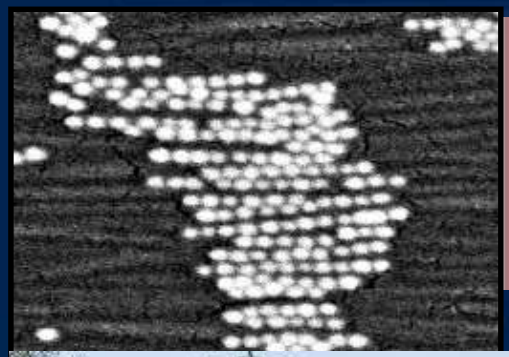
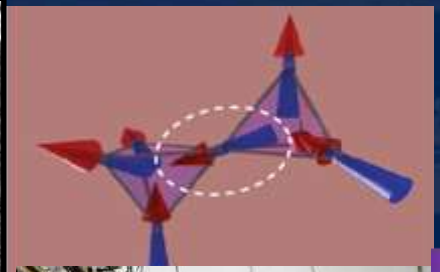
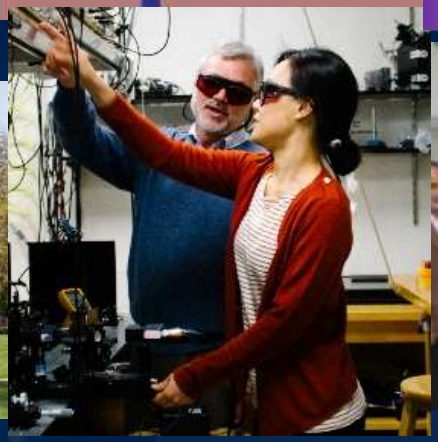
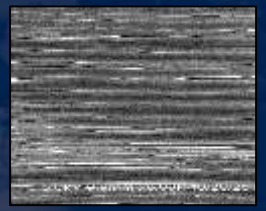
The Illinois MRSEC





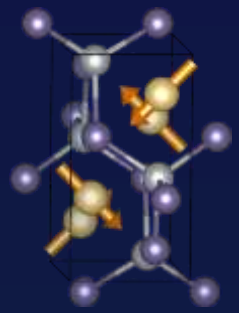




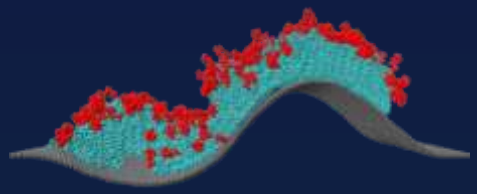
UNIVERSITY OF ILLINOIS

I-MRSEC Overview:

IRG1: Metallic Antiferromagnetic Materials: Ultrafast Charge, Lattice, and Magnetization Dynamics



IRG2: Active Interfaces Between Highly-Deformable Nanomaterials



Integrated education, outreach, and development activities for all levels of students & faculty

I-MRSEC Team


Aluru


Bashir


Cahill


Ertekin


Gilbert


Hoffman


Huang


Lorenz


Mason


Murphy


Nam


Rosenstein


Rosu


Schleife


Shoemaker


van der Zande

Bioengineering, Electrical & Computer Engineering, Chemistry, I-STEM, Materials Science, Mechanical Engineering, Media Studies, Physics, Argonne Lab

4 theorists, 10 experimentalists, 7 materials growth/fabrication
6 Full Professors, 3 Associate, 5 Assistant

I-MRSEC Team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Bashir


Cahill


Ertekin


Gilbert


Hoffman


Huang


Lorenz


Mason


Murphy


Nam


Rosenstein


Rosu


Schleife

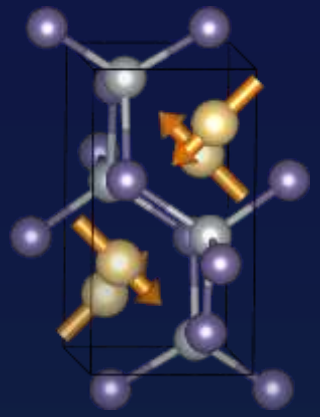

Shoemaker


van der Zande

Management Team: Mason (Director), Cahill (IRG1 Lead), van der Zande (IRG2 Lead), Murphy (Deputy Director), Ertekin (Education/Outreach Lead)

IRG1: Metallic Antiferromagnetic Materials: Ultrafast Charge, Lattice, and Magnetization Dynamics

- Determine the coupling of magnetic order, optical fields, electronic excitations, and lattice vibrations that underlie fundamental limits on the control of magnetic order and magnetization dynamics



- Discover new materials with enhanced response

- Higher density, faster switching, more robust than ferromagnetic domains (for information storage)
- THz sources and detectors
- Why now? Spin orbit torques provide a new approach for manipulating AF order in metallic AFMs

Bulk and thin film crystal growth

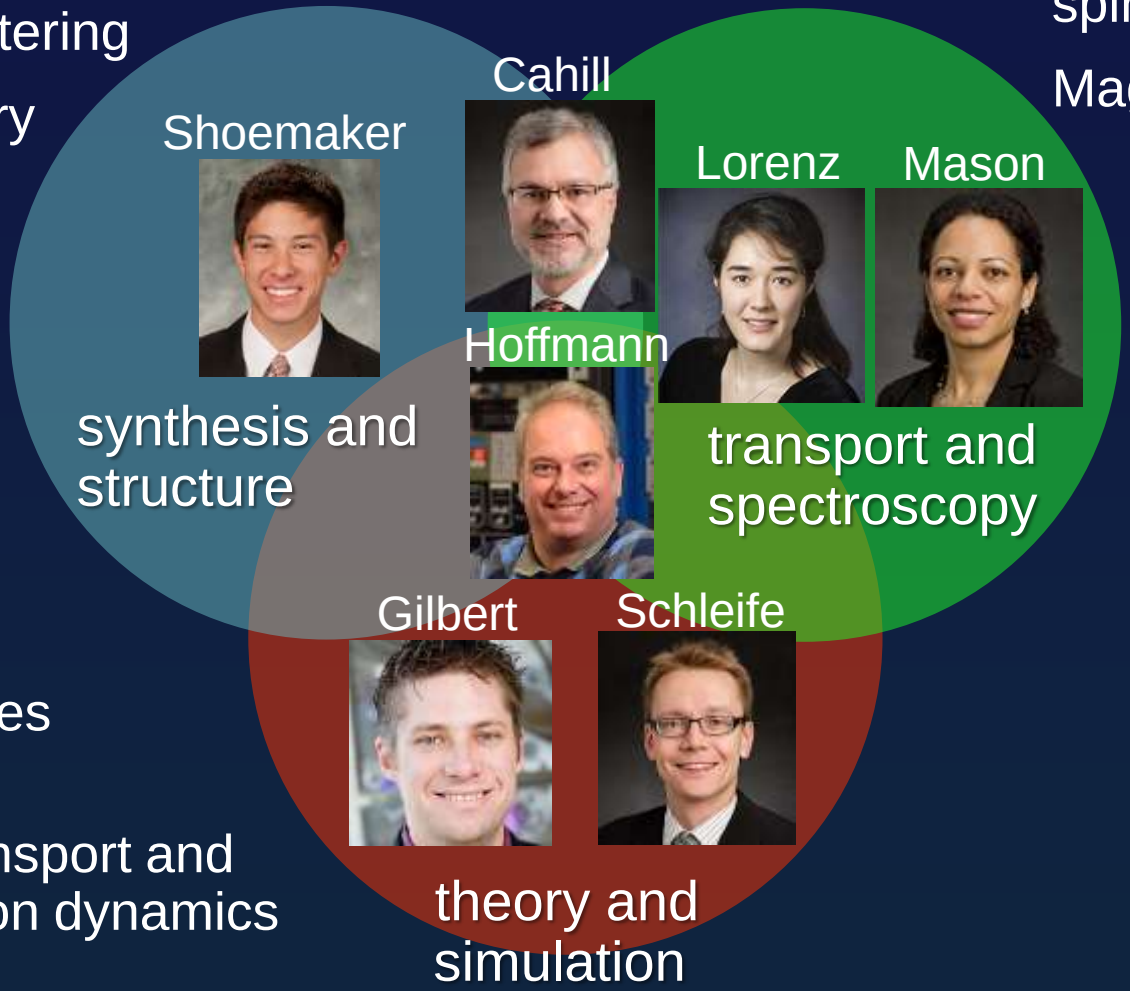
Neutron scattering

Magnetometry

Ultrafast optics

Spintronics and spin-caloritronics

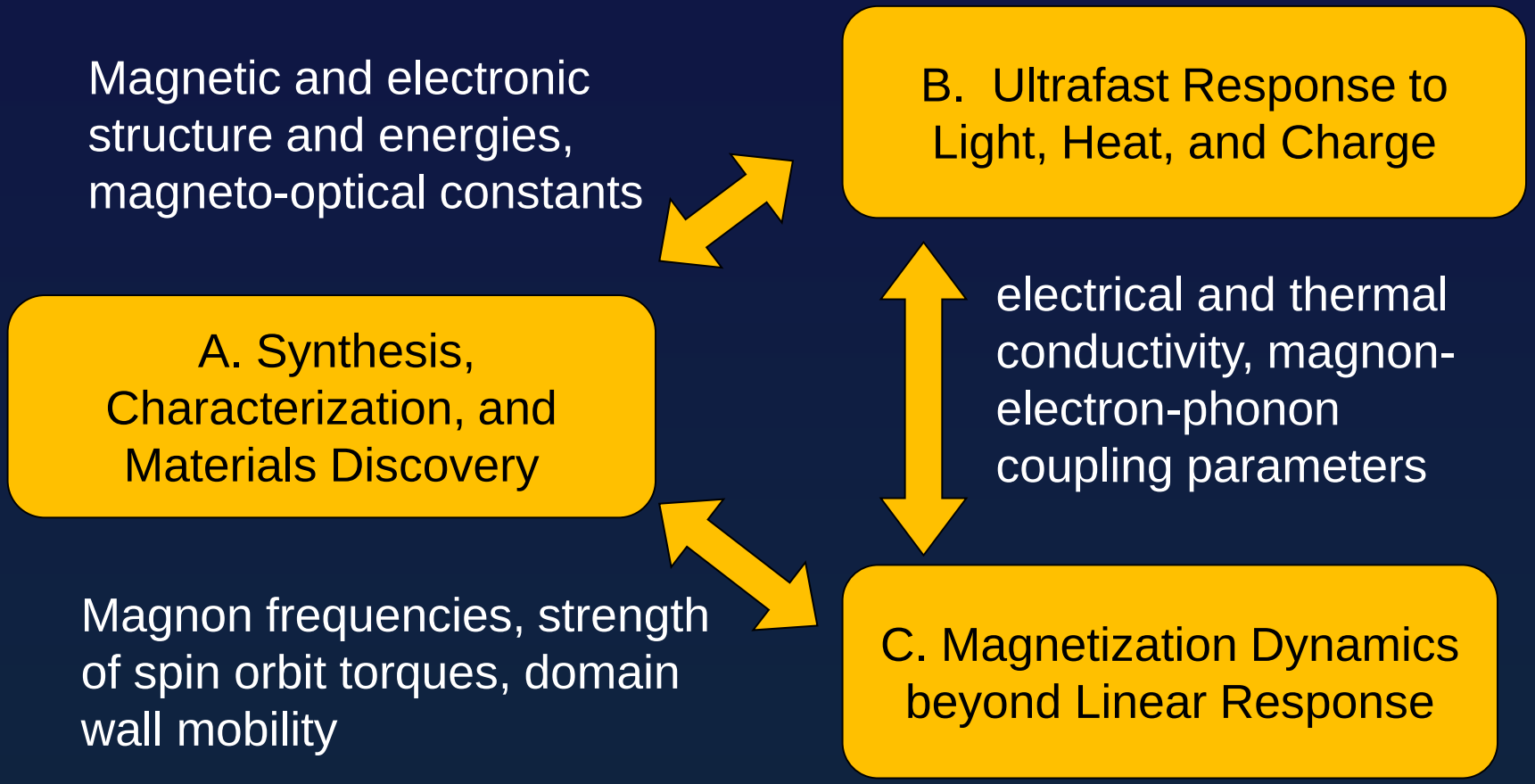
Magneto-transport



First principles calculations

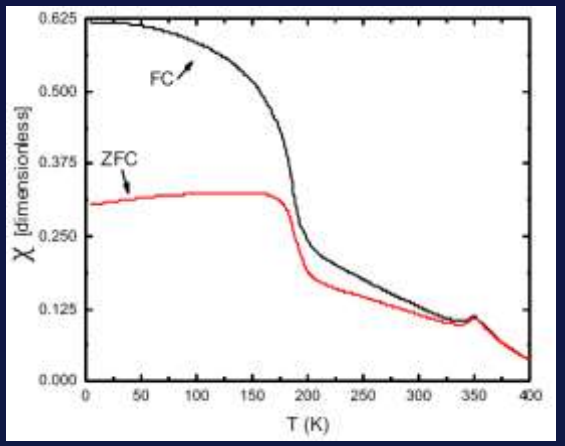
Coupled transport and magnetization dynamics

Thrusts


Magnetic and electronic structure and energies, magneto-optical constants
B. Ultrafast Response to Light, Heat, and Charge
electrical and thermal conductivity, magnon-electron-phonon coupling parameters
A. Synthesis, Characterization, and Materials Discovery
Magnon frequencies, strength of spin orbit torques, domain wall mobility
C. Magnetization Dynamics beyond Linear Response

Example, Thrust A:

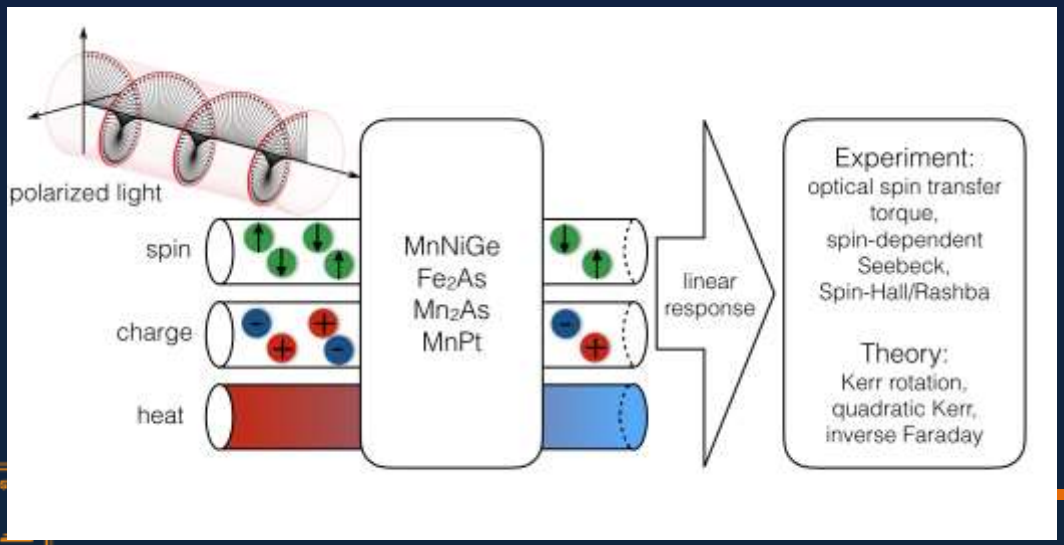
Synthesize metallic antiferromagnetic (AF) materials and Establish link between magnetic and electronic structure, susceptibilities, and coupling parameters

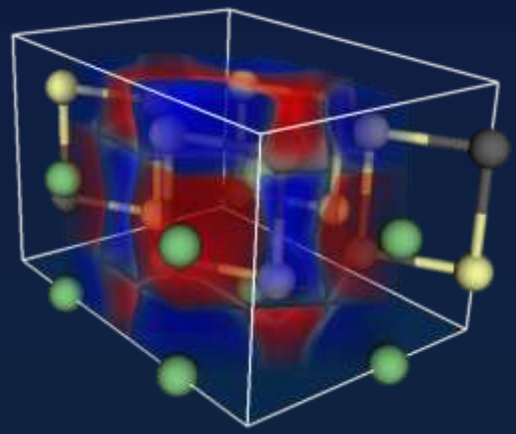


MnNiGe magnetic susceptibility

Example, Thrust B:

Fast heating by pump optical pulse, probe response by time-resolved Kerr rotation in a magnetic field to determine coupling of magnetization to the thermal bath of electrons/phonons





MnNiGe calculated spin density

Intellectual Merit

We will determine limits on the …

- Rate that AF order parameter can be manipulated by a fast temperature excursion
- Current-induced internal magnetic field generated by spin-orbit coupling
- Generation of spin currents, spin accumulation, and spin-orbit torques
- Extent to which spin-orbit torques are enhanced at interfaces
- Switching of the AF order parameter
- Strength of magneto-optic effects and potential for optical control

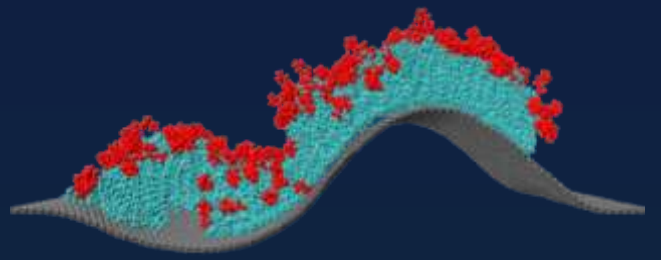
A long-term impact of our IRG will be the discovery of new materials with enhanced response to optical, electrical, and thermal excitations.

IRG2: Active interfaces between highly deformable nanomaterials

- Advance fundamental understanding of how functional properties of nanomaterials and bio-interfaces are tuned by large multi-scale deformations
- Discover new material structures which are simultaneously highly-deformable and electrically active.

Relevant to:

- Conformable electronics for bio and cell interfacing
- Strain resilient devices for 3D flexible and wearable electronics



IRG Team

CVD growth, Nanomechanics, crumpled 2D materials & hetero-structures

Mason

Murphy

Nam

Fabrication, characterization

Interfacial chemistry

3D templated biomolecular nano-interfaces

Huang

van der Zande

Bashir

Ertekin

Aluru

Theory & multi-scale simulation

Ab-initio methods, Atomistic, Coarse-Grained and Quasi-Continuum Techniques

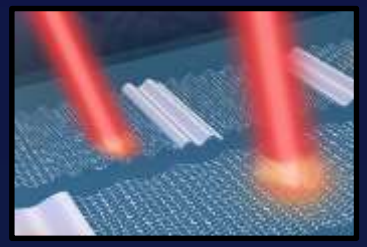
Biological Collaborators (unfunded)

Rhanor Gillette, UIUC

Michael Sheetz, Columbia/ MBI

Thrusts:

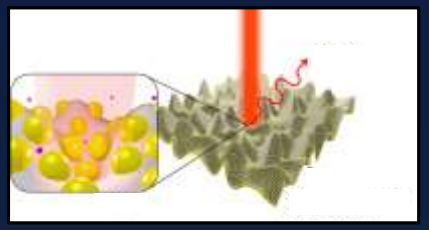
Mechanically tunable devices

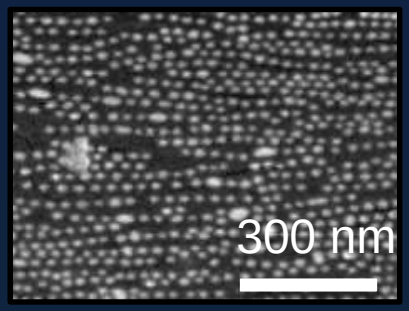


B. Emergent electronic properties of deformed nanoscale materials and interfaces

A. Structure and mechanics of deformations in nanoscale interfaces

Electromechanical sensing of chemical interactions



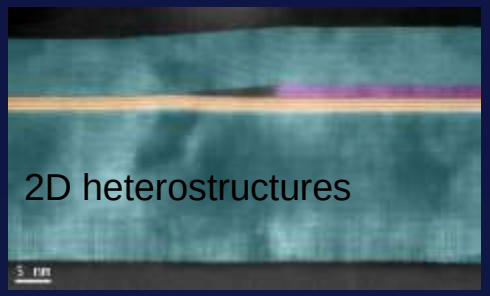


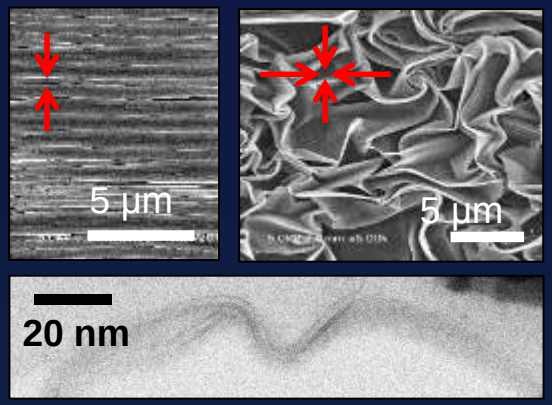
Mechanically informed bio-assembly and restructuring

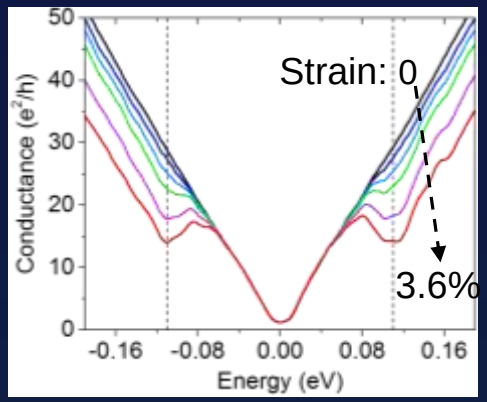
C. Chemical and biological interactions with deformed hybrid interfaces

Example, Thrust A/B:

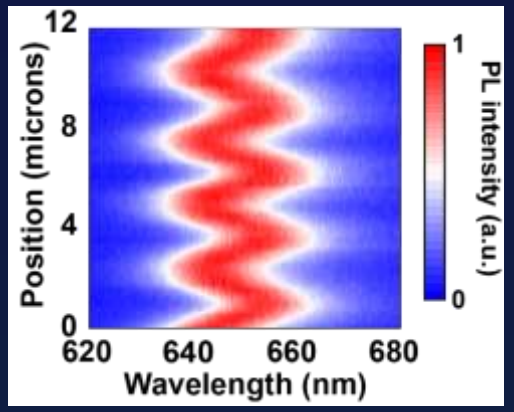
Modeling & fabrication of crumpled 2D heterostructures; measure change in optical and electronic properties







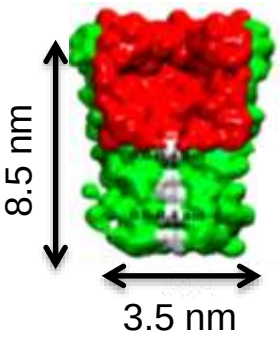
Strain-induced superlattice states in graphene (2D)

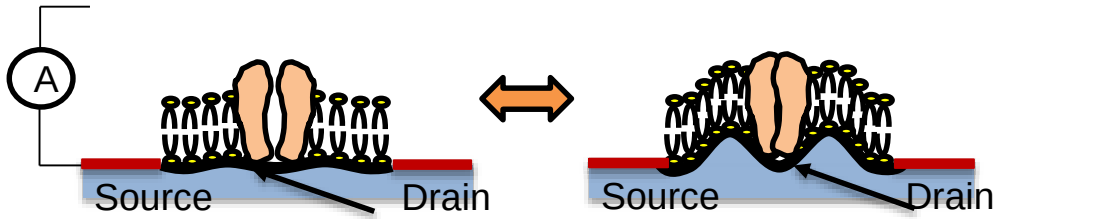


Curvature induced variations in band transitions in MoS_2 (1D)

Example, Thrust C:

Add mechanosensitive ion channels (e.g. MscL) to lipid bilayer





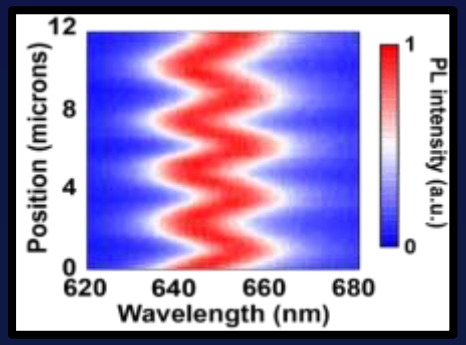
Measure ionic current & gating from 2D material device to solution via the channel

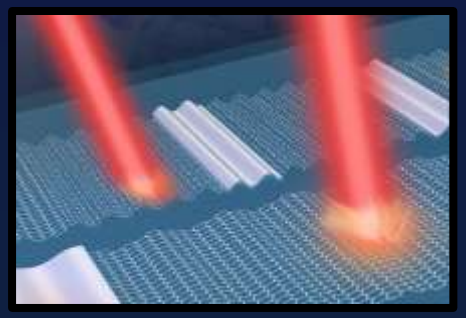
Can we tune protein function by crumpling its 2D substrate?

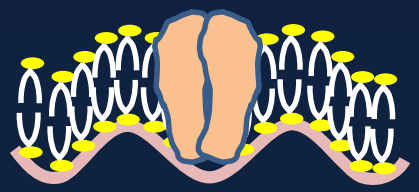
Intellectual Merit

We will …

- Quantify the structure and dynamics of deformations of atomically thin materials and interfaces with curvatures from 10 nm to 10 microns.
- Unravel the interaction between emergent electronic, plasmonic and quantum states, hybrid material interactions, and mechanical deformations.
- Demonstrate synergistic effects of biomolecular form and function on 2D substrates that deform into 3D structures







A long-term impact of our IRG will be the discovery of new materials which are simultaneously highly-deformable, electrically active, and can be interfaced with biologically-relevant structures

iMRC Education & HR Development

Integrated education, outreach, and development activities for all levels of students & faculty

Focus on science communication: workshops for i-MRSEC participants, outreach events for K-12 and public, online videos

REU program, Materials Bootcamp, graduate & postdoc training

Guided by diversity strategic plan & integrated assessment

Outreach coordinator: staff position supported by I-MRSEC to handle organization and logistics

Science Communication

Multi-faceted program to improve science communication and public understanding and confidence in science

Components:

- Workshops and Training for iMRC faculty, students, and post-docs
- Outreach Events (Science Slams, Engineering Open House)
- Movie-Quality Online Videos

Research Experience for Undergraduates

Hands-on training in cutting-edge iMRC research techniques

Support 8 students per summer

Goal: at least 50% participation by female and URM students

Materials growth and characterization training via MRL SIT-UP program

Career development workshops based PHYS496 course: technical writing & speaking, communicating with the public, ethics, applying to graduate schools

Materials Bootcamp

Educate I-MRSEC and external participants, students, and staff in frontier materials science & instrumentation

One day, preceding annual Advanced Materials Characterization Workshop

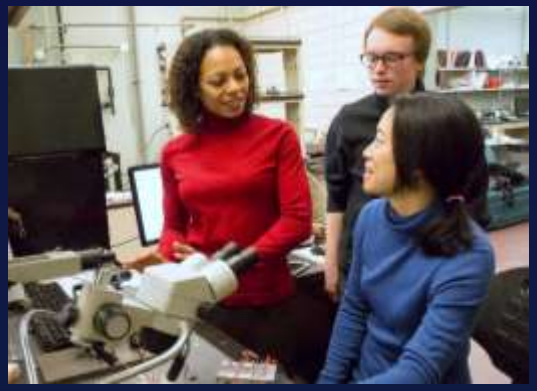
Hands-on training combined with lectures

- Speakers from academia, industry, and national labs
- Enhance connections: industrial participants

Faculty & staff from Midwestern & URM institutions: I-MRSEC as regional hub

Graduate & Postdoctoral Training

Annual support for 19 graduate students and 6 post-doctoral researchers



Enhanced training & professional development opportunities

- Instrumentation training leveraging MRL
- Bi-weekly journal club
- IRG-related seminars, career opportunity seminars, Women in Science meetings

Leadership skill development:

- Illinois Leadership Center workshops
- Student Leadership Council involvement in iMRC management

Diversity Strategic Plan: Recruitment & Retention

Targets for participation
of under-represented students, postdocs, and faculty

Expand pool of URM students via targeted recruiting and outreach

Assessment and Evaluation

Assess student recruitment, faculty involvement, career
& professional development, effectiveness of outreach & diversity plan

Directed by Luisa Rosu, I-STEM Interim Director

Campus coalition grounded in Education
school and led by the Office of the Provost

Reporting system:
longitudinal survey data on faculty, students, postdocs

Data on diversity metrics; climate study at mid-point

Leverage Extensive Shared Facilities

Frederick Seitz Materials Research Laboratory (MRL)

50,000 sq ft lab space; 50,000 sq ft facilities
More than 65% PI team is co-located in MRL

Micro and Nanotechnology Laboratory

User facility with 16 clean rooms and a 2,500 ft^2 biosafety level-2 bionanotechnology complex

Beckman Institute for Advanced Science and Technology

User facility for interdisciplinary research & specialized microscopy

National Center for Supercomputing Applications

Blue Waters petascale computer, Campus Cluster, Materials Data Facility data repository

Argonne National Lab Magnetic Facilities

Magnetic films group facilities; Center for Nanoscale Materials

Broad Access to MRL Central Facilities

MRL houses one of the premier midscale, shared facilities in the nation

Center for Microanalysis of Materials
Micro/Nanofabrication Facility
Laser and Spectroscopy Facility

- Operating budget = $2.2 M/yr (direct cost)
  [UIUC contributes $1.05 M/yr]
- More than 40 major instruments ($35 M equipment)
- 24 h access and training by 20 staff scientists
- Dedicated safety officer, integrated safety training
- Straightforward access for new I-MRSEC users, space available for new I-MRSEC facilities

I-MRSEC will be based in MRL and leverage staff, facilities, and administration

Enhancing materials infrastructure

Planned new facilities:

THz spectroscopy, Controlled environment for material synthesis

Development of cross-cutting theoretical and experimental techniques

Strengthening midsize facility (MRL)

- MRL facilities serves > 1000 users: 200 undergraduates, 580 graduate students, 60 industrial/outside academic
- Impact of I-MRSEC will be significant

Illinois MRSEC

Funded by NSF DMR-1720633
"Which supports fundamental research across disciplines, that benefits society"

Thank you!