The Center for Hierarchical Emergent Materials (CHEM)

University of CINCINNATI

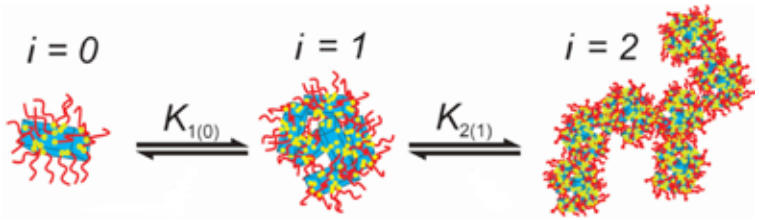
UNIVERSITY OF DELAWARE

UNIVERSITY OF MICHIGAN

CHEM seeks to understand, control and predict the assembly of multi-hierarchical materials of industrial relevance. Reinforced elastomers, paints, inks, biomaterials, surfactants, detergents and coacervates, semi-crystalline polymers, block copolymers, catalysts, filters, membranes, skin. Time dependence in processing/application, 4D.

Synergy: Understanding, simulation methods, dynamic and static properties understood for one field of application could be adapted to another field. Rheology simulation methods from polymers to detergents to paints.

Parallelism and Convergence: Similar solutions for different applications. Aggregate pigments and aggregate reinforcing fillers both rely on micron scale networks in application.



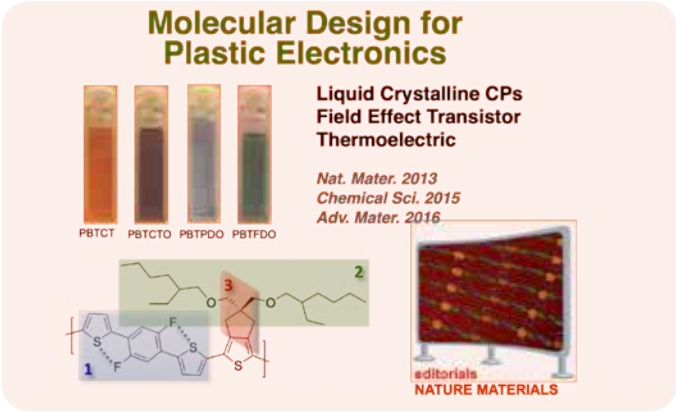
Prof. Jinsang Kim

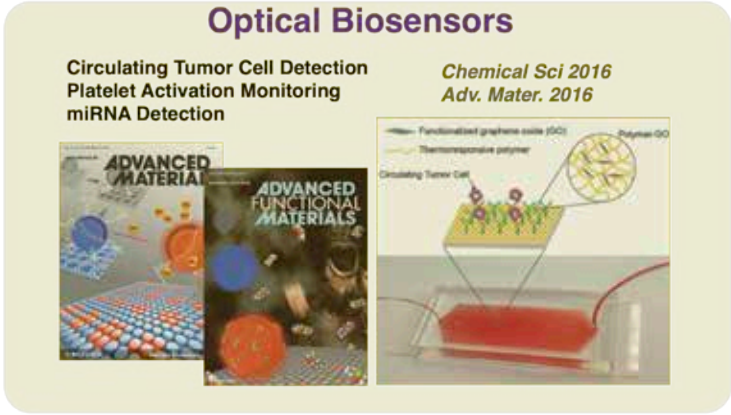
Jinsang Kim, Synthesis, Polymers, Sensing

Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

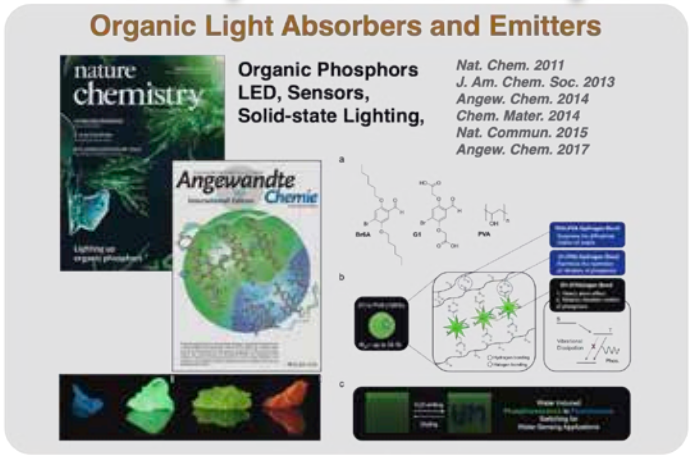
Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

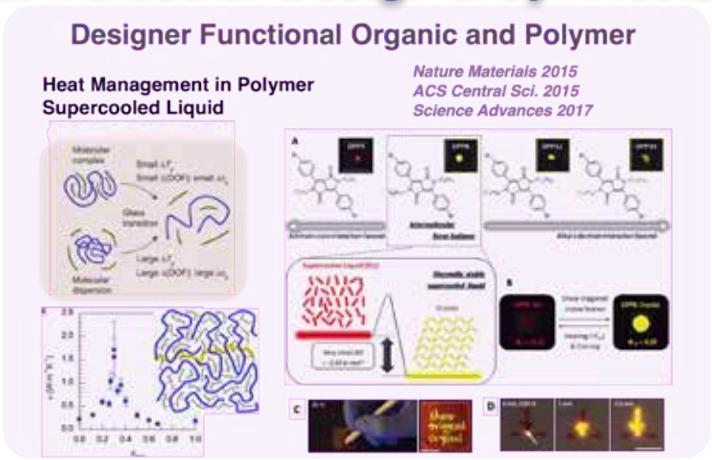
Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants





Kim Group Research Projects - Rational Molecular Design & Synthesis





Prof. Jinsang Kim

Project 1: Thermally Insulating Additives

- Highly branched architecture
- Diverse atomic composition
- Porous hollow nano particles

Project 2: Patternable Surface Functionalization

- Instant robust thin film formation by photochemistry
- High density functional groups
- Patterned surface functionalization via photomasks

Designer Polymeric and Organic Materials

Computation-aid rational molecular design, chemical synthesis, and fabrication engineering

Project 3: Polymers for Sustainable Pavement

- Interface adhesion engineering
- Versatile dopamine chemistry
- Excellent weatherability

Project 4: Tailor-made Optical Materials

- Instant robust thin film formation by photochemistry
- High density functional groups
- Patterned surface functionalization via photomasks

Larson group: Multi-Scale Modeling of the Rheology of Micellar Solutions

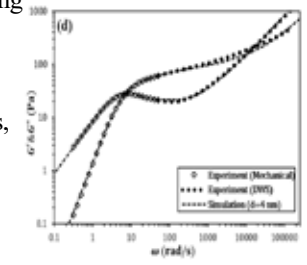
Prof. Ron Larson

Jinsang Kim, Synthesis, Polymers, Sensing

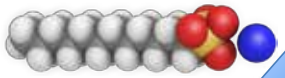
Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants



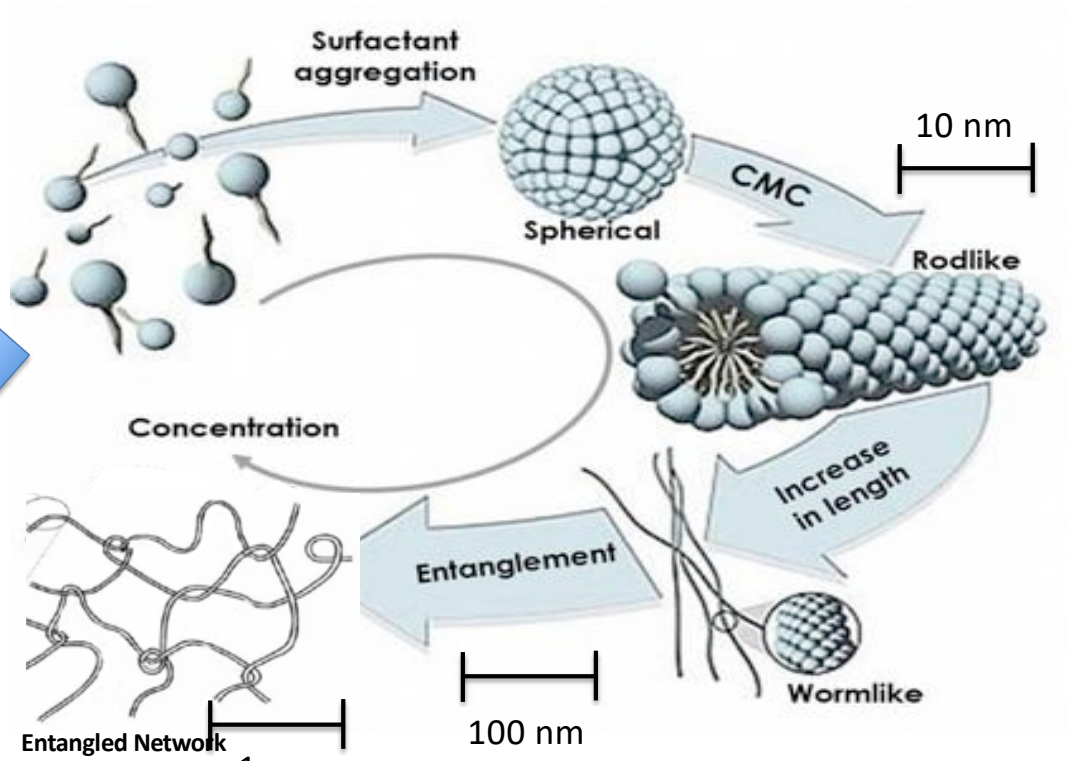
1 nm



sodium dodecyl sulfate

10 cm

10^{23} degrees of freedom!



http://www.ifnh.ethz.ch/vt/research/projects/vivianel

Larson group: Multi-Scale Modeling of the Rheology of Latex Coatings

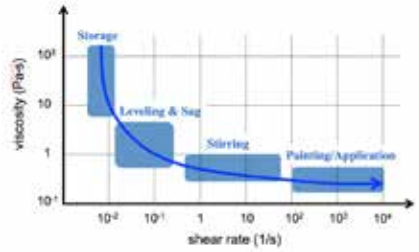
Prof. Ron Larson

Jinsang Kim, Synthesis, Polymers, Sensing

Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants



Multiple Particles

1 μm

100 nm

10 nm

Cl

"HEUR": PEO chains with alkane end "stickers."

R = C10 to C18 alkane

nm

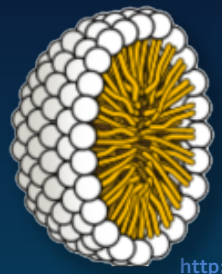
1 m

from Li et al. 2016

Supraparticles: Hierarchical Assemblies of Nanoparticles

Prof. Nick Kotov

Known: Micelles, organic components, 100 nm assemblies



http://en.wikipedia.org/wiki/Micelle

Emerging: Supraparticles, inorganic components, 100 nm assemblies made from 100-300 nanoparticles

Jinsang Kim, Synthesis, Polymers, Sensing

Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

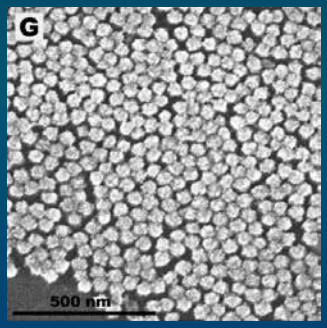
Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants

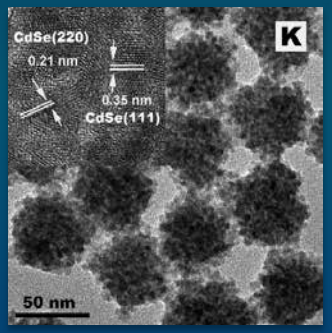
Why:

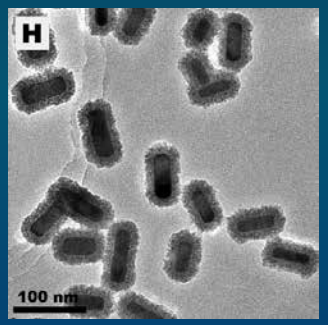
Versatile, Monodispersed, Robust, Catalytic, Inexpensive

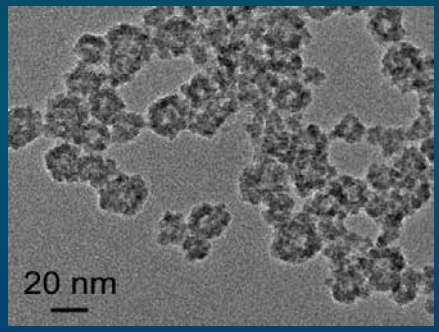
Combined organic + inorganic + biological functionalities

Dispersable in both hydrophobic and hydrophilic media









Omnidispersable Hedgehog Supraparticles

Numerous catalytic materials can be assembled into spiky shapes: ZnO, FeSe, AuS, CdS, SiO_2, TiO_2, Fe_2O_3, Co_3O_4, and many others.

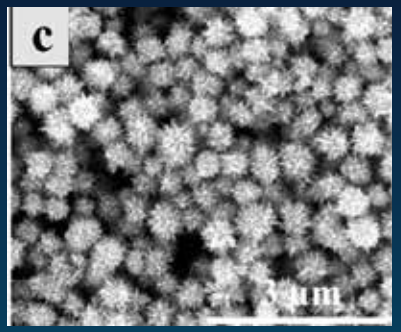
Prof. Nick Kotov

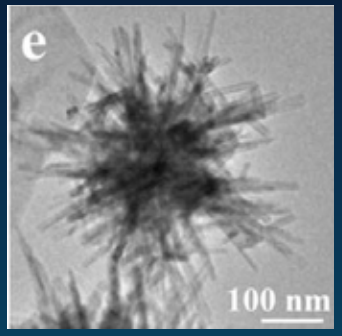
Jinsang Kim, Synthesis, Polymers, Sensing

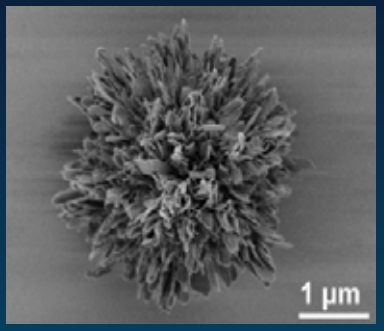
Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

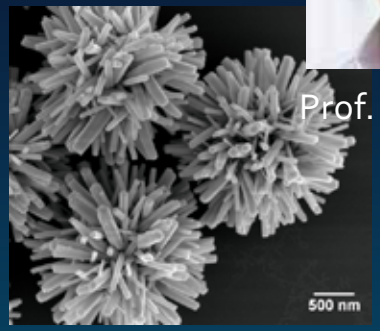
Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants

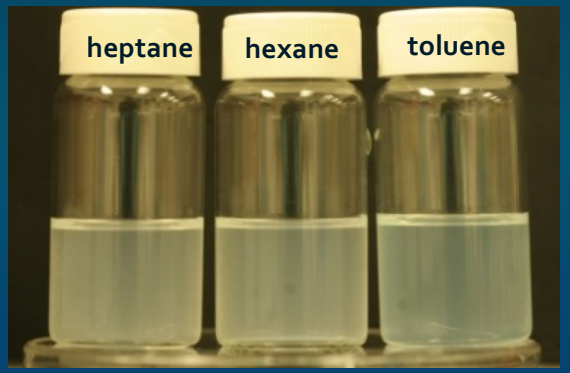








They disperse equally well in hydrophobic and hydrophilic media due to 100 times reduction in inter-particle van der Waals attractive forces.



Dispersions of Hydrophilic ZnO hedgehogs in organic hydrophilic and Hydrophobic solvents

Surfaces with Extreme Wettability

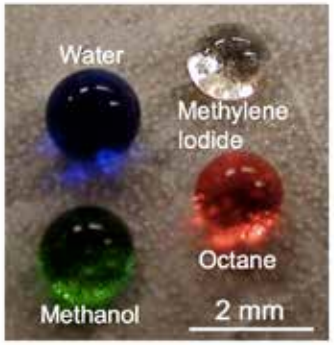
Prof. Anish Tuteja

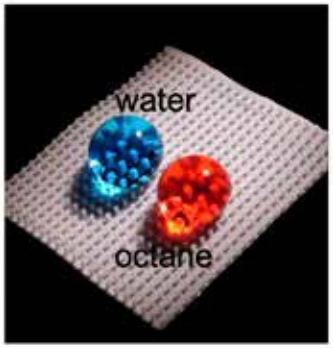
Jinsang Kim, Synthesis, Polymers, Sensing

Ron Larson, Rheology, Modeling, Nanocomposites, Surfactants Pigments

Nick Kotov, Nanoparticles, Hierarchical Assembly, Surfactants, Biomed delivery

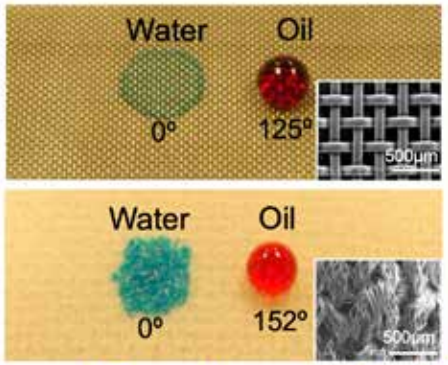
Anish Tuteja, Surfaces, Coatings, Adhesives, Nanocomposites, Surfactants

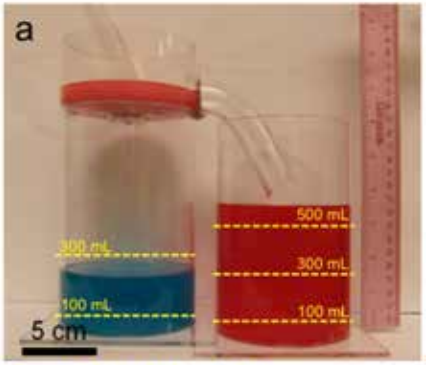




Designing Omniphobic Surfaces

Tuteja *et al., Science*, 2007; Tuteja *et al., PNAS*, 2008; Kota *et al., Advanced Materials*, 2012





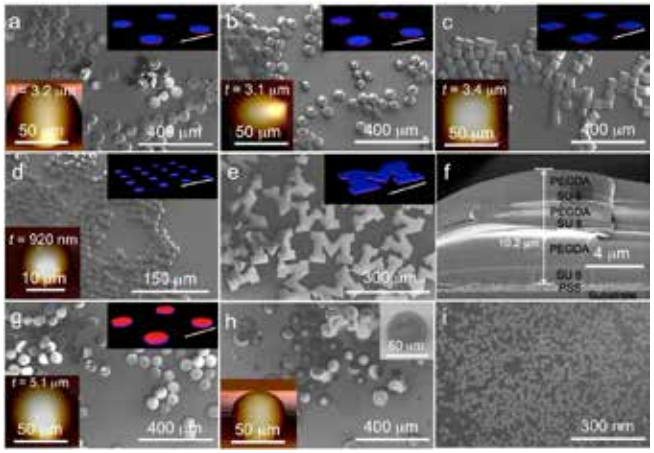
Membranes for Liquid- Liquid Separation

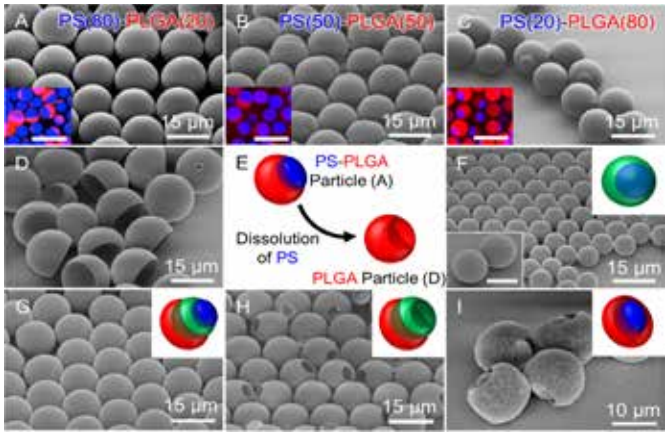
Kota *et al. Nature Communications*, 2012
Kwon *et al. Advanced Materials*, 2012

Surfaces with Extreme Wettability

Novel Ice-shedding Surfaces

Golovin *et al., Science Advances,* 2016; *Science Advances,* 2017;
Golovin *et al., Science,* 2019





Monodisperse, multi-phasic particles

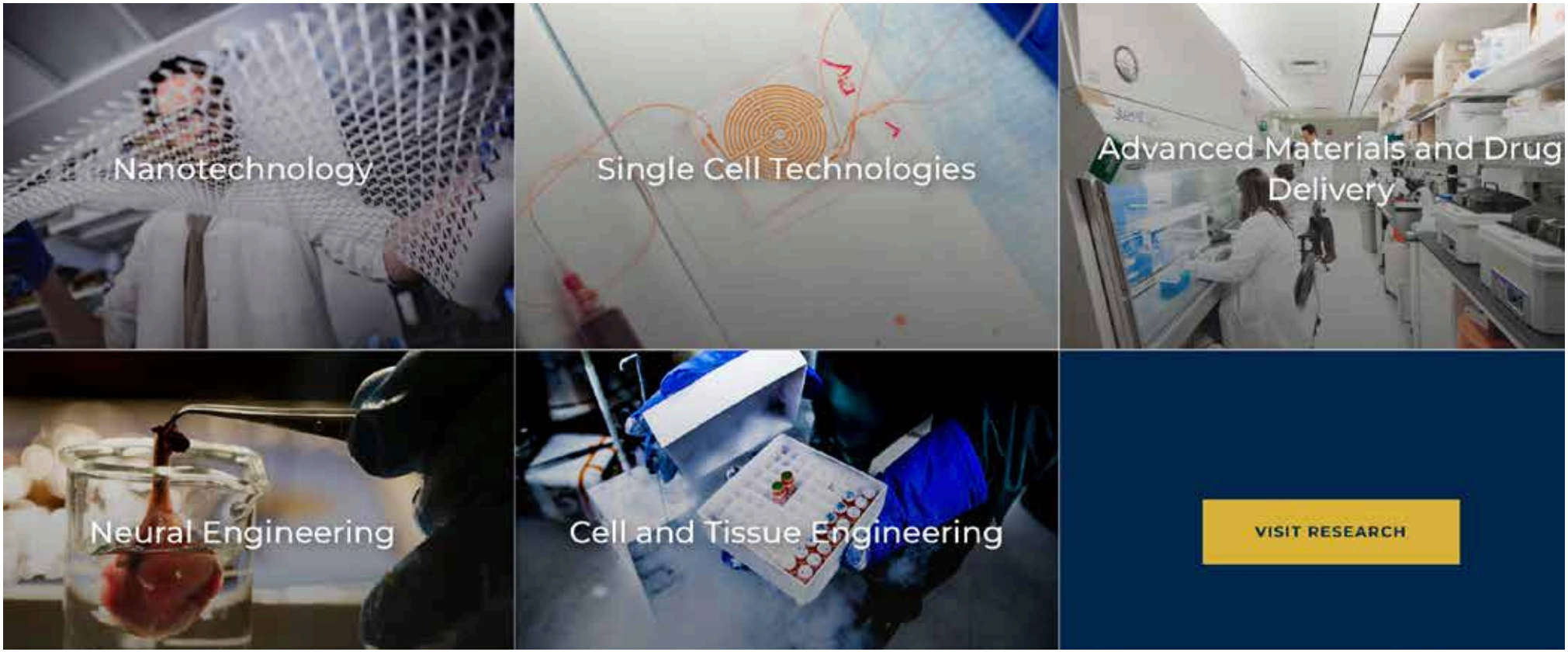
Prof. Anish Tuteja

Kobaku *et al.*, *ACS Appl. Mater. Interfaces*, **2015.**

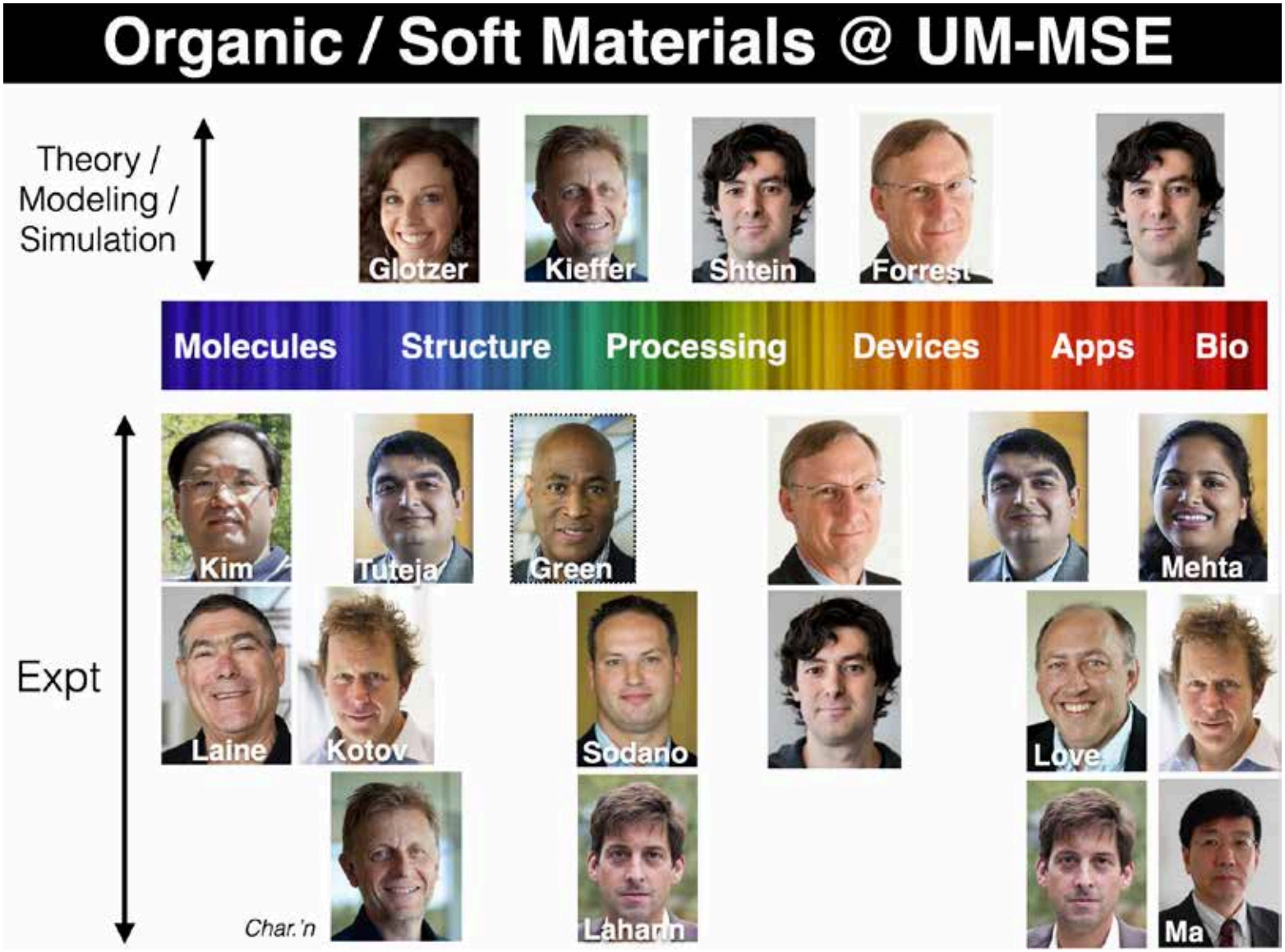
Kobaku *et al.*, *ACS Macro Letters, 2019*

BIOINTERFACES INSTITUTE
UNIVERSITY OF MICHIGAN

https://biointerfaces.umich.edu/



Organic / Soft Materials @ UM-MSE



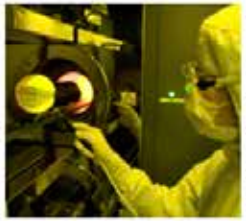
MICHIGAN ENGINEERING
MACROMOLECULAR SCIENCE & ENGINEERING PROGRAM

Electron Microbeam Analysis Laboratory (EMAL)

The University of Michigan Electron Microbeam Analysis Laboratory (EMAL) and X-ray Microanalysis Laboratory (XMAL) is a university-wide user facility for the microstructural and microchemical characterization of materials. This world-class facility now showcases a JEOL 2100F CS-Corrected Analytical Electron Microscope. **FEI Helios 650 Nanolab SEM/FIB, FEI Nova 200 Nanolab SEM/FIB, FEI Quanta 3D SEM/FIB, JEOL**

Center for Ultrafast Optical Science (CUOS)

The Center for Ultrafast Optical Science (CUOS) is an interdisciplinary research center in the College of Engineering. Its mission is to perform multidisciplinary research in the basic science and technological applications of ultrashort laser pulses, to educate students from a wide variety of backgrounds in the field, and to spur the development of new technologies. CUOS researchers develop optical instrumentation and techniques to generate, manipulate, and detect ultrashort and ultrahigh-peak-power light pulses. They use these ultrashort pulses to study ultrafast physical phenomena in atomic, nuclear, plasma, and materials physics, in solid-state electronics, in high-energy-density physics, and in biomedicine.



Lurie Nanofabrication Facility (LNF)

The Lurie Nanofabrication Facility (LNF) at the University of Michigan is one of the leading centers worldwide on micro electromechanical systems (MEMS) and microsystems. It provides facilities and processes for the integration of Si integrated circuits and MEMS with nanotechnology, with applications in biology, medical systems, chemistry, and environmental monitoring.

Michigan Nanotechnology Institute for Medicine and Biological Sciences (MNIMBS)

The Michigan Nanotechnology Institute for Medicine and Biological Sciences is a true multidisciplinary team of chemists, physicists, engineers, toxicologists, physicians, biologists, pharmacists, and (bio)informatics specialists collaborating on nanoscience in biology and medicine. The Institute involves approximately 60 faculty in a "no-walls" model using facilities in the Engineering, Medical and LS&A schools to enhance competitiveness for externally funded grants and contracts.

Center of Solar and Thermal Energy Conversion (CSTEC)

The Center for Solar and Thermal Energy conversion is an Energy Frontier Research Center (EFRC) supported by the US Department of Energy (DOE). The goal of CSTEC is to discover and develop the science necessary to maximize the energy conversion efficiencies of photovoltaic (PV) and thermoelectric (TE) devices through integrated theoretical, experimental, and computational strategies.

The Michigan Institute of Plasma Science and Engineering (MIPSE)

MIPSE is a community of faculty, staff and students at the University of Michigan whose research and education programs are devoted to the advancement of the science and technology of plasmas. The breadth of research is impressive, from laser-produced plasmas for particle acceleration to plasmas in the earths magnetosphere. We take pride in the excellence of the research and in the resulting societal benefits.