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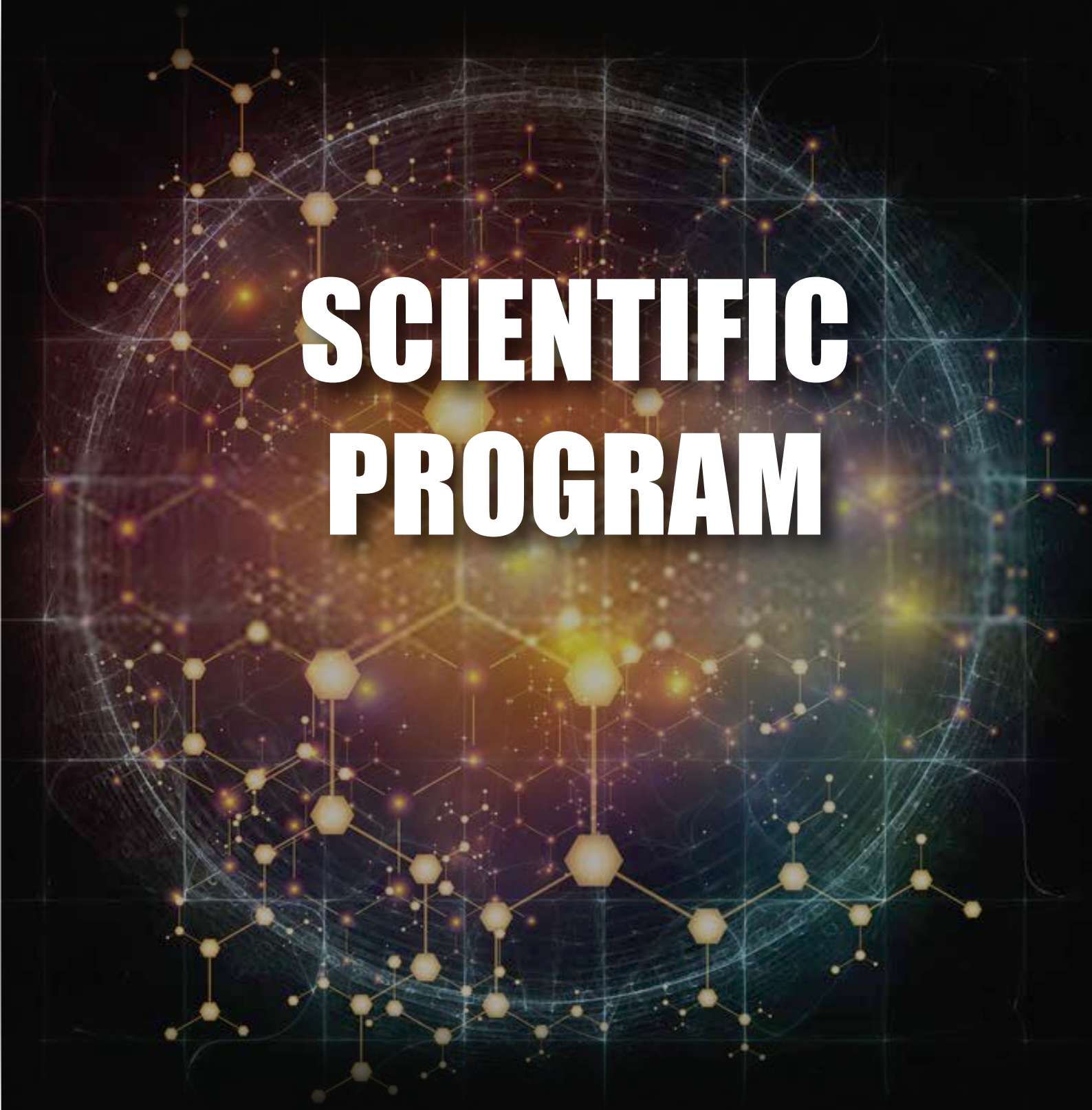

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Date: 23 January 2021

PS. The meeting time zone is Central European Time (CET).

Session 3

Science, Engineering and Technology

Moderator

Dr. Sheena Singh from Vebelo

- **14.00 - 14.40**: Plenary Talk; **Prof. Maria Vallet-Regi**, Universidad Complutense de Madrid, Spain

Talk Title: *Mesoporous silica nanoparticle: From tissue regeneration to a good nanocarrier*

- **14.40 - 15.10**: Keynote Talk; **Prof. Mohsen Adeli**, Freie Universität Berlin, Germany

Talk Title: *Two-dimensional polyols: Functional platforms for biomedical applications*

- **15.10 - 15.40**: Keynote Talk; **Prof. Liyuan Deng**, Norwegian University of Science and Technology, Norway

Talk Title: *Nanomaterials enhanced membranes for CO_2 capture: Journey from lab to pre-pilot in-field testing*

- **15.40 - 16.10**: Keynote Talk; **Prof. Mingxu You**, UMass Amherst, United States

Talk Title: *Imaging cell signaling and intercellular forces with nucleic acids*

- **16.10 - 16.40**: Keynote Talk; **Prof. Martin Ostoja-Starzewski**, University of Illinois at Urbana-Champaign, United States

Talk Title: *Violations of the entropy production inequality in molecular fluids and granular media*

- **16.40 - 17.10**: Keynote Talk; **Prof. Mark Schulz**, University of Cincinnati, United States

Talk Title: *Carbon hybrid materials - by design*

- **17.10 - 17.50**: Plenary Talk; **Prof. Zhifeng Ren**, University of Houston, United States

Talk Title: *How can physicist help to contain the spread of COVID-19 pandemic?*

- **17.50 - 18.10**: Invited Talk; **Prof. Eggehard Holler**, Cedars-Sinai Medical Center, United States

Talk Title: *Linear structured nano platform for vectorized delivery through cascades of bio barriers*

- **18.10 - 18.40**: Keynote Talk; **Prof. Mercouri Kanat**, Northwestern University, United States

Talk Title: *High performance when you least expect it: How halide perovskites are transforming photovoltaics*

- **18.40 - 19.10**: Keynote Talk; **Prof. Euan McLeod**, University of Arizona, United States

Talk Title: *Optical positioning and linking for 3D nanofabrication*

Webinar on
Science, Engineering and Technology

Mesoporous silica nanoparticle: From tissue regeneration to a good nanocarrier

María Vallet-Regí

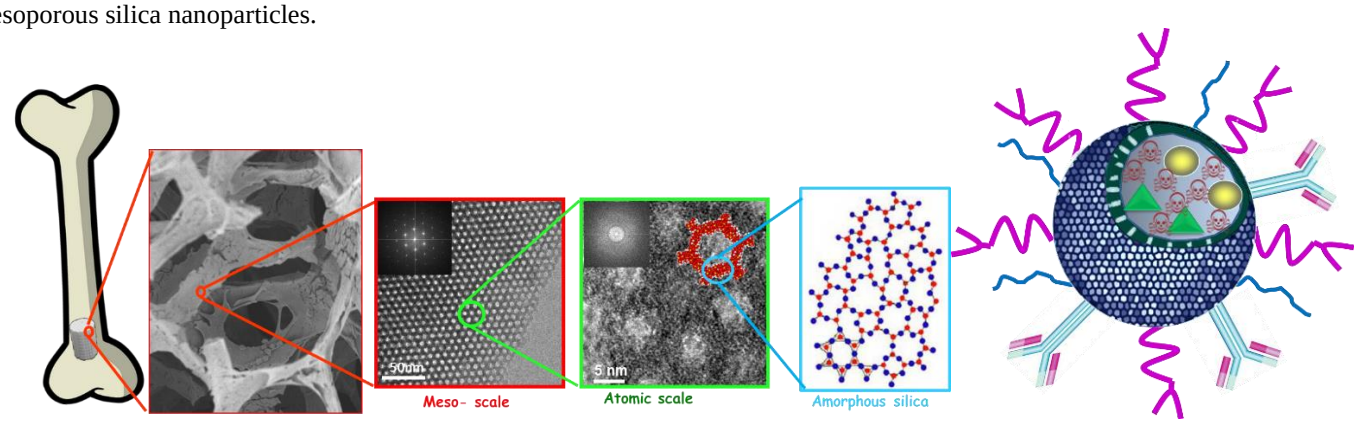
Department of Chemistry in Pharmaceutical Sciences, School of Pharmacy, Universidad Complutense de Madrid, Instituto de Investigación Sanitaria Hospital 12 de Octubre i+12, Plaza Ramón y Cajal s/n, Madrid, 28040 Spain. Networking Research Center on Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Madrid, Spain

Biography

Professor María Vallet-Regí is a Spanish chemist, scientist and Professor at Universidad Complutense de Madrid, Spain. She is recognized as a pioneer in the field of ceramic materials applied to medicine. She was the pioneer who suggested introducing drugs into the pores of mesoporous silica materials, which inspired thousands of publications worldwide involving mesoporous silica nanoparticles for drug delivery. She is a Highly Cited Researcher 2018 (Clarivate Analytics). Her publications have been cited over 46.000 times and her h-index is 101. Prof. Vallet-Regí has been awarded many important International prizes. She has recently obtained an ERC Advanced Grant entitled “Polyvalent mesoporous nanosystem for bone diseases.

Graphical Abstract

Different scales of mesoporous silica materials and schematic layout of potential modifications to its inner and outer surfaces of mesoporous silica nanoparticles.



Abstract

Research on bioceramics has evolved from the use of inert materials for mere substitution of living tissues towards the development of third generation bioceramics aimed at inducing bone tissue regeneration. Mesoporous silica nanoparticles have already proven to be adequate nanocarriers for various chemical and biological species. For instance, they are valuable tools when carrying antitumor agents selectively to a tumor tissue, and releasing them there thanks to the application of an external stimulus. We use the term smart because those nanocarriers are able to release the drugs when and where they are needed. The surface of our nanosystems can be decorated with molecules able to recognize specifically tumor cells and to trigger the penetration of nanocarriers into them. The main advantage of developing selective nanocarriers able to accumulate only in tumor tissues are: increased selectivity of the therapy, which allows reducing the cytotoxic dosage; higher control over the administered doses; and the reduction of side effects, because the drugs will not be distributed throughout the whole body. Taking into account that most anticancer drugs are cytotoxic, their release must take place only inside tumor cells.

Keywords: Tissue regeneration; Nanocarriers; Bone infections; Osteoporosis; Antitumor agents.

Acknowledgements: European Research Council, ERC-2015-AdG (VERDI), Proposal No. 694160.

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Nanomaterials enhanced membranes for CO_2 capture: Journey from lab to pre-pilot in-field testing

Saravanan Janakiram[1], Fabio Santinelli[2], Riccardo Costi[2], Arne Lindbråthen[1], Juan Luis Martín Espejo[1], Zhongde Dai[1], Luca Ansaloni[3], Liyuan Deng[1,*]

[1]*Department of Chemical Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

[2]*Colacem S.p.A., Gubbio, Italy*

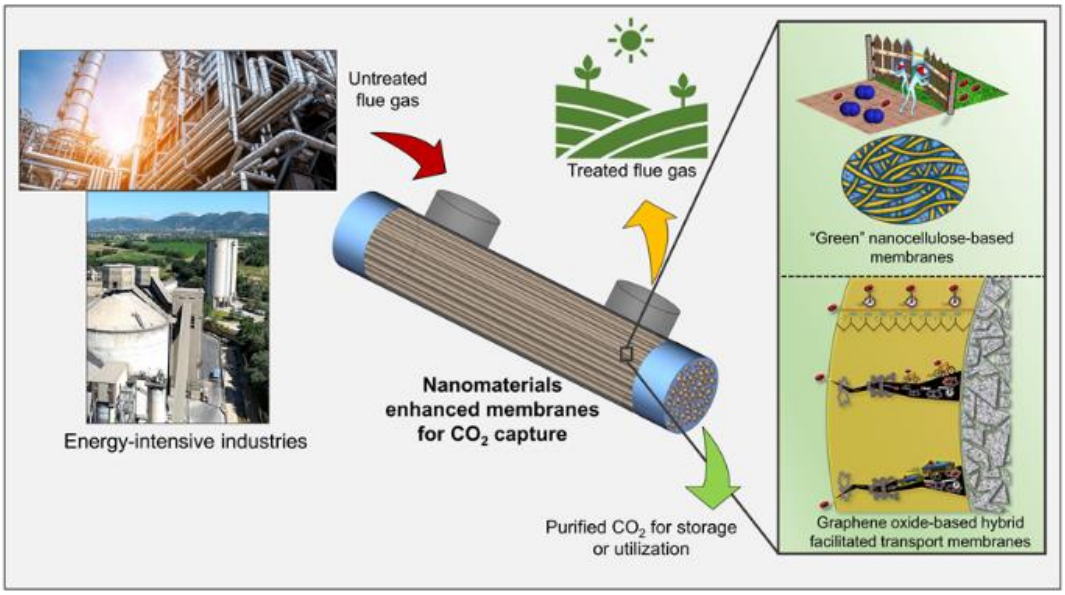
[3]*Department of Sustainable Energy Technology, SINTEF Industry, Oslo, Norway*

Biography

Dr. Liyuan Deng is a Professor of Chemical Engineering at the Norwegian University of Science and Technology (NTNU). She received her Ph.D. degree in Chemical Engineering from NTNU in 2009 and then pursued post-doctoral research in the Membrane Research group (Memfo). Liyuan accepted a faculty position at NTNU in 2011 and started to head the Memfo group in 2015. The Memfo group has extensive research activities on basic membrane material development, membrane contactors, membrane gas separation processes, and allied modelling and simulations. One major focus of the group is CO_2 separation membranes for various applications, including CO_2 capture from flue gas, biogas upgrading, natural gas sweetening, and hydrogen recovery.

Professor Deng has more than 20 years' research experience in membrane materials and processes, and in particular, in facilitated transport membranes. Her primary research interests relate to clean energy and carbon capture, utilization, and storage (CCUS). She has been leading many national research projects on developing various CO_2 separation membranes and membrane processes for subsea natural gas treatment. She has also been involved in several EU-projects for new CO_2 capture technologies, either as the primary investigator or WP leader. By now, she has supervised 12 Ph.D. students (10 graduated) and 6 postdocs or researchers in connection with the research projects, and more than 40 master students. She has also published ~ 80 scientific journal papers and has an h-index of 21 (Web of Science, Scopus), given or contributed to > 100 scientific presentations at international conferences and workshops, and filed around 10 patents.

Graphical Abstract



Abstract

Implementation of membrane-based technology for efficient CO_2 capture to mitigate climate change relies on developing thin-film composite (TFC) membranes with superior separation performance under real industrial conditions.

In this work, a hybrid facilitate transport membrane (HFTM) is developed and validated in the industrial environment. Graphene oxide (GO), due to its 2D morphology, intrinsic strength and chemical compatibility, has been selected and specifically tailored

for physical and chemical properties suitable as nanofillers and developed into hybrid membranes. Analyses of size and chemistry, followed by optimization of these nanofillers in optimized polymeric matrices containing facilitated transport carriers, were carried out by evaluating the performance of the fabricated hybrid membranes consisting of different polymer matrices.

Subsequently, a series of thin-film composite membranes were prepared as flat sheet membrane modules and further extended to hollow fiber modules, with areas ranging from 10 to 16 cm^2. The membrane modules were evaluated for CO_2/N_2 separation. The performances of the lab-scale hollow fibers membranes peaked at CO_2 permeance of 800 GPU with CO_2/N_2 separation factors of 30. Further, three optimized hybrid membrane materials were chosen and scaled up to pre-pilot modules with the membrane areas ranging from 150 to 2000 cm^2.

The up-scaled modules were tested using a slipstream of flue gas emission stack at COLACEM, a cement plant located in Gubbio, Italy. All pre-pilot modules exhibited performances similar or even better than lab-scale tests, most likely owing to a more reliable water profile of the in-field feed stream across the module, which is a critical factor for achieving good performances in facilitated transport membranes. Transmembrane fluxes of about 870 - 970 NL m^{-2} h^{-1} were obtained with a CO_2 purity of all the modules enriched from 10% at the feed stream to 50-55% at the permeate side through a single-stage module. The membrane stability has also been studied using un-treated flue gas for two weeks, showing no significant performance drops.

Furthermore, the membranes with mobile carriers were exposed to the feed gas containing SOx and NOx and exhibited good resistance to performance deterioration despite high concentrations of acidic impurities. Simulation studies based on validated experimental performance under industrial conditions reveal the high potential of the fabricated membranes as an efficient separation unit capable of achieving industrial capture rate and CO_2 purity requirements at a relatively low cost.

Keywords: CO_2 capture; hybrid membrane; graphene oxide; facilitated transport; in-field testing.

Acknowledgements: The financial support by the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement n° 727734 (NANOMEMC2 project) and by the Research Council of Norway under No. 294533 (FaT H2 project) are acknowledged.

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Linear structured nano platform for vectorized delivery through cascades of bio barriers

Eggehard Holler [1], Liron L. Israel[1], Julia Y. Ljubimova[1], Keith L. Black[2]

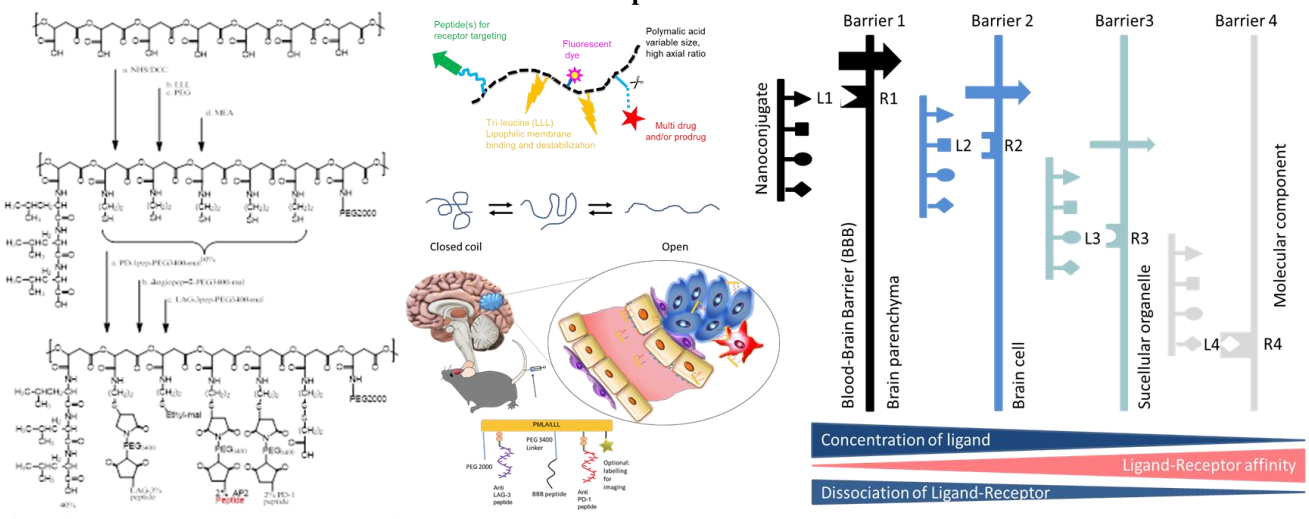
[1]*Nanomedicine Research Center, Department of Neurosurgery, Cedars-Sinai Medical Center, Los Angeles, 90048, California, USA*
[2]*Department of Neurosurgery, Cedars-Sinai Medical Center, Los Angeles, 90048, California, USA*

Biography

Eggehard Holler, Prof. PhD. Director of Chemical Syntheses and Professor of Neurosurgery at Cedars. Ph.D. in Organic/Biochhemistry/Physical Chemistry active in biochemical, biophysical and pharmaceutical (animal) projects for more than 40 years, teaching at the University at Regensburg/Germany and after 2008 at Cedars-Sinai Medical Center. PI of numerous research groups, conducted over 20 PhD- and 30 Chemistry/Biology Diploma-dissertations and examinations. He published more than 180 peer reviewed contributions in renowned journals. He discovered polymalic acid in the myxomycete *Physarum polycephalum* and successfully applied the poly anionic polyester as platform for targeted drug delivery to treat brain and breast cancer in mouse models. He was rewarded in Stockholm 2017 for pioneering work in nano drug delivery.

Publications: (1) Lee BS, Fujita M, Khazenon NM, Wawrowsky KA, Wachsmann-Hogiu S, Farkas Dl, Black KL, Ljubimova JY, Holler E. Polycefin, new prototype of multifunctional nanoconjugate based on poly(β-L-malic acid) for drug delivery. *Bioconjug Chem*, 2006;17:317-326. PMCID: PMC3487710. (2) Ding H, Inoue S, Ljubimov AV, Patil R, Portilla-Arias J, Hu J, Konda B, Wawrowsky KA, Fujita M, Karabalin N, Sasaki T, Black KL, Holler E, Ljubimova JY. Inhibition of brain tumor growth by intravenous poly (β-L-malic) acid nanobioconjugate with pH-dependent drug release. *Proc Natl Acad Sci USA*, 2010;107:18143-18148. PMCID: PMC2964197. (3) Israel LL, Braubach O, Galstyan A, Chiechi A, Shatalova ES, Grodzinski Z, Ding H, Black KL, Ljubimova JY, Holler E. A combination of tri-leucine and Angiopep-2 drives a poly-anionic polymalic acid nanodrug platform across the blood brain barrier. ACS Nano, 2019;13:1253-1271. PMID: 30633492. (4) Galstyan A, Markman JL, Shatalova ES, et al. Blood-brain barrier permeable nano immunoconjugates induce local immune responses for glioma therapy. Nature Communications 10, 3850 (2019).

Graphical Abstract



Linear polymalic acid (PMLA)-conjugate of vectors, drugs, fluorescent dye (left), dynamic opening and coiling (upper middle), injection into mouse (lower middle), penetration through barriers, driven by increasing vector-receptor affinities (right).

Abstract

Nanomedicine could be more effective if targeting vectors and carrier design accepts that (a) carriers and (b) targeting are suboptimal: Encapsulating micelles, liposomes, solid particles, and other entities often in combination with antibodies are inappropriately large for deep tissue penetration and offering surfaces unable to intimately cover receptor carrying biological surfaces. High affinity antigen-antibody binding often counteracts speedy deliver and together with repulsions between equal electric charges, or hydrophiles preventing the snug annealing of lipophilic binding partners.

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Webinar on
Science, Engineering and Technology

Two-dimensional polyols: Functional platforms for biomedical applications

Ehsan Mohamadifar[1], Vahid Ahmadi[1], Rainer Haag[1], Mohsen Adeli[1,2]

1) Institut für Chemie und Biochemie, Freie Universität Berlin, Germany
2) Department of Chemistry, Faculty of Science, Lorestan University, Khorramabad, Iran

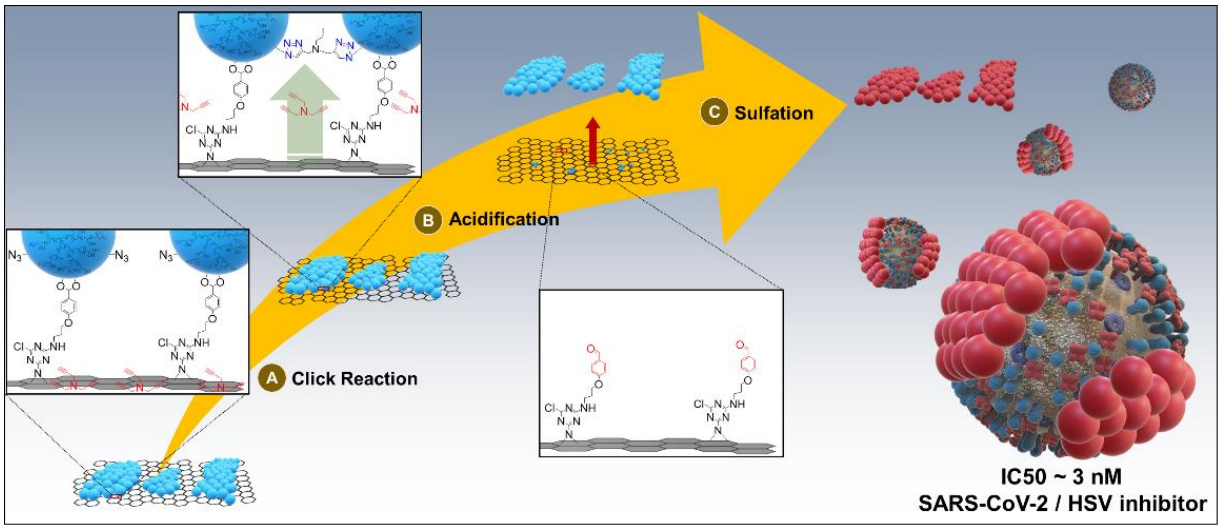
Biography

Mohsen Adeli, Full professor at Lorestan University and guest professor at Freie Universität Berlin (Since 2014). google scholar: h-index 33.

My research interests address several innovative subjects in Macromolecular Chemistry including functional biocompatible two-dimensional nanomaterials along with their interactions at biointerfaces. More specifically, my research focuses on the synthesis and applications of polyfunctional dendritic and two-dimensional nanomaterials consisting citric acid, glycerol and cyclodextrins as well as controlled covalent functinalization of graphene, MoS2, black phosphorus and carbon nanotubes by biomaterials. The fundamental studies of the supramolecular two-dimensional polymerizations as well as biomedical applications of the synthesized nanomaterials including drug delivery, photothermal therapy, pathogen interactions, and diabetic wound healing are among my interests.

Esteem factors
130 publication in international scientific journals and 20 patents, 2705 citations, h-index: 29 (Source, Scopus, 17.05.2020).
Top 10 scientists in Nanoscience and Nanotechnology 2019 (Iran Nanotechnology Innovation Council)
Top 7 scientists in Iran in 2019 (Iran Science Elites Federation)
Top 50 scientists in Iran in 2018 (Iran Science Elites Federation)
Top 50 scientists in Iran in 2017 (Iran Science Elites Federation)
Top 50 scientists in Iran in 2016 (Iran Science Elites Federation)
Award from Lorestan University for the selected best researcher (2017, 2018, 2019)
Award from Iranian Nanotechnology Initiative Council for the most developed professors (2013)
Razi Festival award from Ministry of Health and Medical Education, Iran (2012)
Award from Iran's National Elites Foundation (2012)
Award for young assistant professors from Iran's National Elites Foundation (2010)
Award for selected young scientist by Young National Organization of Iran (2006)
Award from Iranian Nanotechnology Initiative Council for PhD thesis (2005)
Second best, PhD student in Iran in the polymer and macromolecules field in 2005 (Iranian polymer Society)
Selected best MS student in Tabriz University (2000)
Selected best BS student in Lorestan University (1998)

Webinar on
Science, Engineering and Technology
Graphical Abstract



Abstract

Two-dimensional nanostructures (2DNs) have been in the forefront of cutting-edge interdisciplinary research fields, since exploring graphene at 2004 [1]. They have shown great potential for a wide range of biomedical applications including drug delivery, virus interactions and tissue engineering [2]. Currently, different methods have been used to produce 2DNs. These methods could be classified in "top-down" strategies including the physical, mechanical and chemical exfoliation of 3D layered structures and "bottom-up" approaches such as chemical vapor deposition and wet-chemistry protocols [3]. Template assisted synthesis of 2DNs is an interesting method which includes crosslinking monomers on a suitable substrate. Although this approach has been used abundantly, it suffers from complicated separation and transferring the synthesized 2DNs from the templates [4]. We are interest in the synthesis of two-dimensional biocompatible polyols using different templates. In one of our current researches, we have synthesized two-dimensional polyglycerols using graphene template. The obtained two-dimensional networks were further sulphated and heparin mimic matrixes for interactions with viruses were obtained. It was found that sulphated sheets are able to interact with viruses strongly and inhibit the infection significantly. Taking advantage of their strong virus interactions and biocompatibility, the synthesized two-dimensional networks can be used for in vivo virus inhibition.

Keywords: Two-dimensional nanomaterials, Template assisted, Two-dimensional polymers, Antivirus.

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Violations of the entropy production inequality in molecular fluids and granular media

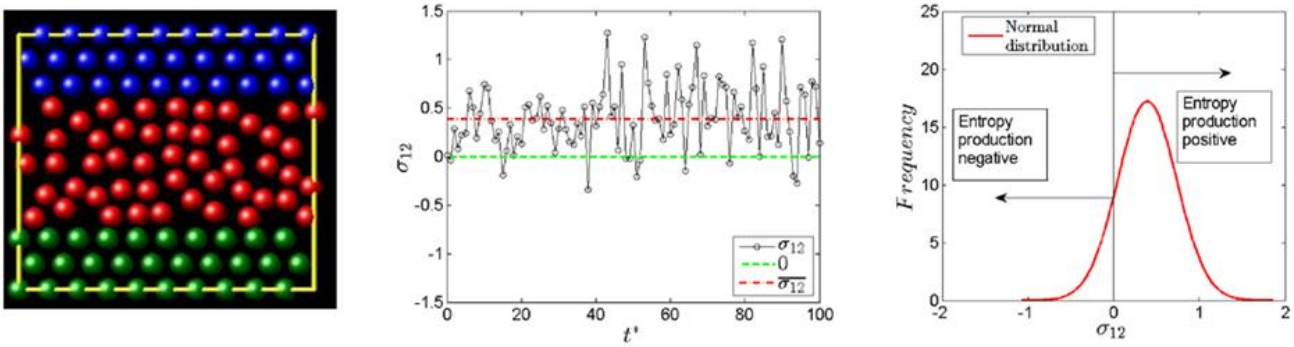
Martin Ostoja-Starzewski[1,2], Anatoliy Malyarenko[3], Bharath V. Raghavan[1], Pouyan Karimi[1], Rossella Laudani[4]

[1]*Department of Mechanical Science & Engineering, University of Illinois at Urbana-Champaign, IL, USA*
[2]*Institute for Condensed Matter Theory, and Beckman Institute, University of Illinois at Urbana-Champaign, IL, USA*
[3]*Mälardalen University, Västerås, Sweden*
[4]*University of Messina, Messina, Italy*

Biography

Martin Ostoja-Starzewski is a Professor of Mechanical Science & Engineering at the University of Illinois at Urbana-Champaign. He obtained a Ph.D. (1983) in mechanical engineering at McGill University. He (co-)authored 222 journal papers and 4 books: 1. *Microstructural Randomness and Scaling in Mechanics of Materials*, CRC Press (2008); 2. *Thermoelasticity with Finite Wave Speeds*, Oxford University Press (2009); 3. *Tensor-Valued Random Fields for Continuum Physics*, Cambridge University Press (2019); 4. A. Malyarenko, M. Ostoja-Starzewski, and A. Amiri-Hezaveh, *Random Fields of Piezoelectricity and Piezomagnetism*, Springer (2020). He serves as Editor of *Acta Mechanica*, Editor-in-Chief of the *Journal of Thermal Stresses*, and Chair Managing Editor of *Mathematics and Mechanics of Complex Systems*. He has also been on Editorial Boards of ~10 other journals. He is a Fellow of ASME, American Academy of Mechanics, Society of Engineering Science, and Associate Fellow of AIAA. In 2018 he received the Worcester Reed Warner Medal of ASME. In 2012 he was Timoshenko Distinguished Visitor at Stanford University. Since 2014 he has been a Site co-Director of the NSF Industry/University Cooperative Research Center for Novel High Voltage/Temperature Materials and Structures.

Graphical Abstract



Abstract

That "*the second law is of the nature of strong probability … not an absolute certainty*" was already recognized by J.C. Maxwell. However, it has only been in the past three decades that theoretical, simulation, and experimental results in physics in support of that old statement have been generated. Fundamentally, there is a non-zero probability of negative entropy production rate on very small length scales and (relatively) short times. Violations of the Second Law are relevant as the length and/or time scales become very small. The Second Law then needs to be replaced by the *fluctuation theorem* [1] with the irreversible entropy recognized as a submartingale. First, we discuss the consequences of these results for the axioms of continuum mechanics, arguing in favor of a framework relying on stochastic functionals of energy and dissipation [2, 3]. In effect, the random fields of viscosity and/or diffusion tensors are not required to satisfy the positive definiteness everywhere. Statistical mechanics and LAMMPS-based molecular dynamics lead to a generalization of the *fluctuation theorem* to non-Gaussian fluctuations, hydrodynamic stability, and turbulence in Couette flows of atomic fluids [4, 5]. On a parallel track, a continuum physics framework is employed to show that spontaneous random fluctuations of the microrotation field arise in Couette and Poiseuille flows in the absence of random (turbulence-like) fluctuations of the classical velocity field. All these developments have implications in two areas on macro scales:

1. Porous media. First, permeability, which is classically modeled by the Darcy law or its modifications, has to be modified to admit flows with spontaneously negative increments of entropy production. This effect then has implications for the poromechanics of deformable materials, both man-made or living, such as foams and soft tissues.
2. Granular matter. By changing the pair potential from Lenard-Jones to hard-core, we study the granular matter by the same techniques as in molecular dynamics. We find that the collisional dynamics of small systems (up to ~200) of elastic disks (with diameters on length scales of *mm* to *cm*) exhibit violations of the entropy inequality. This result even applies to

macroscopic (!) systems of 10-20 disks with a diameter of 1 *m*. We end by reporting the effects of deformation rates, varying gravity, and grain elasticity (from very soft up to ultra-hard) in Couette flows of disks.

Keywords: granular media, molecular fluids, Second Law, entropy production inequality, fluctuation theorem.

Acknowledgements: This article is based on work supported in part by the NSF (Grant No. CMMI-1462749) and the NIH (Grant No. 1932099).

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Carbon hybrid materials - by design

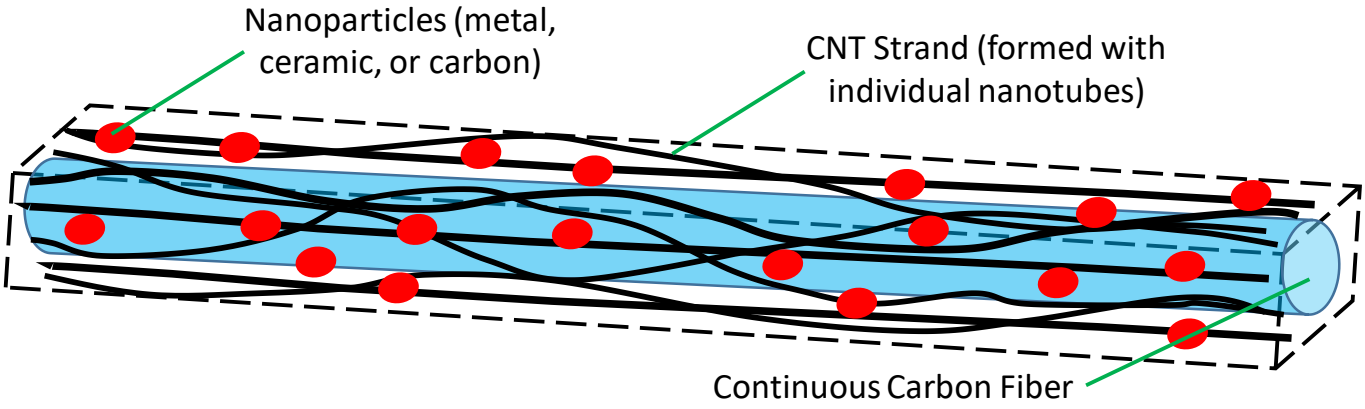
Mark Schulz[1], Vesselin Shanov[1], Sung Yong Kim[2], David Mast[1], Devika Chauhan[1], Rui Chen[1], Vianessa Ng[1], Megha Chitranshi[1], Anuptha Pujari[1], Ronald Hudepohl[1], Ashley Kubley[1,] Devanathan Anantharaman[1], Amit Bhattacharya[1], Svitlana Fialkova[3], Sergey Yarmolenko[3]

[1]*University of Cincinnati, Cincinnati, Ohio 45211, USA*
[2]*Pukyong National University, Busan 45813, Republic of Korea*
[3]*North Carolina A&T State University, Greensboro, North Carolina, 27411, USA*

Biography

Mark J. Schulz is Professor of Mechanical and Materials Engineering at the University of Cincinnati and is Co-director with Dr. Vesselin Shanov of the Nanoworld Laboratories at the University (https://ceas.uc.edu/research/centers-labs/nanoworld.html). Nanoworld is a large academic laboratory for carbon nanoscale materials research. The strategic goal of the Nanoworld laboratory is to integrate nanotech into university-wide curricula, to interest students to go to graduate school, and to develop new engineering and medical devices based on carbon materials and biodegradable metals. Nanoworld focuses on trailblazing and road mapping innovation, translating the discoveries to industry, and training a next generation workforce that will be in high demand. Mark teaches the *Introduction to Smart Structures* course. He co-founded the "Nanotechnology Materials and Devices (NMD) Workshop." The NMD Workshop is organized by the University of Cincinnati, the Air Force Research Laboratory and the University of Dayton Research Institute. Nanotube experts from around the world attend. Mark advised over 70 graduate students. He and his students have 200 publications, 10 patents/pending, and conducted 80 research projects. Mark co-edited four books on nanotechnology. He has a PhD degree in Mechanical Engineering from the State University of New York at Buffalo. Mark collaborates with researchers at other universities (North Carolina A&T SU, the University of Pittsburgh) and industries. He is a fellow of the American Institute for Medical and Biological Engineering and has been a Distinguished Engineering Researcher in the College of Engineering and Applied Sciences.

Graphical Abstract



The scale of the components of Carbon Hybrid Materials (CHM) span three orders of magnitude. The unit cell of CHM incorporates: CNTs (circa 7 nm), within strands (7-70 nm), Nanoparticles (70-700 nm), and a Micro-fiber (7,000 nm).

Abstract

This lecture gives an overview of the design and synthesis of Carbon Hybrid Materials (CHM) for specific applications. Customized CHM are formed by combining different Additive Materials (AM) with a Carbon Nanotube (CNT) nonwoven matrix material. The process starts by forming a CNT sock which is web-like assembly of strands composed of individual CNTs. The sock is deposited onto a drum and acts as a non-woven fabric. A key advance is using the CNT sock to form the matrix material for CHM. Nanoparticles (NPs) are also integrated within the matrix. The CNT strands encapsulate the micro-fibers which are in the form of short fibers or continuous fibers. Other types of AM can also be used. However, the AM should be small in diameter to best integrate with the CNT fabric matrix. Adding NPs into the inlet of the synthesis process is done using a custom designed particle injector that can inject different types of dry nano and micro particles into the high temperature nanotube synthesis process. NPs and short and continuous fibers can also be incorporated into the CNT sock matrix as it is being wound onto a take-up drum in the harvesting box. Solvent can be used to densify the CNT sock. Properties of the CHM produced depend on the AM used. CHM can be designed to be strong in tension, and can form lightweight composites, electrical conductors and shields, radiation shields, filters, and other types of customized materials. CHM composite materials are different than conventional polymeric composites since the CNT fabric replaces the polymer matrix. The CNT sock should completely encapsulate the particle or fiber to have the greatest effect as a matrix material to hold and protect the fiber. Van der Waals forces and entanglement forces are most effective at the nanoscale, thus the

AMs must be separated and dispersed when integrated into the CNT sock. Continuous carbon fibers are integrated by winding onto the drum but a flat tow of carbon fibers is needed so that the CNT sock can encapsulate the CF individually or in small bundles. The CHM formed can be composite fabrics with a binder, and in some cases, using no polymer matrix material. Potentially, these polymer-free composites can have modest and tailorable stiffness in bending, and would be useful for applications where a polymer matrix is unsuitable. Looking ahead, molecular nanocarbon science has been focusing on new forms of carbon and hydrocarbons using organic synthesis. In [1], it is stated that "modification of nano-carbons will lead to new fields and applications associated with their unforeseen properties and functions." In line with the possibilities foreseen in nanocarbon science, this lecture also generally discusses combining chemically and physically the CNT with metals and other carbon and ceramic materials. Adding metals to the nanotube synthesis process has created sheets, spirals and cone shaped carbon forms, and CNT bundles have been "glued" together at their ends with Ag-Cu spheres [2-5]. The CHM method thus provides excitement about what new types of carbon hybrids might be created.

Keywords: Carbon Nanotube; Fabric Matrix; Additive Materials; Nanoparticles; Continuous Fiber.

Acknowledgements: This research was supported by the NSF ERC EEC-0812348 and the UCTAC Seed Grant under ESP TECH 15-0160. This research study was also partially supported by the National Institute for Occupational Safety and Health Pilot Research Project Training Program of the University of Cincinnati Education and Research Center Grant #T42/OH008432.

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Webinar on
Science, Engineering and Technology

High performance when you least expect it: How halide perovskites are transforming photovoltaics

Mercouri G. Kanatzidis

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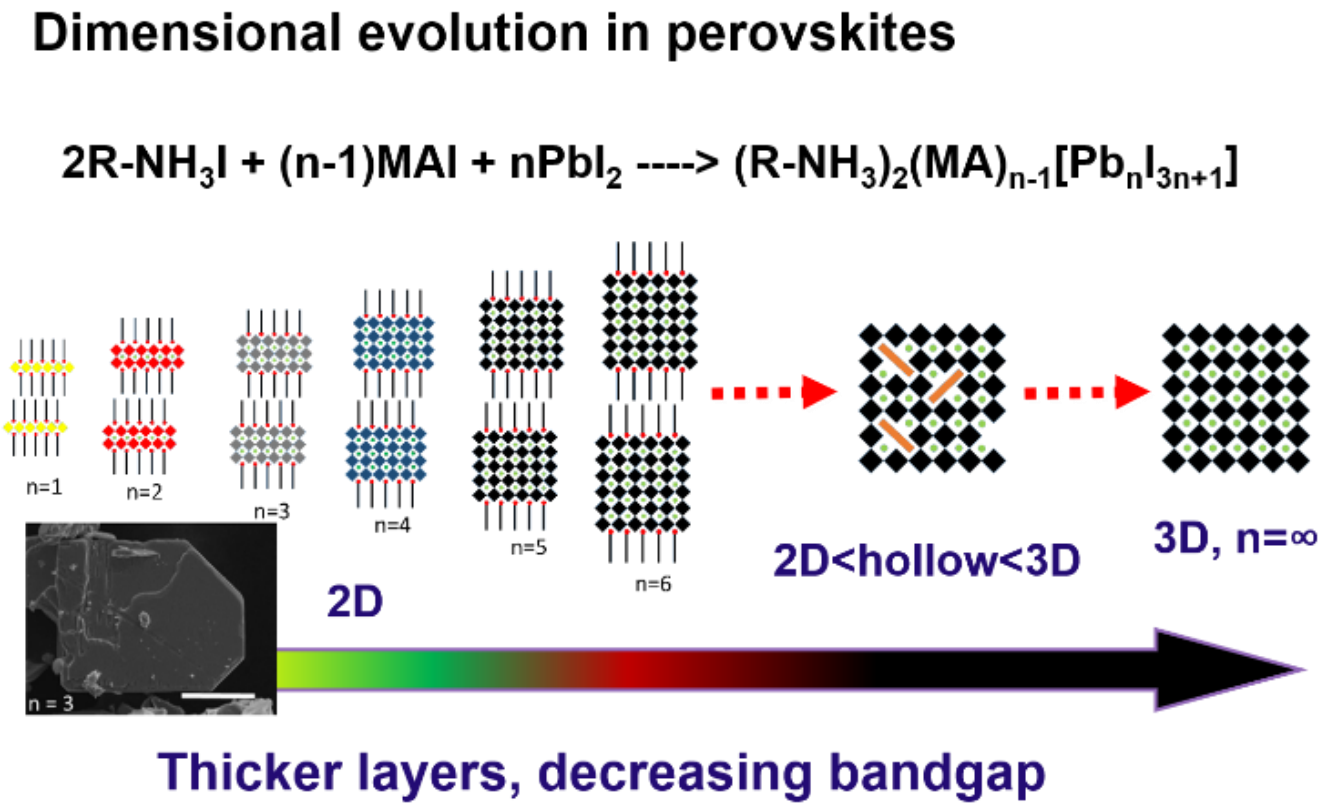
Biography

Mercouri Kanatzidis was born in Thessaloniki, Greece in 1957. After obtaining a BSc degree from Aristotle University in Greece, he received his PhD degree in Chemistry from the University of Iowa in 1984. He was a postdoctoral research associate at the University of Michigan and Northwestern University and is currently Charles E. and Emma H. Morrison Professor of Chemistry at Northwestern University. His research areas include halide perovskites, solid state and coordination chemistry of chalcogenide compounds, design and synthesis of new materials, solar energy materials, thermoelectric materials, intermetallics, porous semiconductors and quantum materials. He is the recipient of the Royal Chemical Society DeGennes Prize 2015; 2015 ENI Award for the ‘‘Renewable Energy Prize’’ category; the ACS Award in Inorganic Chemistry 2016; and the American Physical Society 2016 James C. McGroddy Prize for New Materials; 2016 Samson Prime Minister's Prize for Innovation in Alternative Fuels for Transportation; 2019 - DOE Ten at Ten Scientific Ideas Award for the first demonstration of all-solid-state solar cells using halide perovskite materials..

Graphical Abstract



Abstract

How did the ongoing revolution in the science of halide perovskites begin? The chemical versatility and structure diversity in the class of hybrid organic inorganic main metal halides is astounding. The interplay of weak covalent and ionic bonding in the inorganic framework allows the formation of an amazingly broad variety of structures most of which can be divided into two larger classes: three-dimensional (3D) and 2D perovskites. The lone pair of electrons in Pb^{2+} and Sn^{2+} impart defect tolerance beneficial to charge transport. The 2D metal halide perovskites have also become highly promising semiconductors for tunable optoelectronic devices. They have a general formula of $(A')_2(A)_{n-1}M_nX_{3n+1}$, where A = Cs^+, $CH_3NH_3^+$ (MA), $HC(NH_2)_2^+$ (FA), M = Ge^{2+}, Sn^{2+}, Pb^{2+} and X = Cl^-, Br^-, I^-, are the perovskite components and $A'^+ = RNH_3$ is an organic spacer. There are three kinds

of 2D organic inorganic hybrid perovskites so far: Ruddlesden-Popper, Cation-ordered and Jacobson-Dion. These vary from one another in ways the inorganic slabs stack and the way the spacer cations interact with the inorganic slabs. Generally, 2D perovskites form from solution via the bottom-up self-assembly of individual, semiconducting perovskite sheets having an adjustable slab thickness of up to few nanometers, separated by insulating bulky organic molecules. As a result, they behave as natural multiple quantum wells (QWs) with the semiconducting perovskite layers representing the wells and the insulating organic spacers representing the barriers. The width of the barrier is fixed and depends only on the length of the A' cation, while the width of the well can be adjusted by varying the thickness of perovskite slabs, which is defined by the n variable in $(A')_2(A)_{n-1}M_nX_{3n+1}$. The chemical and structural aspects of these materials will be presented and devices made from them will be described.

Keywords: Perovskite; Photovoltaics; Semiconductors;

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How can physicist help to contain the spread of COVID-19 pandemic?

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Biography

Zhifeng Ren is the M. D. Anderson Chair Professor of Physics and the Director of the Texas Center for Superconductivity at the University of Houston (TcSUH). He received his BS in 1984 from Xihua University, MS in 1987 from Huazhong University of Science and Technology, and PhD in 1990 from the Institute of Physics, Chinese Academy of Sciences. His research has been on thermoelectrics, boron arsenide single crystals for high thermal conductivity, enhanced oil recovery, water splitting for H_2 generation, heated filters for catching and killing SARS-CoV-2 causing COVID-19 pandemic, carbon nanotubes, solar absorbers, flexible transparent conductors, superconductors, *etc*.

Abstract

SARS-CoV-2 virus has caused COVID-19 pandemic leading to over 62 million infections and 1.5 million death worldwide. Normally we would not think physicist can help too much on containing the spread of the virus. Well, we proved that physicists can also help. I will present our recent work on developing a heated filter to effectively catch and kill the SARS-CoV-2 virus and any other viruses, bacteria, germs, *etc*. to contain the spread of COVID-19 pandemic.

Imaging cell signaling and intercellular forces with nucleic acids

Mingxu You

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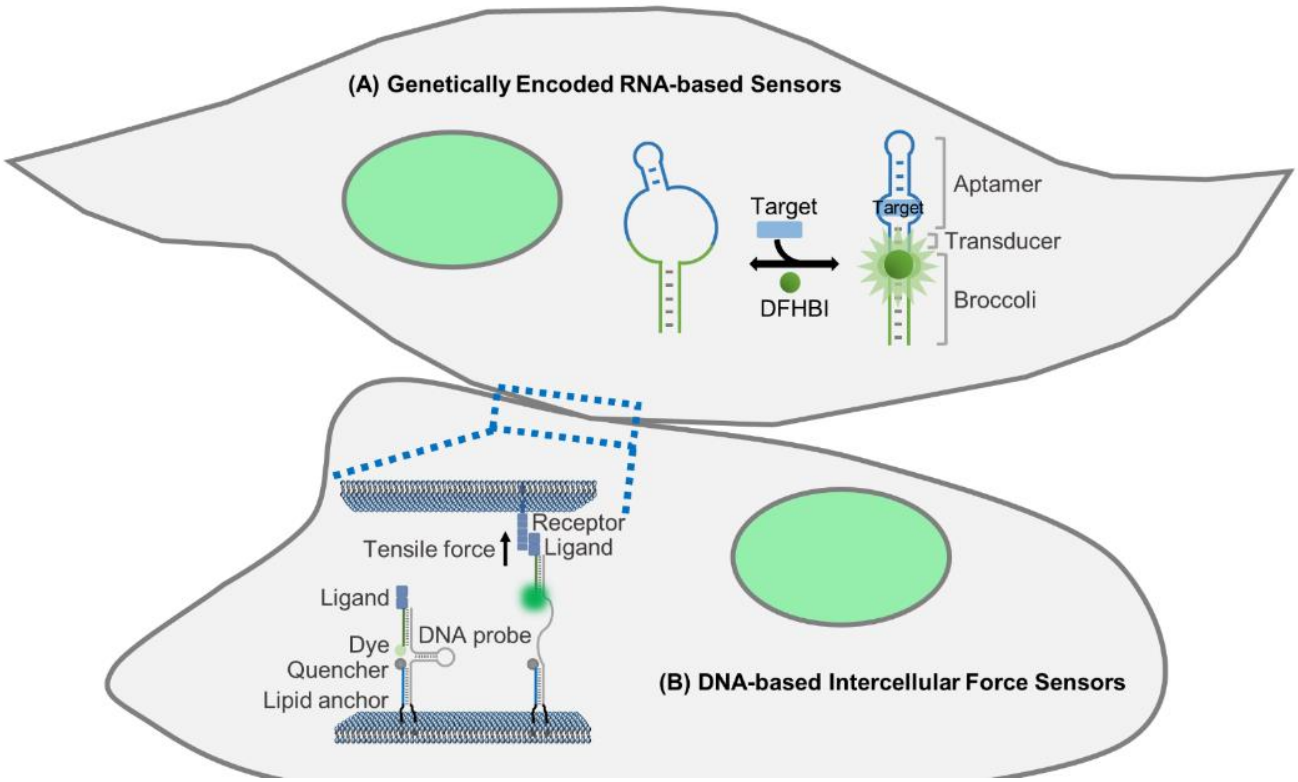
Biography

Dr. Mingxu You is currently an Assistant Professor of Chemistry at the University of Massachusetts Amherst, United States. He received his B.S. in Chemistry from Peking University in 2008, and his Ph.D. in Analytical Chemistry from the University of Florida in 2012. During his doctoral study with Prof. Weihong Tan, Dr. You focused on developing DNA-based devices for cancer diagnosis and cell membrane biophysical studies. Dr. You further pursued his postdoctoral research with Prof. Samie R. Jaffrey at Weill Cornell Medicine, interested in developing RNA-based fluorescent sensors for imaging metabolites and signaling molecules in live cells. Since starting his independent career in September 2016 at UMass Amherst, the research aim of Dr. You has been to develop next-generation platform for disease diagnostics and therapy. To realize this aim, Dr. You is interested in playing with nature's building blocks, DNAs and RNAs. He has published over 70 manuscripts and his contribution has been recognized in several awards, including the Alfred P. Sloan Research Fellow, NIH Maximizing Investigators' Research Award (MIRA), and NSF CAREER Award. In addition, Dr. You has been recognized as an Emerging Investigator in journals including Analytical Methods, Supramolecular Chemistry, Frontiers in Chemistry, and Nanoscale.

Graphical Abstract



Abstract

Biosensors that can report the abundance, distribution, and flux of cellular analytes are critical tools for our understanding of the biological world. Although powerful, current chemical or genetically encoded fluorescent sensors are not easily generalizable for detecting many cellular molecules of interest. A great deal of effort has been made in evolving target-binding domains, as well as in improving the dynamic range and signal-to-background ratio, such as in those fluorescent protein-based FRET sensors. In the first half of my presentation, I will introduce an alternative approach to develop fluorescent probes for a wide range of biological analytes. Our approach is based on genetically encoded fluorogenic RNAs, e.g., so-called Spinach and Broccoli. We have streamlined a generalized pipeline to develop RNA-based sensors for imaging small molecule and RNA in living cells. We are

now developing "next-generation" RNA-based sensors to allow more quantitative, sensitive and selective detection of cellular targets. For example, we have engineered an RNA Integrator sensor and two RNA circuits, termed CHARGE[1] and INSIGHT[2], to image low-abundance cellular metabolites and RNAs. In addition, we are developed the multi-colored RNA-based sensor for quantitative ratiometric imaging of cellular metabolites and antibiotics[3]. In the second half of this talk, DNA-based tools will be described for imaging some previously undetectable biophysical events in live cell membranes, including intercellular mechanical forces[4] and dynamic lipid-lipid and lipid-protein interactions[5]. Mechanical forces have been shown to play fundamental roles in development, morphogenesis, tumor metastasis, and wound healing. However, the molecular mechanisms that govern these finely balanced mechanotransduction events are still poorly understood. The far-reaching implications and diversity of mechanisms have placed mechanobiology at the forefront of current research. Our goal is to revolutionize the study of mechanobiology by providing quantitative force sensors to detect various force-regulated processes at cell–cell junctions. We have recently developed two sets of DNA-based tensile force probes[4]. These probe consists of three hybridized DNA strands: a stem-loop DNA hairpin, a ligand-modified strand with dye, and a lipid anchor strand with quencher. When the tensile force between the ligand and receptor exceeds the threshold to unfold the DNA hairpin, a drastic increase in fluorescence is observed. We believe the innate biocompatibility, precise sequence-specific self-assembly, and programmability have made these DNA- and RNA-based tools uniquely compelling for bioanalytical and biomedical applications.

Keywords: aptamer; fluorescent sensor; nucleic acid, mechanobiology; imaging.

Acknowledgements: The author gratefully acknowledge the UMass Amherst start-up grant, NIH R01AI136789, NIH R35GM133507, NSF CAREER, Alfred P. Sloan Research Fellowship, and IALS M2M seed grant to M. You. The authors also thank all the members in the You Lab for their hard work and contribution.

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Webinar on
Science, Engineering and Technology

Optical positioning and linking for 3D nanofabrication

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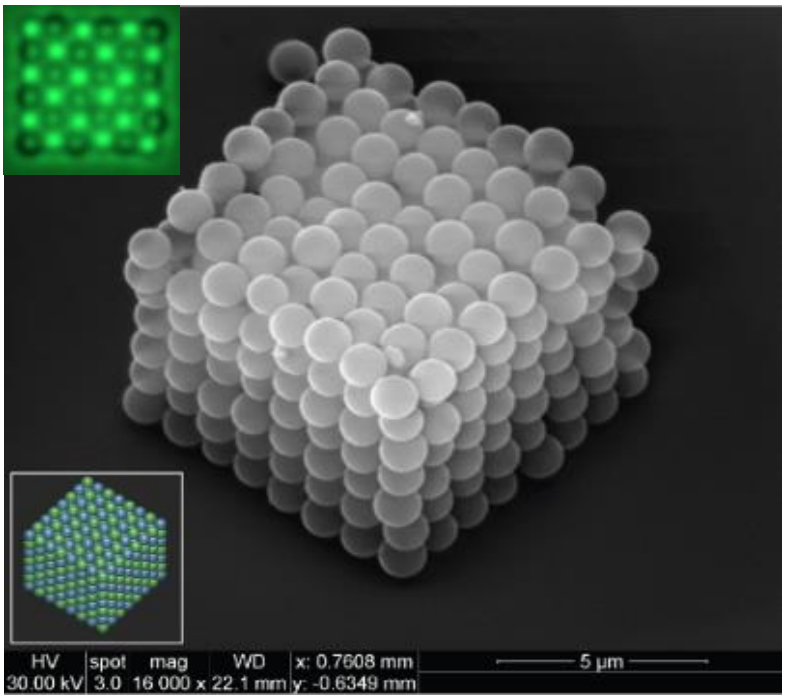
Biography

Euan McLeod is an Assistant Professor in the College of Optical Sciences at the University of Arizona (UArizona) since 2015. He is also an Assistant Professor of the UArizona BIO5 Institute and an Affiliate Member of the UArizona Cancer Center. He was previously a postdoc in Electrical Engineering and Bioengineering at UCLA, as well as a postdoc in Applied Physics at Caltech. He received his Ph.D. from Princeton University and his B.S. from Caltech. Euan is a Senior Member of the Optical Society of America and a Life Member of SPIE. Euan's background and interests lie at the intersection of optics, nanoscience, and soft bio-materials science. He has published more than 35 papers on these topics in peer-reviewed journals, with major contributions in the areas of high-speed varifocal lenses based on acoustic modulation; lensfree holographic imaging of nanoparticles, viruses, and biomarkers; and the use of optical tweezers in fabricating micro- and nano-structured materials. His Ph.D. work on tunable acoustic gradient index (TAG) lenses led to numerous innovation awards, including: a 2013 R&D 100 Award; a 2013 SPIE & Photonics Media: Prism Award; and a 2017 Thomas Alva Edison Patent Award. This patented technology is now fully licensed by Mitutoyo Corp and commercially sold.

Graphical Abstract



Assembly of >440 1-µm diameter particles using optical tweezers.

Abstract

Improved three-dimensional (3D) nanofabrication approaches could enhance the performance of many advanced photonic devices, including superresolution lenses, high density photonic chip interconnects, or plasmonically-enhanced ultra-high-quality factor whispering gallery mode biochemical sensors. Existing fabrication approaches such as self-assembly do not provide precise placement control, while commercial two-photon polymerization (laser direct writing) is limited to photopolymerizable materials and smallest feature sizes of ~160 nm laterally and several hundred nanometers vertically. These specifications can be prohibitive for visible-wavelength and near-infrared photonic metamaterials, which often demand feature sizes $<\lambda/10$. Optical tweezers present an attractive fabrication alternative due to their ability to trap and position nanoscale objects of various materials with high precision. However, it is challenging to develop an automated platform that is robust and high-speed enough for rapid prototyping involving many building blocks. Here we present an optical tweezers based optical positioning and linking (OPAL) approach for assembling 3D structures out of large numbers of multi-material microscale and nanoscale building blocks. OPAL provides a route

for fabricating structures that were previously infeasible, including precision augmentation of microtoroid optical resonator sensors, and complex 3D nanoscale light guiding structures that could ultimately be used as an interconnect between other photonic systems, or as part of a superresolution lens. We will discuss computational approaches that we have developed for designing these and other photonic devices based on the assembly of discrete building blocks. We will also discuss the assembly platform performance, including positioning accuracy of ~60 nm and building block manipulation speeds >0.15 mm/s. We will demonstrate the platform's robustness via the assembly of more than 440 microscale building blocks, which is the largest number of objects assembled into a single structure using optical tweezers to date. Based on its current capabilities, OPAL can be used to rapidly prototype multi-material, 3D nanostructures that are currently infeasible to fabricate using other techniques.

Keywords: Optical tweezers; Directed assembly; Nanofabrication; Additive manufacturing; Optical manipulation;

Acknowledgements: The authors acknowledge the support of the National Science Foundation grant ECCS-1807590 and the Defense Threat Reduction Agency grant HDTRA1-18-1-0044.

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