engineering and Sciences. He received the B.E. degree from the Birla Institute of Technology and Science (BITS), Pilani, India, in 1989, the M.S. degree from Rensselaer Polytechnic Institute, Troy, NY, in 1991, and the Ph.D. degree from Stanford University, Stanford, CA, in 1995. He was a Postdoctoral Associate at the Massachusetts Institute of Technology (MIT), Cambridge, from 1995 to 1997. He was on the faculty at the University of Illinois at Urbana-Champaign from 1998 to 2021.

Dr. Aluru’s general area of research is computational nanotechnology. His group works on the development of multiscale methods combining quantum, atomistic, mesoscale and continuum scales, and application of multiscale methods to study physics of nanofluidics, bionanotechnology, nanomaterials/nanoelectromechanical systems, and soft matter. Some of the applications his group works on include water desalination, nanopower generation, DNA sequencing, protein recognition, 2D materials-based chemical and biological sensing, CO_2 reduction, energy storage, etc.

Nanofluidic Transport in Low-D Materials: Role of Fluctuations and Quantum Effects

N. R. Aluru

Department of Mechanical Engineering, Oden Institute for Computational Engineering and Sciences, The University of Texas at Austin, Austin, TX 78712 USA

Abstract

In this talk, we will first investigate how fluctuations in a low-dimensional (Low-D) material affect nanofluidic transport. Specifically, by performing all atom molecular dynamics (MD) simulations, we investigate how the solid-fluid interfacial properties such as wetting, friction, and slip are affected by fluctuations and vibrations in the solid. We discuss the mechanisms governing physicochemical behavior of fluids at solid-fluid interfaces. We also investigate water and ion transport through fluctuating Low-D materials and discuss the coupling between fluctuations in the solid and water/ion transport.

In the second part of the talk, we discuss the importance of quantum effects in Low-D materials. By taking advantage of proton transport via quantum tunneling and defects in Low-D materials, we introduce the concept of quantum water desalination. Finally, we show that Low-D materials with catalyst centers can enable separation of water isotopes.

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Thursday, Jan 19, 2023

Mainak Majumder

Department of Mechanical Engineering, Monash University, Clayton, Australia

Prof. Majumder applies fundamentals of materials science, notably Carbon, to emerging and multidisciplinary areas of separation engineering & energy storage and in doing so, creates scientific & business opportunities. He has developed an international reputation for inventing innovative fabrication & processing methods, grounded on strong fundamentals, with impact in a wide gamut of engineering applications for e.g. membrane-based separations, supercapacitors, batteries, strain sensors, micro-/nano-fluidics and anti-corrosion coatings.

He is a nationally recognized leader in industry engagement & translational research on graphene. His track record & standing in this topical area is such that he has received ARC funding continually (LP11, LP14) and most recently, ARC Graphene Hub (IH16). His LP11 was the first ever Australian research grant establishing a deep symbiotic University-Industry relationship reliant on creating IP surrounding graphene. The impact of his research has been such that the original resource company has now demerged to form a technological start-up – Ionic Industries. While advising this new Australian SME, initially as the founding board-of-directors, he has created an 'innovation ecosystem' involving early stage corporate investment, competitive public funding, scientific discovery, patenting & licensing intellectual property, joint-venturing with end-users & commercialization, generally in the order stated. He is member of the founding board-of-directors of several graphene-related national activities. He has published > 50 articles in journals inclusive of Nature, Nature Chemistry, Nature Communications, and has received >3400 citations with an h-index of 24. He was the founding board-of-directors of Ionic Industries (>2500 share holders) which is an Australian public company engaged in commercialization of graphene-based products. He has delivered >20 invited talks in countries such as US, China, Portugal, UK, Australia & India.

Realization of the potential of *practical* Graphene Oxide membranes for molecular separations

Mainak Majumder

Department of Mechanical Engineering, Monash University, Clayton, Australia

ARC Research Hub on Advanced Manufacturing with 2D Materials (AM2D), Monash University, Australia

Abstract

Membrane-based separation technologies have many advantages over traditional separation methods such as adsorption, and distillation in terms of energy- and cost-efficiency and modular deployment of technology. In practice, these advantages can be meaningfully harnessed only if advanced membranes with properties such as high permeance, tailorable selectivity, chlorine, pH and solvent resistance, low-fouling characteristics, long-term stability under operational conditions alongside green and sustainable manufacturability are demonstrated. In the last 7-8 years, our research group has taken rapid strides to realize these properties in membranes made from graphene-oxide, including scaled-up manufacturing in roll-to-roll approaches. In this talk, I will summarize this journey reflecting on our work including some aspects of translation to industry and future directions.

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Thursday, Jan 19, 2023

Rakesh Joshi

School of Materials Science and Engineering, University of New South Wales, Sydney Australia

Rakesh Joshi is an Associate Professor at the School of Materials Science and Engineering and leading the Graphene Research Group (UNSW Team Graphene). Before joining UNSW, he was a Marie Curie International Fellow with Nobel Laureate Sir Andre Geim at the University of Manchester. A/Prof Joshi is currently leading various industry-funded research projects on the application of graphene. He has ~$2.0 million of industry funding as Principal Investigator (Lead Chief Investigator) and over $4 million as Chief Investigator (CI) on ARC projects. Rakesh Joshi has over 100 journal articles (and 4 international patents), with over 75 articles as the first/corresponding author.

Graphene oxide membranes for purification and separation

Rakesh Joshi

School of Materials Science and Engineering, University of New South Wales, Sydney Australia

Abstract

We have developed graphene oxide (GO) based membranes with proper control in structure and morphology to be used for water purification, selective gas separation and adsorption. In a collaborative project with "Sydney Water" Australia, we have successfully employed our GO membrane to remove Natural Organic Matter (NOM) from water. Our study shows that GO membranes can reject ~100% of NOM while maintaining high water flux. Furthermore, we have developed a technique that allows controlled reduction of graphene oxide to tune the interlayer spacing and make it suitable for desalination. The reduced graphene oxide (rGO) can have the potential for desalination applications owing to its appropriate interlayer spacing (0.34–0.37 nm) that enables it to block salt ions as small as Na^+ with high precision. I will also present our recent findings on the transition metal-incorporated graphene oxide (TMGO).

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Thursday, Jan 19, 2023

Luda Wang

Academy for Advanced Interdisciplinary Studies & Center for Nanochemistry, Peking University, Beijing, 100871, China.

Prof. Luda Wang is a Principle Investigator at the Academy for Advanced Interdisciplinary Studies & Center for Nanochemistry at the Peking University.

Research Interests

Flow at molecular scale

Fundamentals on gas/ion separations

Gas/Ion Sensing

Gas separations for clean energy, water desalination and purification, dialysis

Education & Training

Massachusetts Institute of Technology (MIT), Postdoctoral Associate（2014-2018）

University of Colorado at Boulder, PhD（2009-2014）

Beihang University (BUAA), Beijing, China M.S.（2006-2009）

Beihang University (BUAA) B.E. & B.S.（2002-2006）

Ionic transport through controllable angstrom- to nanometer-sized pores

Luda Wang

National Key Laboratory of Science and Technology on Micro/Nano Fabrication, School of Integrated Circuits, Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, 100871, China.

Abstract

Ion transport through angstrom/nanometer-sized pores attracts enormous interest in both scientific researches and practical applications. On the one hand, investigation of ionic transport under such confinement is essential for understanding the kinetic and thermodynamic properties of ions. On the other hand, precise control of ionic transport on the angstrom/nanometer scale is a great impetus for development in the fields of separation, sensing, iontronics, and energy conversion.

Here, we report the investigation on ionic transport through controllable nano- to angstrom-scale pores. As the precise fabrication of confined spaces is the prerequisite, we developed a scalable top-down method to fabricate nanoporous graphene membranes with sub-nanometer precision by two successive plasma treatments. By decoupling defect sites nucleation and defect growth with low-energy argon plasma and Faraday cage-assisted oxygen plasma, a narrow pore size distribution was achieved. This method exhibits broad compatibility for different separation processes with distinct pore sizes from gas separation, gas-liquid separation, ion sieving to dialysis. Besides, considering the inevitable nature of grain boundaries in CVD graphene, which are usually composed of atomic defects, we directly utilized grain boundaries to control the ionic transport. By controlling the grain boundary density, proton permeance can be tuned with a range of 2 orders of magnitude. A higher reactivity of grain boundaries and nitrogen-functionalized pores conferred 3–4 orders of magnitude higher proton conductivity and 3–4 times higher selectivity than commercial Nafion membranes after selective etching by N_2 plasma. Owing to the ultimate thickness, atomically thin nanopores have also emerged as a promising platform for sensors with single-molecule resolution. However, the low-frequency flicker noise would limit the electrical readout and signal-to-noise ratio, thus deteriorating the performance of nanopore devices. Based on this, we investigated low-frequency flicker noise in graphene nanopores and demonstrated that low-frequency flicker noise is associated with surface charge fluctuations. By adding trace amounts of multivalent cations, the amplitude of flicker noise can be controlled up to 3 orders of magnitude via reversible adsorption-desorption of ions. Our findings show great potential to study and control the ionic transport under angstrom-scale to nanoscale confinement. Further investigations will focus on mass transport at the atomic level and the realization of 2D nanopores for practical applications.

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Thursday, Jan 19, 2023

Yang Hui Ying

Engineering Product Development Pillar, Singapore University of Technology and Design

Prof. YANG's research is driven by the design and fabrication of low dimensional nanomaterials. She pushes forward the boundaries of knowledge in a wide variety of fundamental materials and structure-property relationships. Her team pioneered in chemical doping, work function engineering and defect states analysis in one dimensional and two dimensional nanomaterials for a variety of applications in high efficient optoelectronics devices, electrochemical energy storage and water purification to generate economic benefits for Singapore.

Research Areas

Material Science, Additive Manufacturing, Energy and Chemicals, Water

Selected Awards & Achievements

Nov. 2018, **IUMRS – MRS** Singapore Young Researcher Award 2018 Finalist.

Mar. 2018, **IPS Nanotechnology Medal** (Outstanding Nanotechnology Physics Research), Institute of Physics Singapore.

Feb. 2016, **SUTD Long Service Award**, Singapore University of Technology and Design.

Feb. 2015, **SUTD Research Excellence Award**, Singapore University of Technology and Design.

Oct. 2014, **Nanonica Prize 2014**, Nanonica Europe S.L., Europe.

June 2014, **Outstanding Young Manufacturing Engineer Award**, Society of Manufacturing Engineers (SME), USA.

Low-dimensional Nanomaterials for Water Treatment

Yang Hui Ying

Engineering Product Development Pillar, Singapore University of Technology and Design

Abstract

Low-dimensional nanomaterials have attracted significant research interest in the water treatment field due to their extraordinary physical and chemical properties over the past decade. In our research lab, we have developed low energy consumption devices with exceptional low-energy consumption desalination and water treatment performance. We have discussed how the design of low dimensional nanostructure-based electrode can correlate with the ion transportation efficiency, the activity of electrochemical reaction and ion selectivity. We have also studied the prospects of low energy water treatment based a series of innovative, low-energy desalination techniques derived from electrochemistry called capactive deionization (CDI). In its primary form, CDI has already made waves in terms of competitiveness against prevailing desalination technologies such as reverse osmosis. By leveraging on advanced redox nanomaterial electrodes, we have broadened the field of CDI to include applications in water treatment, softening and energy recovery. We pioneered in the cross-disciplinary development of converting battery materials for use in water desalination and treatment, achieving a revolutionary desalination battery system which can perform both functions simultaneously.

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Friday, Jan 20, 2023

Sui Zhang

Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore

Prof. Sui Zhang is an Assistant Professor at the Department of Chemical and Biomolecular Engineering, National University of Singapore. Her research focuses on membranes based on emerging materials with new transport channels/mechanisms (nanoporous graphene, layered 2D membranes, etc); patterned membranes; applications in water, gas separation, organic solvent nanofiltration.

Education

B.S.: Fudan University (2008)

PhD: National University of Singapore (2012)

Research Fellow: NUS (2015)

Postdoctoral Fellow: MIT (2017)

2D nanoporous and microporous membranes for challenging separations

Sui Zhang

Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore

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Friday, Jan 20, 2023

Jörg Vogel

Open Innovation, Aquaporin A/S

Dr. Jörg Vogel is responsible for innovation through collaboration. This includes internal as well as external R&D for advancing the Aquaporin Inside® technology. Internally, they are working with the Aquaporin Academy where they train and guide talents and the next generation of researchers. And Externally, he is engaging in multi-faceted public and privately funded research projects with academic and industrial partners.

He has more than 8 years of leadership experience in the industry up to the department level. He works with innovation and interdisciplinary challenges in coating, production, testing, and application of membranes and membrane processes in diverse teams.

Rethinking water filtration with biotechnology and how to upscale

Jörg Vogel

Open Innovation, Aquaporin A/S

Abstract

Since the discovery of thin film composite membranes by interfacial polymerization in the 1970s, highly selective water filtration membranes for RO processes are based on largely the same chemistry. Advances have been made with additives and optimized production and post-treatment processes, but RO membranes are still limited by the permeability–selectivity trade-off. Breaking this barrier requires new approaches. One of them is the incorporation of biological components to mimic water filtration in nature. Here, aquaporin proteins offer great promise as a disruptive water treatment technology, due to their potential of improving membrane permeability without compromising solute rejection. Harnessing the high selectivity and permeability of these naturally occurring water channels is challenging since they require careful material selection and upscaling with cost competitiveness in mind is a key to market introduction. Here, we present the development of the first biomimetic aquaporin-based membrane from idea to market introduction. The presented work will cover the introduction of proteoliposomes and their advancement into proteopolymersomes to stabilize the protein and to simplify and enable incorporation in membranes. In addition, we will discuss protein and biomimetic membrane upscaling into full scale production processes.

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Friday, Jan 20, 2023

Utkur Mirsaidov

Departments of Physics and Biological Sciences, National University of Singapore, Singapore

Prof. **Utkur Mirsaidov** is an Assistant Professor at the Department of Physics and Biological Sciences, National University of Singapore. His research focuses on development and application of advanced electron microscopy techniques (in situ liquid & gas phase TEM, cryo-TEM, and computational tools), physics and chemistry at interfaces, Nanoscience, energy storage materials and devices, catalysis, and soft-matter.

Education

Ph.D. Physics, The University of Texas-Austin, USA. (December 2005)

B.S. Physics, The University of Texas-Austin, USA. (May 2000)

Awards

The Nanotechnology Physics Medal, Institute of Physics-Singapore, 2016 NUS Young Scientist Award, 2016

NUS Young Investigator Award, 2014

Nanoscale elastocapillary forces

Utkur Mirsaidov

Departments of Physics and Biological Sciences, National University of Singapore, Singapore

Abstract

When the capillary force dominates over elasticity, the interplay between them gives rise to elastocapillary effects, which are responsible for the bundling of wet hair, buckling and folding of flexible high-aspect-ratio (HAR) structures, capillary rise between parallel sheets, or collapse of microstructure patterns. This effect is amplified for nanostructures, where the surface-to-volume ratio is high, and the effective structure stiffness is much less. Nanoscale elastocapillary effects can be both a nuisance and a powerful approach to fabrication. For example, it presents a big challenge in semiconductor nanofabrication, where the solution-based processes routinely used for lithography, etching, and cleaning can cause the collapse of patterned nanostructures. Here, using in situ liquid cell transmission electron microscopy (TEM), I will describe how water interacts with nanoscale features both during the wetting and drying processes. I will show that, at the nanoscale, these seemingly simple processes deviate from what we intuitively expect for bulk solutions. We will explore how nanoscale capillary forces can damage nanostructures and explore ways to mitigate this damage.

More broadly, our approach to imaging the interactions between nanostructures and various liquids is a powerful metrology platform that can help to reveal nanoscale fluid properties.

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Friday, Jan 20, 2023

Dan Zhao

Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore

Prof. Dan Zhao is a Dean's Chair Associate Professor at the Department of Chemical and Biomolecular Engineering, National University of Singapore. Dr. Zhao obtained his PhD degree in Inorganic Chemistry under the supervision of Prof. Hong-Cai Joe Zhou at Texas A&M University in 2010. After finishing his postdoctoral training at Argonne National Laboratory, he joined the Department of Chemical & Biomolecular Engineering at National University of Singapore in July 2012 as an Assistant Professor, and was promoted to Associate Professor with tenure in July 2018. He started to serve as an Associate Editor of *Industrial & Engineering Chemistry Research* in June 2021. His research interests include advanced porous materials and hybrid membranes with the applications in clean energy and environmental sustainability.

Porous Cages as Water Channels in Reverse Osmosis Membranes

Dan Zhao

Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore

Abstract

Porous cages, mainly metal-organic cages (MOCs) and porous organic cages (POCs), are discrete porous molecules with well-defined apertures and cavities. They have been widely studied in many applications, including molecular reactors, host-guest chemistry, gas sorption, substrate for hierarchical structures, etc. Unlike extended porous materials, the solubility of porous cages enables solution-based processing, facilitating their incorporation as additives into more complex systems such as membranes. In this talk, I will summarize our recent progress in studying porous cages as water channels in reverse osmosis (RO) membranes. We have identified water-stable zirconium MOCs as efficient additives to increase the water flux of RO membranes. As a proof-of-concept study, POCs were loaded into lipid bilayers and studied for their water and ion permeation. Water molecules were found to preferentially flow in single-file, branched chains within the channel networks formed by POC nanoaggregates. This configuration allows high water permeation on the same magnitude as aquaporins, as well as almost perfect cation and anion rejections.

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Friday, Jan 20, 2023

Piran Kidambi

Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, TN 37212, USA

Prof. Piran Kidambi is an **Assistant Professor of Chemical and Biomolecular Engineering,** Vanderbilt University. His research leverages the intersection between i) in-situ metrology, ii) process engineering and iii) material science to enable bottom-up novel materials design and synthesis for energy, novel membrane, electronics, catalysis, metrology and healthcare applications. The key scientific questions in his field relate to understanding mechanisms for atomistic control during nanomaterial synthesis, while the engineering challenges center around developing scalable production processes and interfacing nanomaterials into functional systems to realize applications.

Education

Ph.D., Engineering, *University of Cambridge*

M.S., Process Engineering, *Swiss Federal Institute of Technology (ETH Zurich)*

B.Tech., Chemical Engineering, *National Institute of Technology, Tiruchirappalli*

Selective Nanoscale Mass Transport through Atomically Thin 2D Membranes

Piran R. Kidambi

Department of Chemical and Biomolecular Engineering, Vanderbilt University, Nashville, TN 37212, USA

Abstract

Atomically thin 2D materials represent a fundamentally new platform to study and control mass transport at the Angstrom-scale. Here, I will discuss our recent work in bottom-up 2D material synthesis and processing to enable fully functional large-area nanoporous atomically thin membranes for desalination, dialysis, and ionic/molecular separations. I will introduce novel size-selective defect sealing approaches for functional large-area 2D membranes processing. Finally I will detail our advances in enabling highly-selective sub-atomic species transport through atomically thin membranes for energy conversion/storage applications.

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Friday, Jan 20, 2023

Marija Drndic

Department of Physics and Astronomy, University of Pennsylvania

Prof. Marija Drndic is an **Assistant Professor at the** Department of Physics and Astronomy, University of Pennsylvania. Her research and the research in her lab is focused on the exploration of mesoscopic and nanoscale structures in the areas of experimental condensed matter physics, nanoscience and nanotechnology. We study the fundamental physical properties of low-dimensional and small-scale structures such as nanocrystals, nanowires and biomaterials and we develop their device applications. Examples include the study and control of nanocrystal assembly, fabrication of electronic devices and understanding the basic mechanisms of charge and spin transport in them: the effects of Coulomb interactions, electron tunneling and charge fluctuations. Experimental techniques involve electrical measurements, microscopy, and nanofabrication. Some specific research topics include: Nanocrystal synthesis, assembly and manipulation Nanoparticle-based electronics Fluorescence of single nanoparticles and nanoparticle ensembles Molecular analysis with nanoelectrode devices Force microscopy of nanoparticles Nanofabrication (nanogaps, TEBAL) Charge detection with mesoscopic structures Graphene nanodevices and nanoelectronics Single-molecule (DNA, microRNA etc.) detection and analysis with nanopores

Education

Ph.D. Physics, Harvard University (2000)

A.M. Physics, Harvard University (1997)

M.Phil. Physics, University of Cambridge (1995)

Sculpting of 2D Materials: From Pores and Nanoporous Membranes

Marija Drndic

Department of Physics and Astronomy, University of Pennsylvania

Abstract

Introducing atomic-scale holes in 2D materials changes their electrical and optical properties. When 2D materials are suspended, vacancies make the membranes permeable to ions and molecules in liquid or gas phases, allowing transport studies at atomic scales. Angstrom-size holes allow the passage of water molecules but block the larger hydrated salt ions and can effectively desalinate water. Raman peak shifts combined with TEM, provide a comprehensive approach to characterize the holes and transport through them. When molecules are driven through 2D nanopores in solution, they can perturb the ion current flow through the pore, from which molecule's physical and chemical properties can be inferred. DNA other biomolecules can be detected in this way. Thanks to advanced materials, device designs and custom electronics, the temporal and spatial resolution for their detection has been rapidly improving.

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Friday, Jan 20, 2023

Sanjin Marion

imec, Kapeldreef 75, 3001 Leuven / Belgium

Sanjin Marion received his Ph.D. from the University of Zagreb/Sveuciliste u Zagrebu in 2017. He works at imec, where his scientific research in the domain of nanotechnology focusing on nanofluidics (nanopores) and single molecule biophysics. He is Passionate about research and leading people. Driven and proactive. Trying to make a difference. Actively working on personal development.

Nanofluidics with ultrathin nanopores

Sanjin Marion

imec

Kapeldreef 75, 3001 Leuven / Belgium

Abstract

Nanopores in solid state membranes are a tool able to probe nanofluidic phenomena or can act as a single molecular sensor. They also have diverse applications in filtration, desalination, or osmotic power generation. Many of these applications involve chemical, or hydrostatic pressure differences which act on both the supporting membrane and analyte, and can influence the ion transport through the pore. Although all of these diverse applications are done in an aqueous environment, little is known about fluid flow and its coupling with ion transport properties.

I will demonstrate an approach using hydraulic pressure coupled with alternating current which is used to probe small differences in ion transport characteristics of ultrathin nanopores. Through hydraulic pressure differences between the sides of the membrane we are able to induce two separate phenomena. First, due to a low hydraulic resistance at the mouth of the ultrathin pore, advective ion transport dominates diffusive, causing nonlinear coupling of ion transport with the applied pressure. This coupling can be leveraged to increase nanopore properties like ion selectivity, and can produce strong pressure dependent effects even without external driving forces. Secondly, we demonstrate that blistering of the membrane under pressure induces enlargement of the pore diameter, and is a direct measure of the strain at the pore. This allows controlled application of in-situ strain on nanopores in 2D materials like MoS_2 or hBN, opening up pathways for probing ionic hydration layers and artificial mechanosensitive sensors.

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Friday, Jan 20, 2023

Aleksandr Noy

Materials Science Division, Physical and Life Sciences Directorate, Lawrence Livermore National Laboratory, Livermore, CA, USA

School of Natural Sciences, University of California Merced, Merced, CA, USA

Prof. Aleksandr Noy received his Ph.D. from Harvard University in 1997. He is interested in understanding the dynamics of complex transport processes at the interface of nanomaterials and biological systems and using these properties to create novel, and useful functionality. Nanomaterials, which replicate some of the geometry and transport properties of biological building blocks represent a truly enabling capability in this area, and provide an unprecedented opportunity to control transport and signal transduction within functional bioelectronic interfaces. His research group builds these interfaces and studies the fundamental physical phenomena that enable transport, energy conversion, and signal transduction in nanobiomaterials. They currently are focussing on nanofluidic phenomena in carbon nanotube pores and poirins, building multifunctional bioelectyronic interfaces based ion silicon nanowire FET devices, and on exploring real-time dynamics of biomolecular assemblies on nanotermpates using high-speed atomic force microscopy.

Nanofluidics in sub-1-nm carbon nanotube porins

Aleksandr Noy

Materials Science Division, Physical and Life Sciences Directorate, Lawrence Livermore National Laboratory, Livermore, CA, USA

School of Natural Sciences, University of California Merced, Merced, CA, USA

Abstract

Nanofluidic transport regime, where ions and molecules move through highly-confined conduits with molecular-scale dimensions, is important for applications ranging from precision separations to industrial water treatment. Living systems move ions and small molecules across biological membranes using protein pores and often rely on nanoscale confinement effects to achieve efficient and exquisitely selective transport. I will show that carbon nanotube porins—pore channels formed by ultra-short carbon nanotubes assembled in a lipid membrane—can exploit similar physical principles to transport water, protons, and ions with efficiency that rivals and sometimes exceeds that of biological channels (*1-3*). I will discuss how molecular confinement, slip flow, and the nature of the pore walls influence ion diffusion, ion selectivity, electrophoretic transport and electroosmotic coupling in these nanopores. Overall, carbon nanotube porins represent simple, versatile, and highly controlled nanofluidics model system that provides an ideal test bed for studying nanofluidic phenomena and develping the next generation of separation technologies.

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Friday, Jan 20, 2023

Viatcheslav Freger

Wolfson Department of Chemical Engineering, Technion – Israel Institute of Technology, Haifa 32000, ISRAEL

Prof. Viatcheslav Freger is a professor at the *Wolfson Department of Chemical Engineering, Technion – Israel Institute of Technology.* He received his Ph.D. from Ben-Gurion University of The Negev in 1999. His research focuses on membrane technology, desalination and water purification, physical modeling and advanced characterization of membranes, novel and modified membranes for environmental and energy applications Interaction of bacteria with surfaces: deposition and biofouling Fuel Cell Membranes.

Research Topics

Transport of ions and molecules in membranes

Modification of commercial membranes for improved performance

Development of novel types of composite membrane

Membranes for fuel cells

Interaction of bacteria with surfaces: bacterial deposition and fouling-resistant surfaces

Ions in sub-nm carbon nanotubes: charging, transfer and pairing

Viatcheslav Freger

Wolfson Department of Chemical Engineering, Technion – Israel Institute of Technology, Haifa 32000, ISRAEL

Abstract

Narrow sub-nm carbon nanotubes (CNTs) are unique mimics of water channels in biological membranes, yet the physics behind their selectivity is still debated. On the experimental side, measurements of ion diffusion by stop-flow experiments in vesicles and of ion migration by single-pore conduction has shed much light on ion transport. These experiments points to differences in the behaviour of different ions as well as surprising discrepancies in ion mobilities deduced for different experiments and other unusual features such as pH-dependent scaling of conductivity and rectification in pH gradient, pointing to strong involvement of OH- ions in CNT charging, ion selectivity and conductance. Molecular dynamics and approximate ab initio simulations have been main tools to rationalize these data, however, their accuracy and assumptions used may still require validation and consider alternative scenarios as well. In the present research, we employ ab initio simulations to compute thermodynamic parameters of transfer of individual ions and ion pairs from solution to the interior of finite-size CNTs surrounded with a dielectric continuum. This identifies the polarization energy of an ion as an important contribution commensurate with intra-CNT (de)hydration and specific ion-CNT interaction. This analysis finds transfer of individual ions prohibitively costly and also unable to explain the high affinity of CNTs to OH-. However, the simultaneous transport of cations and anions, either as a coupled transfer of individual ions and or via formation of ion pairs, strongly promoted by the large polarization energy and ion-CNT interactions, may well explain trends observed for ion selectivities and rationalize most experimental data obtained so far.

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Friday, Jan 20, 2023

Slaven Garaj

Department of Physics and Dept. of Biomedical Engineering, National University of Singapore, Singapore

Prof. Slaven Garaj is a Principal Investigator at the Department of Physics and Dept. of Biomedical Engineering, National University of Singapore. He received his Ph.D. from Swiss Federal Institute of Technology in Lausanne, EPFL in 2003. He and his group explore on curious nanoscale phenomena at the interfaces between soft and hard matter, with particular interest in nanopore sensors, nanofluidics and nanoelectronics.

While pursuing in-depth scientific understanding, their research group drives the development of technologies in the fields of medical diagnostics, water filtration and energy harvesting. Those include:

Single-molecule DNA sequencing using nanopores
DNA data storage
Rapid detection of contaminants in cell therapy manufacturing
Nanofluidics and programmable materials
Novel membranes for filtration and blue energy harvesting
Advanced method for water purification

Their translational research resulted in 10 patents (granted or pending), out of which 5 patents are licensed by a major biotech company. Upon extensive research in electrochemical water treatment, their laboratory spun-off a cleantech company ReActo, focused on removing persistent contaminants from water.

Ionic transport through 2d nanochannels and nanopores

Slaven Garaj

Department of Physics and Dept. of Biomedical Engineering, National University of Singapore, Singapore

The molecular transport phenomena within nanometer-scales constrictions is important for understand basic biological and physical processes, as well as for the rational design of materials for energy and water technologies. 2D materials offer a good model system, with atomically smooth interfaces, sub-nanometer control of geometry, and fine control of surface charges and functionalization.

In this presentation, I will discuss the transport of water and ions across atomically smooth 2D nanochannels and laminar graphene-based membranes. Employing a novel micro-pervaporation chamber, we could measure nanoscale transport of liquids and mixtures – through individual nanopores of 10 – 100 nm in diameter, and 1 – 50 nm high nanochannels – at variable temperature, and we could detect differential fluxes of each component. Comparing different 2D materials, and different liquids and binary mixtures, we could discern the effects of geometry vs. materials properties, and deduce the contribution of surface mediated transports. Highly enhanced flux of water is strongly affected by inclusion of different type of alcohol molecules, leading to either alcohol-water correlations, or alcohol-induced anchoring of water molecules.

Furthermore, we have explored how details of the chemistry of graphene oxide (GO) affect the ion exchange performance of the membranes, by exploring 32 difference commercial GO sources and ~500 different chemical and morphological modifications from our laboratory. The performance of the membranes could be significantly affected, by an order of magnitude, with miniscule changes in membrane chemistry, nanostructure and microstructure.

All those nanoscopic insights allowed us to develop the scaled-up membranes with superior molecular separation properties, and ion exchange membranes with performance matrix that is competitive against that of the currently available champions in the marker.

Panel discussions

Panelists

- Beth Henderson, Startupbootcamp
- Neil Hu, Veolia/Suez
- Rohit Karnik, MIT (moderator)
- David Menzies, NematiQ
- Konstantin Novoselov, NUS
- Gurdev Singh, PUB

Panel discussion overview

- New paradigm membranes are emerging membranes that make use of unconventional materials that are different from already-commercialized and well-established membrane material types such as polymers and ceramics. Examples include artificial water channels, 2D materials, and nanotubes.
- Goals of the panel discussion:
  - Place the research and development of new paradigm membranes (including that presented at the conference) in a broader context
  - Outline emerging and unmet needs in water, industrial separations, energy, and other areas relevant to membranes, and discuss where new paradigm membranes may be advantageous
  - Envision the future trajectory of new paradigm membranes, including R&D focus areas, scale-up and commercialization, opportunities, and challenges
  - Provide government and business perspectives and roles in the journey of 'tough' disruptive technologies from discovery to commercialization
  - Place 2D material membranes in the broader context of 2D materials, their history, and their future

Panelist Bio

“Science / new materials perspective”

K. Novoselov,
NUS

Prof. Sir Konstantin ‘Kostya’ Novoselov FRS is best known for isolating graphene at The University of Manchester in 2004, and is an expert in condensed matter physics, mesoscopic physics and nanotechnology. Every year since 2014 Kostya Novoselov is included in the list of the most highly cited researchers in the world. He was awarded the Nobel Prize for Physics in 2010 for his achievements with graphene.

“Startup perspective”

David Menzies
Nematiq

Dr. David Menzies is CEO of NematiQ, an Australian company that brought to the marked a highly-scalable graphene nanofiltration membrane technology for producing pure and affordable water. He is advanced materials engineer with more than 10 years of company experience, leading marketing and financial operations and strategic planning. Through his career, Dr Menzies has held various positions in Outerspace Design as Business Development and Commercialisation Manager, Securency International as Strategic Marketing Manager, and Founder and Managing Director of Platinum Road, a boutique corporate advisory business.

“VC / accelerator perspective”

Beth Henderson
Startupbootcamp

Beth Henderson has been working with startups since 2015 spanning roles in corporate innovation, product management, startup accelerators and as a startup founder herself. She currently leads Startupbootcamp's Singapore office, running several programmes to accelerate local climate-tech startups and facilitate corporate collaborations. She is the Programme Director for the Shell StartUp Engine Singapore chapter, which supports startups developing solutions that help the world move to cleaner, greener, and more efficient forms of energy across all domains of the energy transition. Beth is a sustainability enthusiast, with a Bachelor of Environmental Politics and Culture from the University of Melbourne.

"Governmental agency perspective"


Gurdev Singh
PUB

Dr. Gurdev Singh, is Senior Deputy Director (Technology) at PUB, Singapore's National Water Agency. He received his PhD from NUS's School of Civil Engineering and was a Research Fellow at the NUS Nanoscience and Nanotechnology Initiative (NUSNNI). Prior to joining PUB in 2016, he spent a decade working at a government funded Environmental & Water Technology Centre of Innovation providing technical consultancy to Start-Ups and Private Companies in the development of new technologies.

"Big business perspective"


Neil Hu
Veolia

Neil Hu is the Senior Product Manager at Veolia, focused on their ZeeLung membranes. He has 20+ years of industry experience ranging from hands-on commissioning, process design and commercial sales. He holds a Bachelor of Applied Science in Environmental Engineering from the University of Waterloo in Canada.

Poster presentations

Poster Code	Surname	First name	Insitution	Title / topic
P1	Wang	Qian	National University of Singapore	Heterostructures of water transport nanochannels and 2D nanolayers for ultra-sensitive climate-controlled intelligent housing
P2	Han	YiXuan	National University of Singapore	STM/AFM characterization from void to 1D channel in black phosphorus
P3	Wen	Xinyue	U New South Wales	Understanding water transport through graphene-based nanochannels via experimental control of slip length
P4	Li	Kun	National University of Singapore	Metrology of Individual Small Viruses
P5	Feng	Fan	National University of Singapore	Molecularly mixed nanocomposite membranes from synergistic blend of commercial polymer and organic macrocyclic cavitands for efficient pre combustion CO 2 capture
P6	Agrawal	Ishita	National University of Singapore	DNA Dynamics and Interactions Probed by Nanopore
P7	Yooprasertchuti	Kittipitch	National University of Singapore	Mechanically Tunable Ionic Conductivity in Thick Graphite Nanopore
P8	Jia	Yuewen	National University of Singapore	Electropolymerized microporous polymer membranes for organic solvent nanofiltration (OSN) and CO2 capture
P9	Mukherjee	Bristy	National University of Singapore	Structural Evolution of Graphene Oxide Probed by Isotopic Labelling Refuting Oxygen Migration Effect
P10	Srinivasan	Ganesh	National University of Singapore	Breaking Through The Trade-off in Graphene-based Laminar Ion Exchange membranes
P11	Lu	Yanqiu	National University of Singapore	Monolayer graphene membrane for high-temperature organic solvent nanofiltration
P12	Spina	Massimo	National University of Singapore	Transport in Individual Graphene Oxide Nanochannels
P13	Li	Yixiang	Singapore University of Technology and Design	Graphene based material for seawater boron removal