

Academic and Research Highlights

Fall 2020

School of Materials Science & Engineering

Naresh Thadhani
Professor and Chair
naresh.thadhani@mse.gatech.edu

MSE Over the Years

- 1897 President Lyman Hall founded A. French School of Textile Engineering – 3rd School to open at GT
- 1924 Advent of kaolin industry - School of Ceramic Engineering formed with B.S. degree program
- 1985 School of Materials Science & Engineering formed from merger of Ceramics and Metallurgy
- 2003 Textile Engineering School renamed School of Polymer, Textile and Fiber Engineering (PTFE)
- 2010 Merger of PTFE with Ceramics & Metallurgy into largest and most diverse MSE program in nation



J. Erskine Love Jr. Manufacturing Building
2000-present



The Present MSE – Faculty by the Numbers

- ❑ **41** Faculty, **9** joint appts., 35.57 FTE, 2 lecturers
- ❑ **34** Courtesy and Adjunct Faculty
- ❑ **6** Chair & **5** Regents' Professors
- ❑ **9** Female (**1** Chaired) & **3** URM Faculty
- ❑ **16** AFOSR/DOE/ONR/NSF/ Career/YIP Awards
- ❑ **1** NAE (US), **1** NAE China
- ❑ **22** Faculty Prof. Soc. Fellows (**41** Fellowships)

The Present MSE – Students by the Numbers

UNDERGRADUATE

- ❑ 275 total: 35%Female/65%Male
- ❑ 44% GA/ 56% Out of State/ 12% International
- ❑ 100% Co-op/Internship/Research
- ❑ USN&WR MSE Rank – 4th

GRADUATE

- ❑ 204 total: 76%PhD/24%MS; 37%Female/63%Male
63%Domestic/37%International
- ❑ 20-25 Non-MSE students
- ❑ 10% Internships (Industry & Natl.Labs)
- ❑ USN&WR MSE Rank – 9th

Materials Science & Engineering (MSE) Programs

Materials Certificate Programs

➤ UG - B.S. Degree: 132 hours

- 21 hours in concentration and 6 hours of capstone design
- Conc: Bio-Materials, Polymer & Fiber Materials, Structural and Functional Materials
- Options: Co-op, Research, Study-abroad, Business

➤ GRAD – Ph.D.

- 2 core + 5 elective + 3 Minor + Seminar, Qualifier, Proposal, Dissertation defense
- Internship, Entrepreneurship, Teaching Practicum
- Matls Science & Eng; Bio-Eng.



Multidisciplinary Biomaterials Certificate Program
for Georgia Tech Undergraduate Students

An undergraduate Multidisciplinary Certificate in "Biomaterials" may be earned by completing the following requirements according to the student's major. Courses must be taken on a letter-grade basis and a grade of "C" or better must be obtained in order to count toward the certificate. Courses must be taken on a 1 letter-grade basis.

EXCEPTIONS: A student may not apply for any course towards the certificate that is required for his/her major.

APPROVED COURSES

| | |
|---|--|
| MSE 2001 Principles and Applications of Engineering Materials Credits: 3-0-3 Prerequisite: CHEM 1310 | CHEM 3412 Physical Chemistry II Credits: 3-0-3 Prerequisites: CHEM 1311 and PHYS 2212 |
| MSE 2021 Materials Characterization Credits: 3-3-4 Prerequisite: PHYS 2212 | ECE 4752 Integrated circuit fabrication Credits: 3-0-3 Prerequisites: ECE 3040 or ECE 3710 |
| MSE 3015 Electrical, Optical, and Magnetic Properties Credits: 3-0-3 Prerequisite: MSE 2001 | PHY 3143 Quantum Mechanics I Credits: 3-0-3 Prerequisites: (PHYS 2212 or PHYS 2232) and (MATH 2403 or MATH 2413) |
| MSE 3015 Electronic Applications Credits: 3-0-3 Prerequisite: MSE 2001 | PHY 4262 Solid State Physics Credits: 3-0-3 Prerequisite: PHYS 3143 |

Other courses related to biomaterials may also be counted subject to the approval of the Program Director for Biomaterials Certificate.

FOR INFORMATION CONTACT:
Professor Fred L. Cook
Associate Chair for Undergraduate Programs
fred.cook@mse.gatech.edu
404.894.2536



Multidisciplinary Composites Certificate Program
for Georgia Tech Undergraduate Students

General Perspectives

The output composites have, due to the use of electronic, produced materials selected areas in a significant way with high performance. They have had appropriate formal training in need here by providing students from the vanguard composites.

Objectives

The object of the undergraduate certificate the study of composites. The program is students while simultaneously demanding mandatory core. The required core cover behavior and also offers hands-on experience. Extensive opportunities are also offered to students.

Course of Study

Semester Hours

- A. Required Core Courses (6 hours, 4791 & 4793)
- 4791 Mechanical Behavior of Composites
- 4793 Composite Materials and Processing
- B. Electives (6 hours) (these courses CANNOT be taken concurrently with 4791 or 4793)
- COE 3001 Mechanics of Deformable Bodies
- ME/CHE/MSE/PETE 4775 Polymer Science
- PFE 2200 Fiber Science
- CEE 4520 Reinforced Concrete Design
8. Relevant undergraduate or graduate course

SPECIAL PROBLEMS IN COMPOSITES:
Special topics to be arranged using approval of the Program Director.
*Special requirements may have to be met for registration.

Students interested in this program should contact:
Dr. Fred L. Cook
Program Director
fred.cook@mse.gatech.edu
404.894.2536



An Undergraduate Certificate in Nanomaterials

may be earned by completing the 12 credit hours taken from the list of classes below.

REQUIRED CLASSES:

- MSE 4330 Fundamentals of Nanomaterials and Nanostructures
- Credits: 3-0-3 Prerequisite: MSE 2001
- MSE 4335 Soft Nano and Bio Materials
- Credits: 3-0-3 Prerequisite: MSE 2001

A grade of "C" or better must be obtained in order to count toward the certificate. Courses must be taken on a 1 letter-grade basis.

EXCEPTIONS: A student may not apply for any course towards the certificate that is required for his/her major.

For example, MSE majors cannot use MSE 2021 as it is specifically required for the MSE major. At least 3 credit hours must be outside the student's major field (cross-listed courses satisfy this requirement) at least 9 credit hours must be at the 3000 level or higher.

APPROVED COURSES

| | |
|---|--|
| MSE 2001 Principles and Applications of Engineering Materials Credits: 3-0-3 Prerequisite: CHEM 1310 | CHEM 3412 Physical Chemistry II Credits: 3-0-3 Prerequisites: CHEM 1311 and PHYS 2212 |
| MSE 2021 Materials Characterization Credits: 3-3-4 Prerequisite: PHYS 2212 | ECE 4752 Integrated circuit fabrication Credits: 3-0-3 Prerequisites: ECE 3040 or ECE 3710 |
| MSE 3015 Electrical, Optical, and Magnetic Properties Credits: 3-0-3 Prerequisite: MSE 2001 | PHY 3143 Quantum Mechanics I Credits: 3-0-3 Prerequisites: (PHYS 2212 or PHYS 2232) and (MATH 2403 or MATH 2413) |
| MSE 3015 Electronic Applications Credits: 3-0-3 Prerequisite: MSE 2001 | PHY 4262 Solid State Physics Credits: 3-0-3 Prerequisite: PHYS 3143 |

Other courses related to nanomaterials may also be counted subject to the approval of the Program Director for Nanomaterials Certificate.

FOR INFORMATION CONTACT:
Professor Fred L. Cook
Associate Chair for Undergraduate Programs
fred.cook@mse.gatech.edu
404.894.2536

Computational Materials Science & Engineering



The MILL - Materials Innovation and Learning Laboratory

An Open-access Make & Measure Space



The equipment for the MILL has been acquired with the generous support of the following sponsors.



Art and Patricia Cox



HEADQUARTERS

Erskine Love
Manufacturing
Building
Room 176

For more info,
email:

themillgt@gmail.com



Ceramic Processing

SEM/EDX

XRD

ATR-FTIR

UV/Vis

3D Printers

Mechanical

Hardness

MSE Education and Research Paradigm

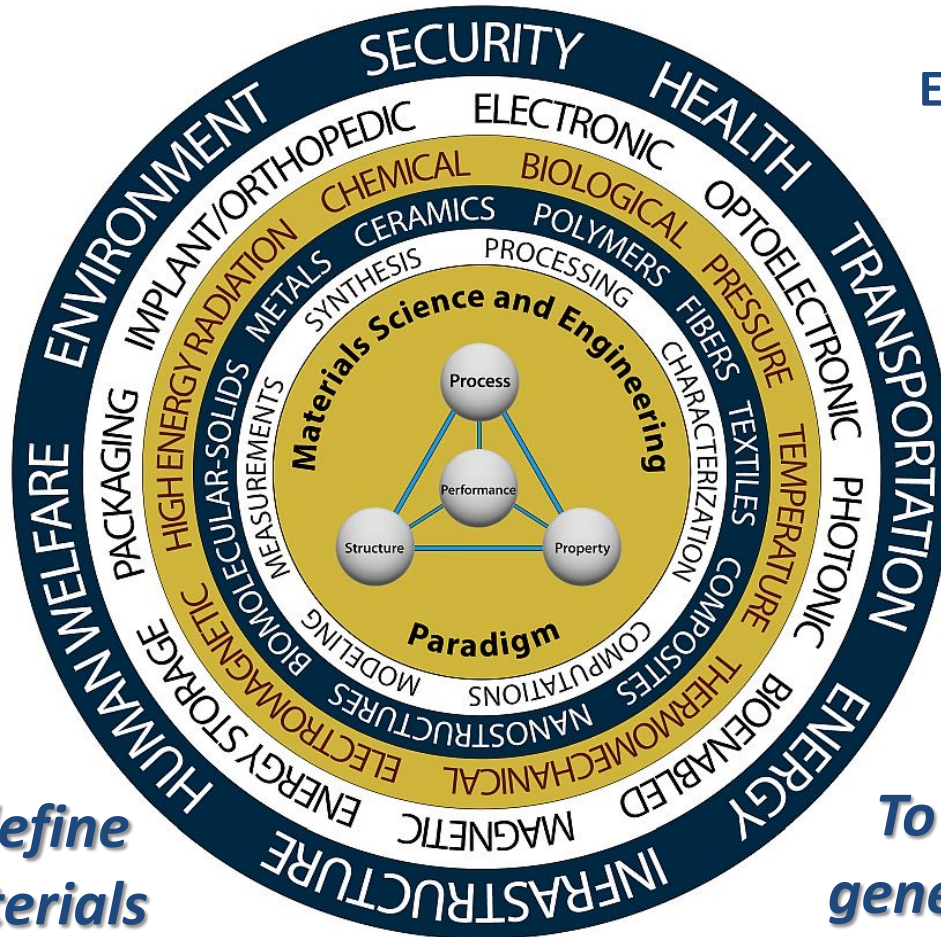
Enabling Discipline

Curriculum plus Education

Experiential Learning

VISION

MSE at GT will define the future of materials science & engineering through academic & research excellence



Entrepreneurship & Innovation

Discovery of New Materials

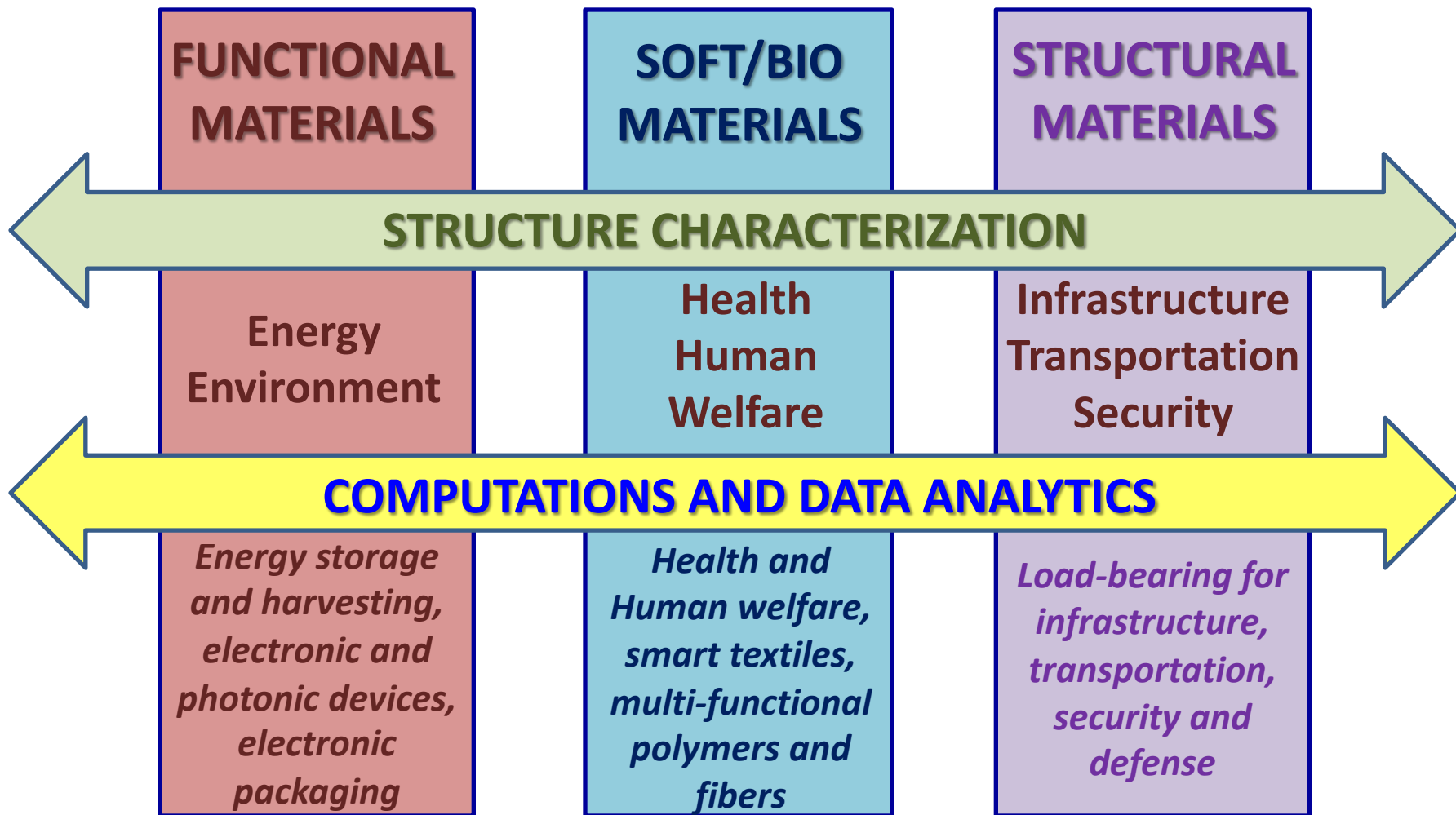
Deployment in New Applications

MISSION

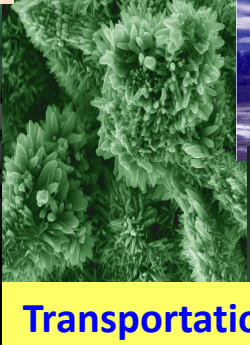
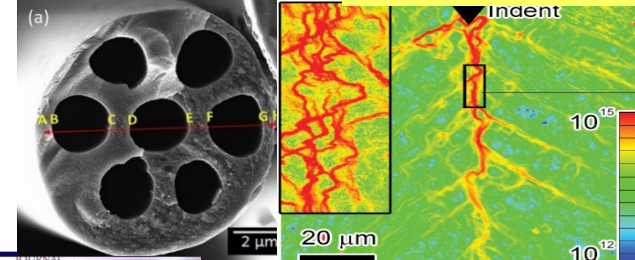
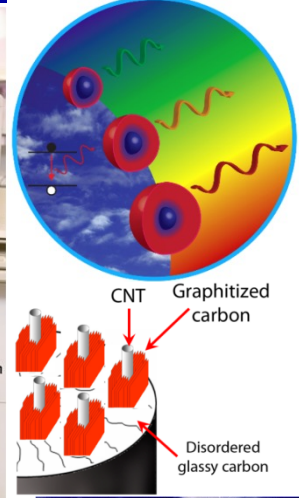
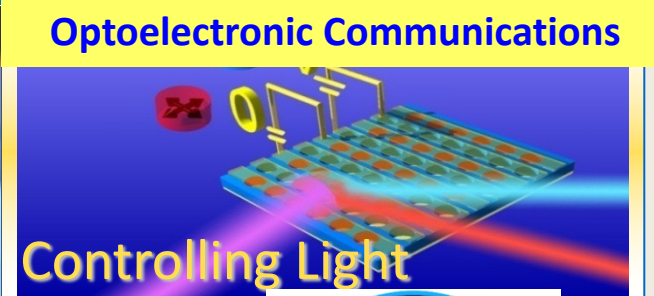
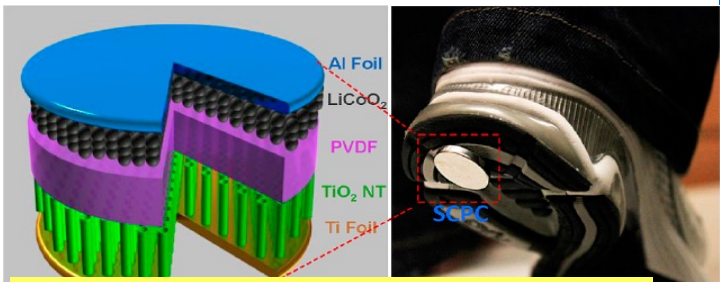
To create the next generation of leaders through education, research innovations, and service to society

TOPICAL WORKING GROUPS IN MSE

Materials – Metals, ceramics, polymers, fibers, textiles, composites, nanostructured, and bio-inspired materials



The World of Materials Research in MSE @ GT



Bio-enabled and Bio-inspired Materials



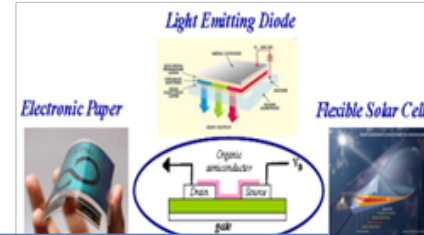
Mohan Srinivasarao



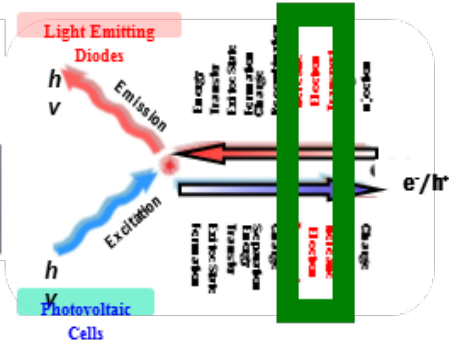
Optics & physics of polymeric fluids & nematic liquid crystals

POLYMER THIN FILM FOR ORGANIC ELECTRONICS

Applications of Conducting Polymer



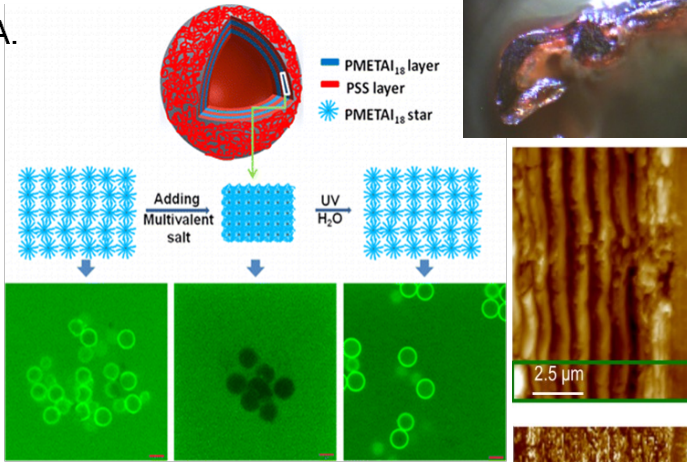
Operation of Organic Electronics



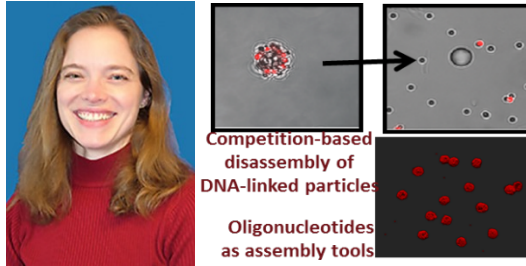
G. L. Brode et al., Chemical Reviews, 104, 4971 (2004)

Vladimir Tsukruk

A.

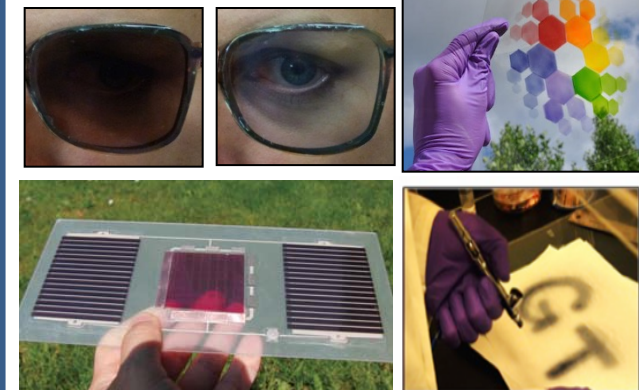


Valeria Milam

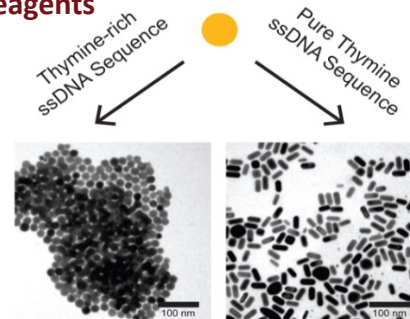


Design, synthesis, and processing of soluble conjugated organic molecules and polymers for electrochemical and solid-state applications

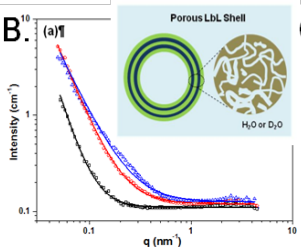
John Reynolds



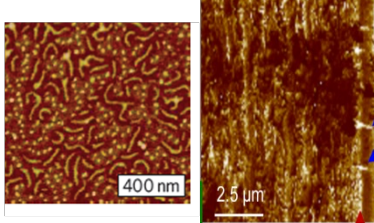
Oligonucleotides Gold Seed as reagents



B.



C.

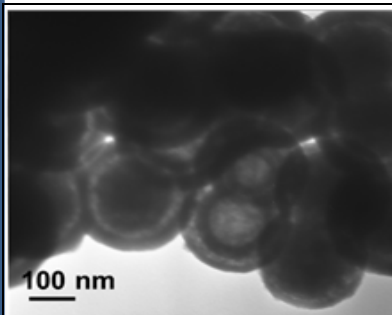


Materials For Health & Human Welfare

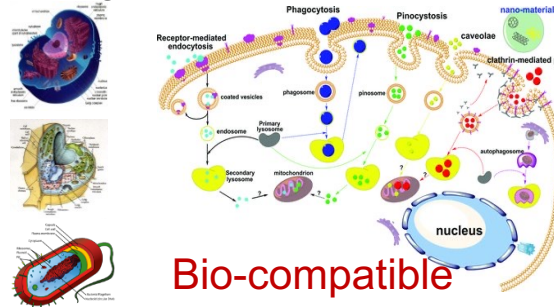
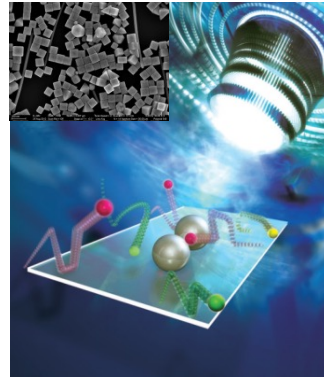


Paul Russo

Therapeutic drug delivery

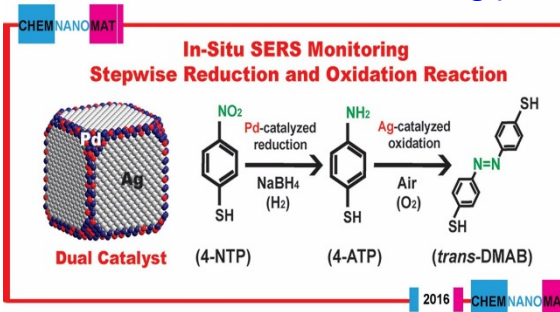


Dong Qin



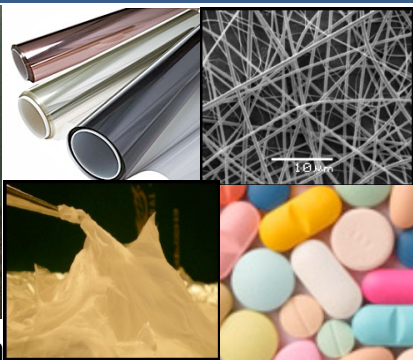
Bio-compatible Nano-platforms

Bimetallic nanocrystals with plasmonic and catalytic properties for applications in surface-enhanced Raman scattering (SERS)

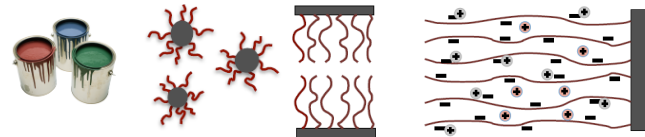


Sundaresan Jayaraman

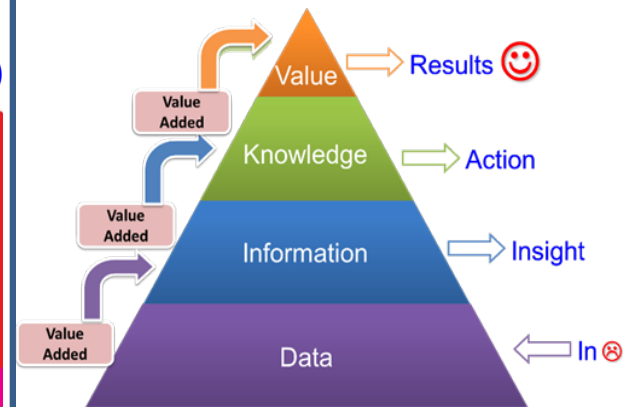
Fabric is the Computer!
Harnessing Pervasive Intelligence through Smart Wearable Fabric



Blair Brettmann



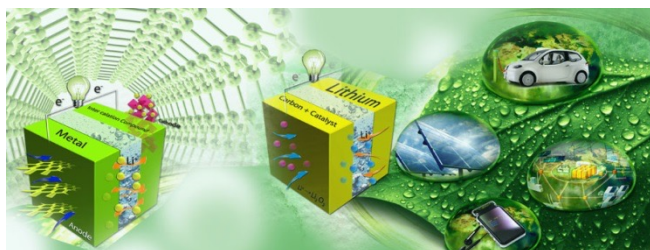
Data-Value Transformation Paradigm



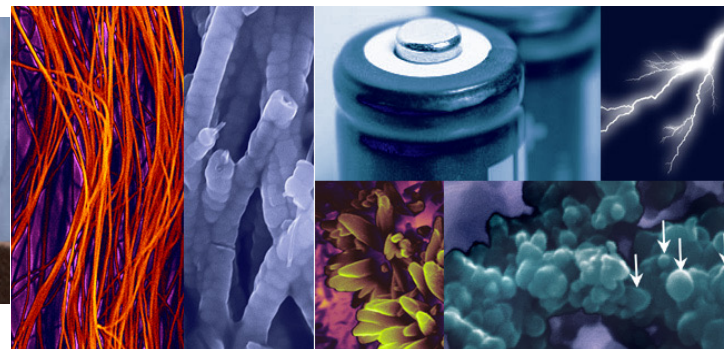
Materials for Energy Storage & Harvesting



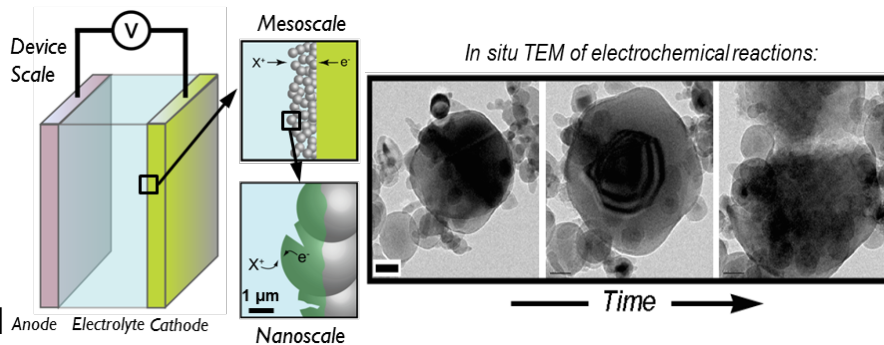
Fuel cells, Batteries, Supercapacitors for efficient storage & conversion



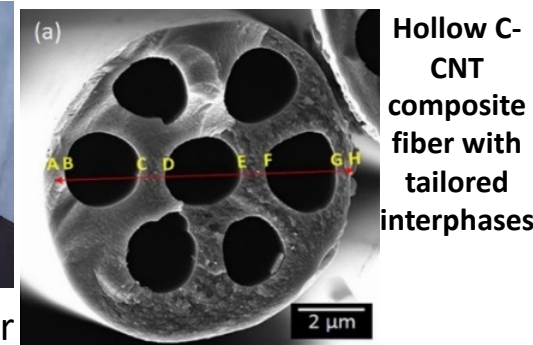
Meilin Liu



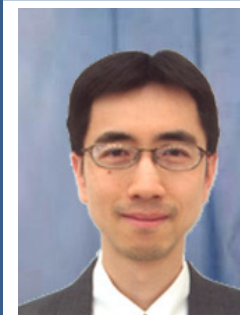
Gleb Yushin



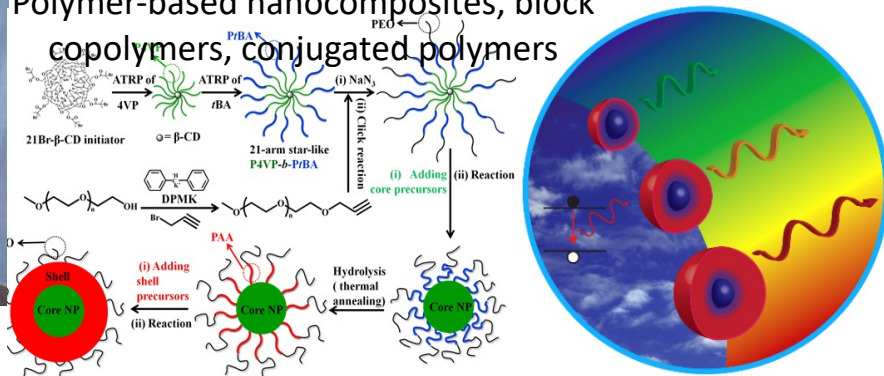
Matt McDowell



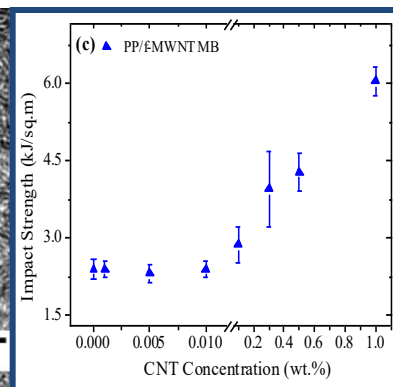
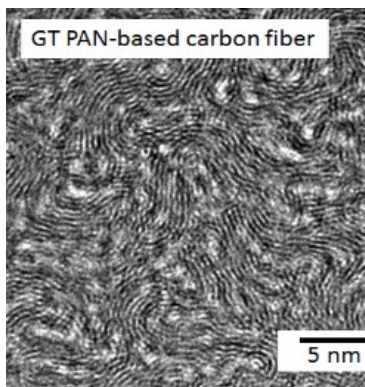
Satish Kumar



Polymer-based nanocomposites, block copolymers, conjugated polymers



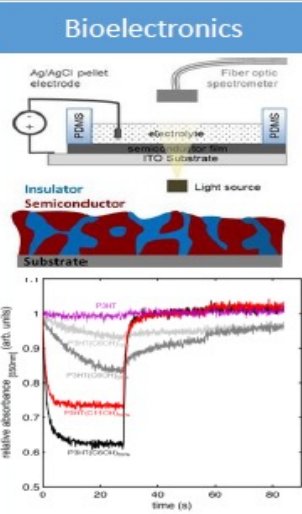
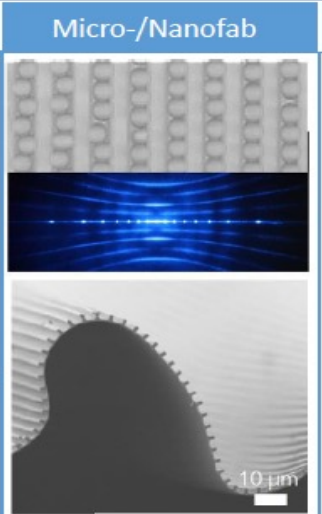
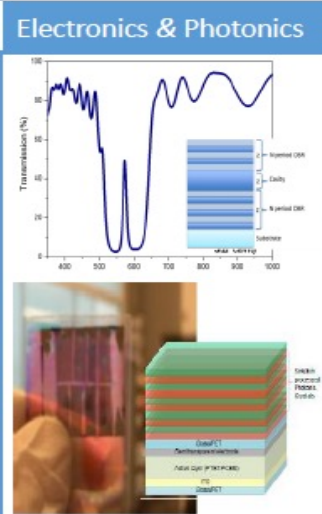
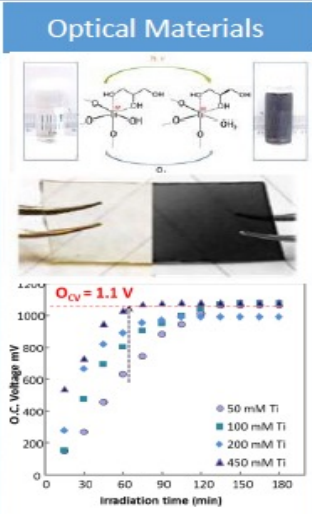
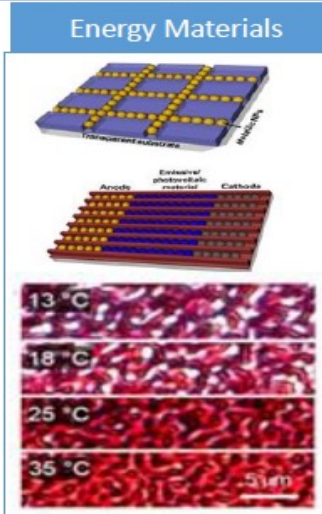
Zhiqun Lin



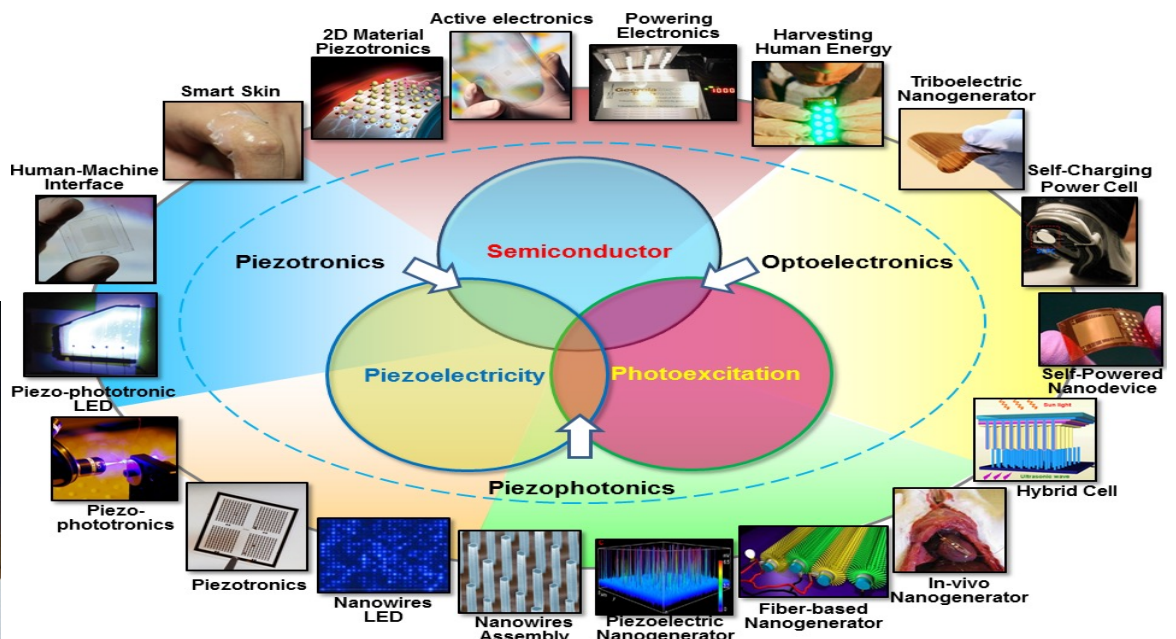
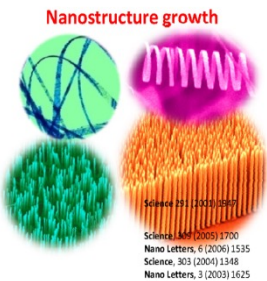
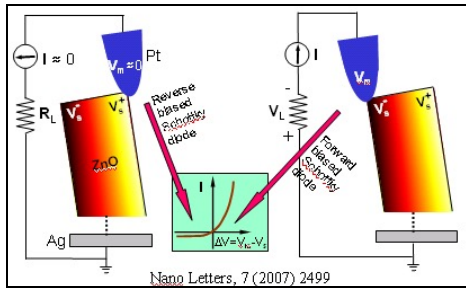
Active Materials & Self-powered Devices



Natalie Stingelin

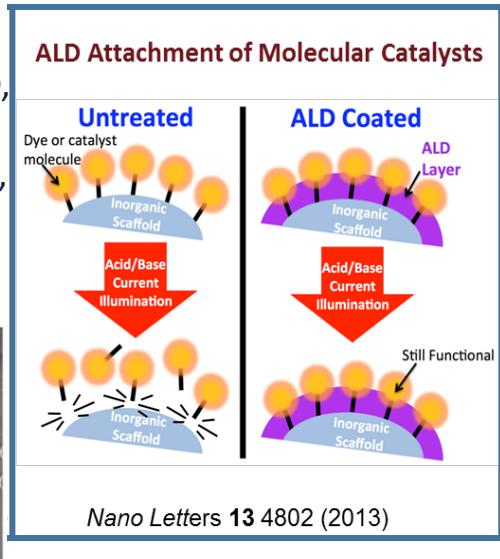
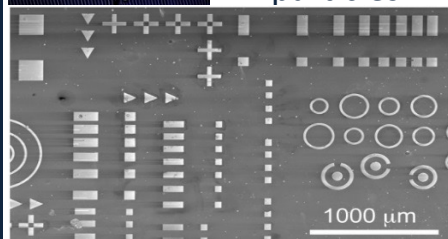


Zhong Li Wang

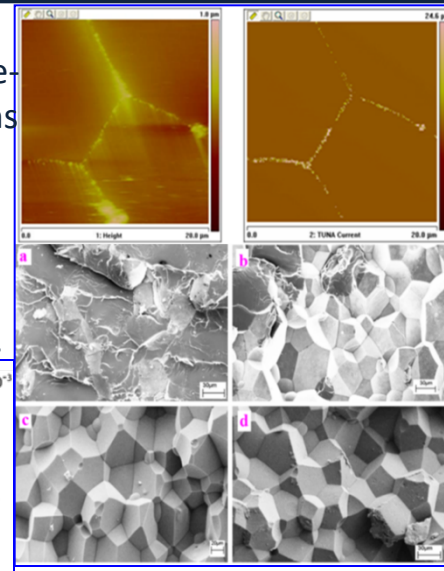
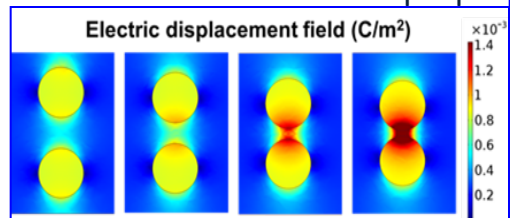


Electronic Devices: Synthesis & Fabrication

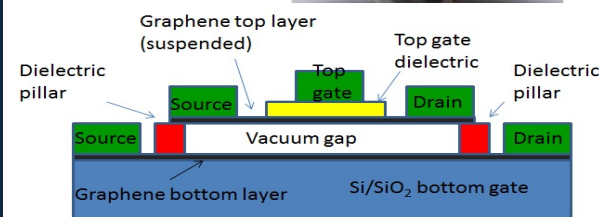
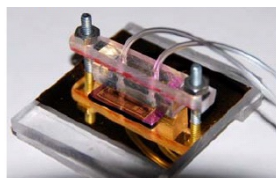
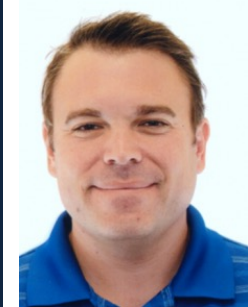
Mark Losego Synthesis via sputtering, ALD, surface polymerization, and colloidal assembly of particles



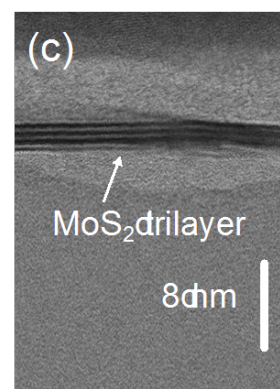
Rosario Gerhardt Process-structure-property relations in electronic materials, impedance spectroscopy, dielectric props.



Eric Vogel Synthesis, structure, and properties of electronic materials and devices

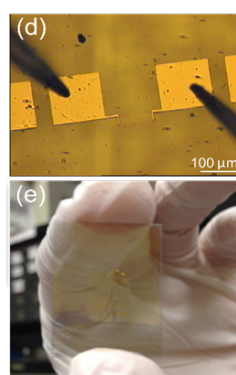


New Synthesis Methods



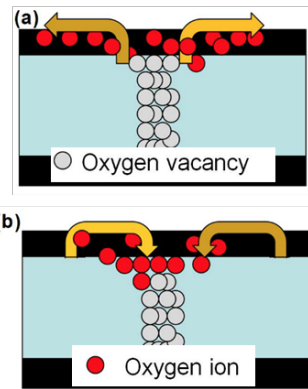
Chemical Vapor Deposition of MoS₂
Advanced Functional Materials **24**, 6389 (2014)

Novel Device Fabrication



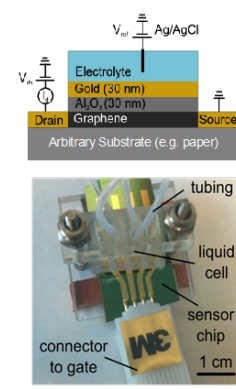
Flexible/transparent MoS₂ transistors
ACS Applied Materials & Interfaces **7**, 12850 (2015)

Atomic Scale Mechanisms



Filament formation in metal oxide memory
IEEE Electron Device Letters **35**, 750 (2014)

Applications



Graphene-based biosensor
2D Materials **2**, 044008 (2015)

Electronic, Optoelectronic, Packaging & Devices



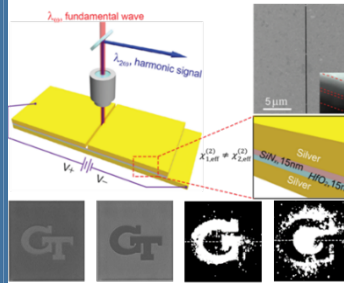
Nanophotonics, optoelectronics, plasmonic nanodevices, optical metamaterials, integrated photonics, optical sensing

Metamaterials with exotic properties



Advanced Materials 27 1124 (2015)

Nonlinear optics with plasmonics

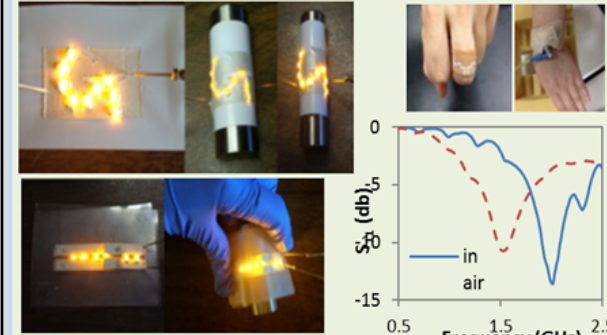


Nature Materials 14 807 (2015)

Wenshan Cai
Engineered nanostructures for light manipulation



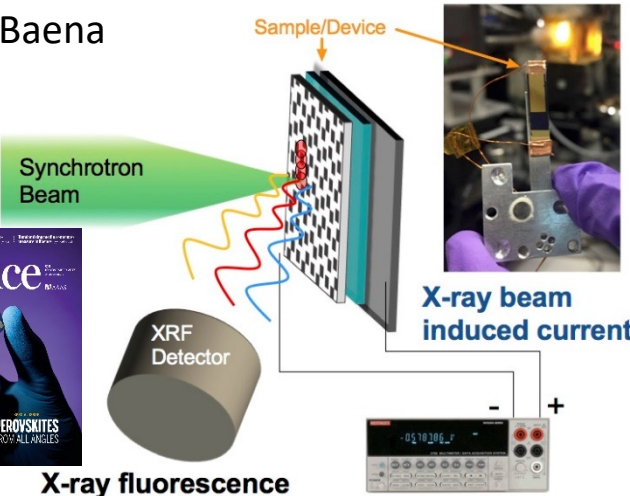
Wearable and printable devices



Highly conductive, flexible polyurethane-based adhesives for flexible and printed electronics

C.P. Wong

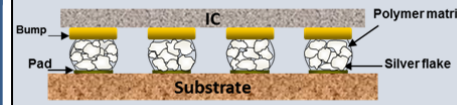
Juan-Pablo Correa-Baena



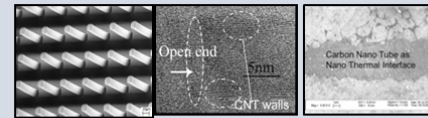
X-ray fluorescence

Understanding and controlling low-cost semiconductor electronic dynamics at nanoscale

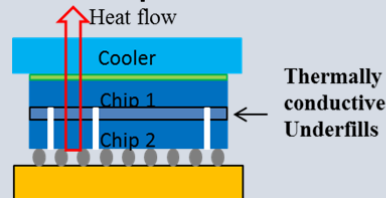
Electrical Interconnects



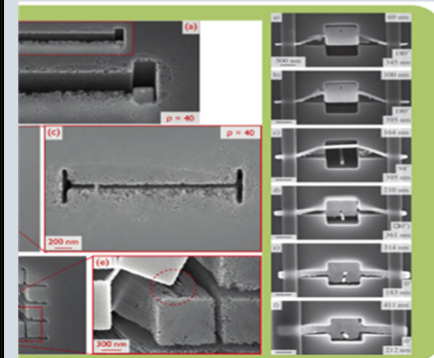
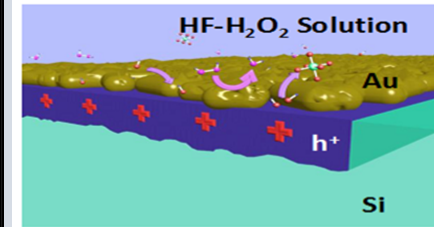
Nano Thermal interface materials (carbon nanotubes)



Thermally conductive IC Encapsulant Underfill



3D Nanomanufacturing



Infrastructure and Transportation

Auxetic & Tensegrity Structures

Meisha Shofner

Cellulosic Nanomaterials & Nanocomposites

Donggang Yao

Modeling & Simulation

Hybrid processes

Josh Kacher

Indent

Hamid Garmestani

Mechanical Design → Properties → Microstructure → Processing

Statistical Representation N-Point Function

$$P(X_n, P_n) = \sum_n P_n X_n$$

$$F(X_n, C_n) = \sum_n C_n X_n$$

$$\frac{dF^{inv}}{d\eta} = H^{inv} = \sum_{top} F_n^{inv}(\eta) \sigma_n^{top}$$

1. Digital and Mathematical Representation of Microstructures (materials...)
2. Mathematical Representation of Processing and evolution (*invertible* capabilities)
3. Proper and *invertible* Homogenization Techniques

Inverse Methodologies

- Materials Forensics
- Machining
- 3D Manufacturing

Chris Muhlstein

Materials Systems

Macro-to-Nano Length Scales

Deformation & Failure Phenomena

Preet Singh

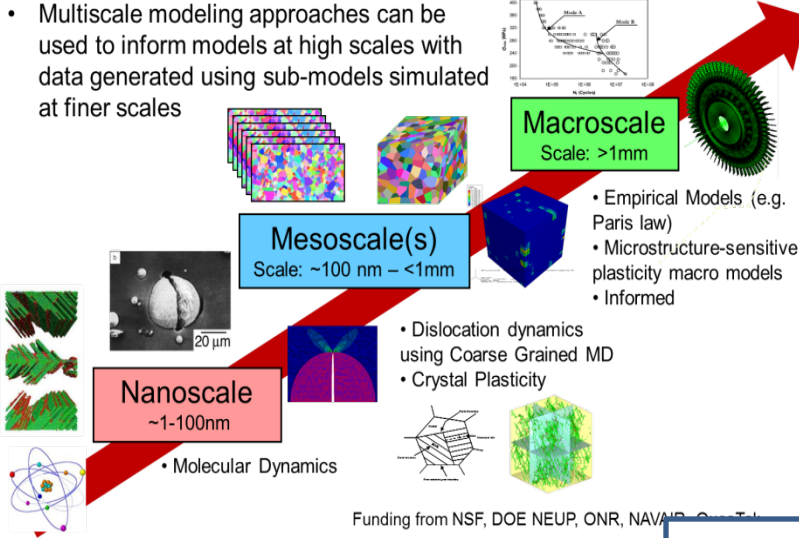
Stress Corrosion Cracking

Youjiang Wang

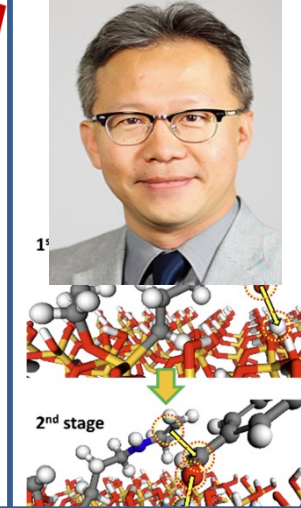
Computational Materials Science and Design



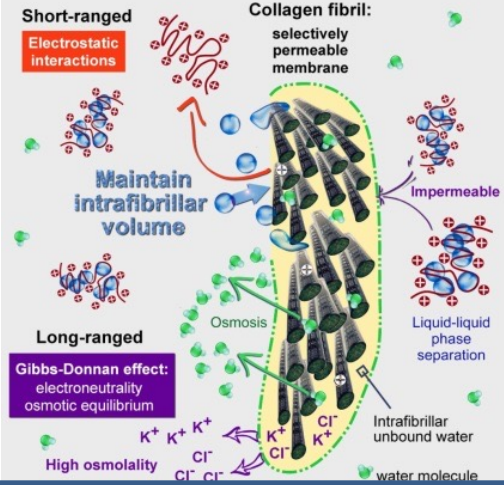
Dave McDowell



Seung Soon Jang

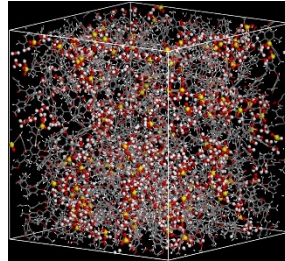


Collagen Mineralization

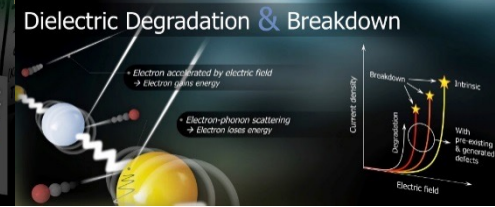
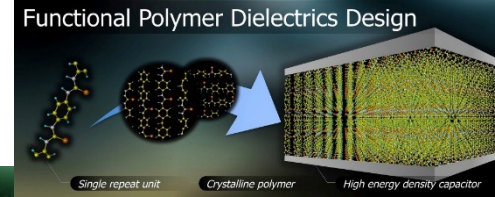
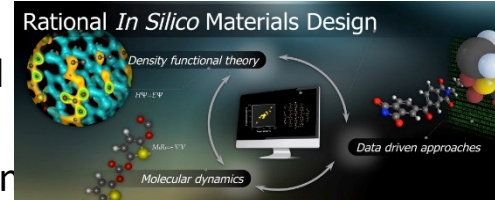


Karl Jacob

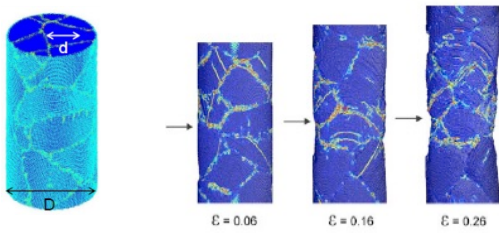
Experimental & computational approach to study material behavior



Rampi Ramprasad
Computational Aided Materials Discovery



Mo Li Electromigration in Nanoscale

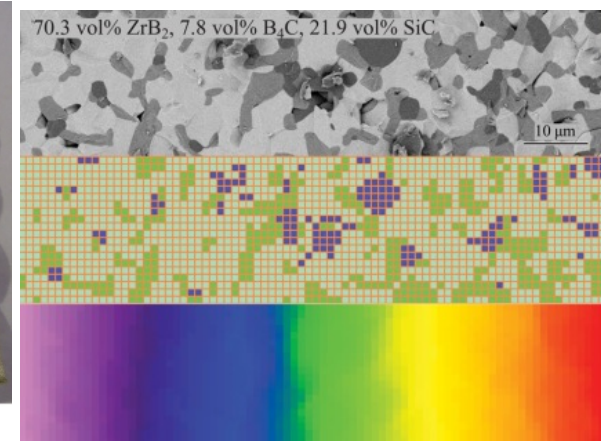
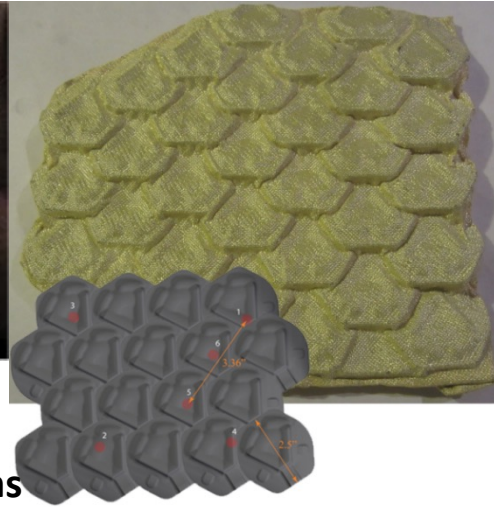


Materials Informatics & Machine Learning



Security: Materials Under Dynamic Extremes

Robert Speyer

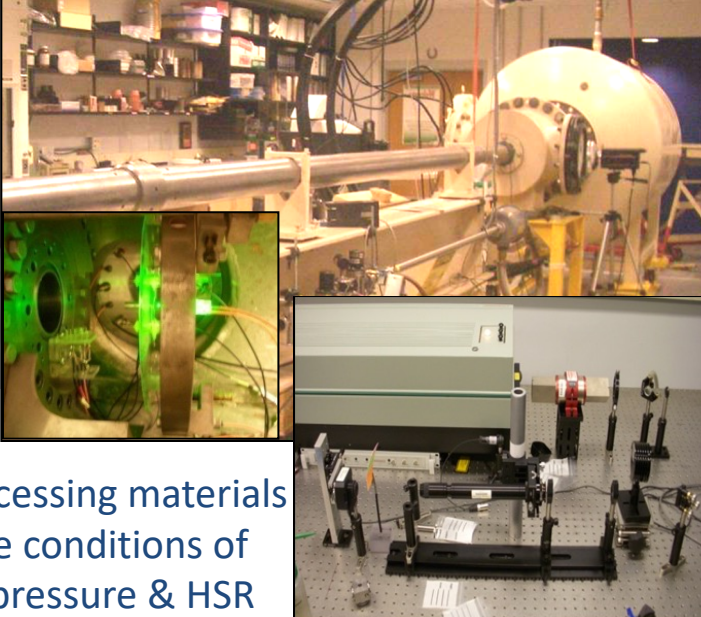


Thermal conductivity and emissivity

Ultra-hard ceramics (B_4C and SiC) for light-weight armor and ultra-high temperature ceramics (ZrB_2-SiC) for aerospace applications

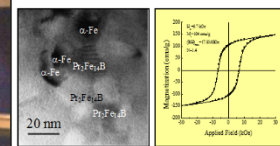


Naresh Thadhani



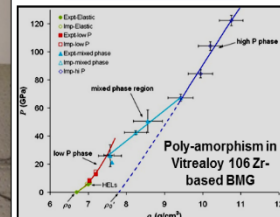
Probing and processing materials under extreme conditions of dynamic high pressure & HSR

MATERIALS PROCESSING



Shock-consolidated (Nd-Fe-B/ α -Fe) exchange-coupled nanocomposite permanent magnet ($BH_{max} \sim 18MGoe$)

PHASE TRANSITIONS



Poly-amorphism in Vitreloy 106 Zr-based BMG
Measurement of change in compressibility provides indication of phase transition in metallic glass

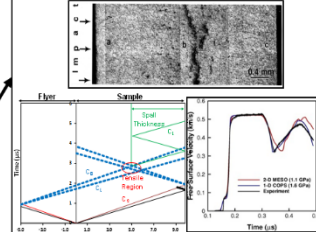
Traumatic Brain Injury
Short and long term diagnostics & modeling

High-pressure Shock-Compression

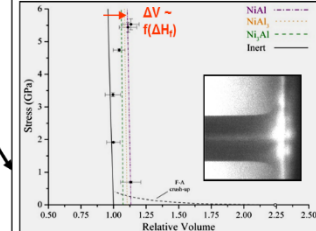
Projectile Impact (uniaxial stress)

Targeted Drug Delivery
Laser activation of nano-C allows drug permeation in cells

MECHANICAL BEHAVIOR



CHEMICAL REACTIONS



Time-resolved diagnostics of expanded state, wave-speed increase, light emission & strain gradients, reveal shock-initiation

"Materials" Research Across Georgia Tech

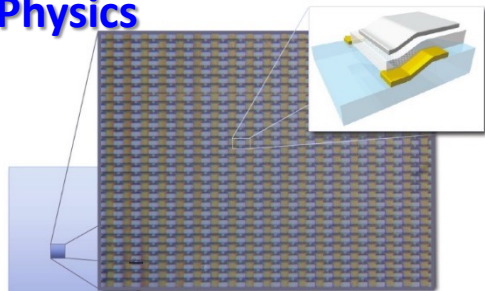
Georgia Tech

BIOLOGY

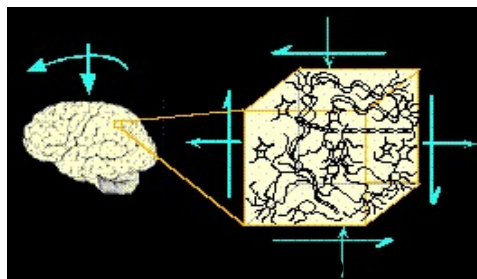
MOLECULAR & CELL BIOLOGY
COMPUTATIONAL BIOLOGY & BIOINFORMATICS
EVOLUTION, ECOLOGY & BEHAVIOR

Integrative & Systems Biology @ Georgia Tech

Physics

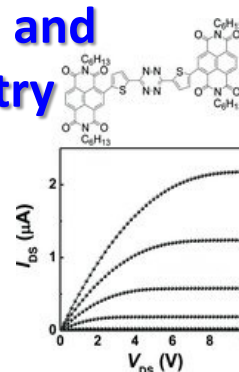


Epitaxial Graphene



Georgia Tech Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University

Chemistry and Biochemistry



Daniel Guggenheim School of Aerospace Engineering

Sand blasts on corrugated panels

Peridynamics modeling of damage

Chemical and Biomolecular Engineering



Georgia Tech School of Electrical and Computer Engineering

LEADING-EDGE RESEARCH

CROSS-DISCIPLINE EDUCATION

Electrical Design Mechanical Design Nano-Materials Nano-Components

Interconnections, Assembly, Reliability Thermal Technologies System Integration

GLOBAL INDUSTRY COLLABORATION

SYSTEM PROTOTYPES

Civil and Environmental



Georgia Tech Institute for Materials

Georgia Tech STAMI

Georgia Tech Manufacturing Institute

Goals/Needs (Inductive)

Performance

Structure

Properties

Processing

Cause and effect (Deductive)

System

Assembly

Part

Material Selection

Design methods are available

Goal-Oriented Design Methods

Cause/Effect Analysis Methods

Continuum

Mesoscale

Atomistic

Quantum

G.B. Olson, *Science*, 29 Aug., 1997, Vol. 277

Woodruff School of Mechanical Engin.

Georgia Tech Materials Characterization Facility

Marcus Nanotechnology Building

Marcus Characterization Lab

Loc. in basement of Marcus.

- FEI Nova Nanolab 200 FIB-SEM
- Hitachi HD2700 STEM
- Hitachi HT7700 TEM
- Hitachi SU8230 FE-SEM
- Hysitron T900 Nanoindenter
- Keyence Digital Microscope
- Kratos Axis-Ultra XPS
- Thermo K-Alpha XPS
- Thermo-Nicolet Confocal μ -Raman
- IONToF ToF-SIMS
- Veeco Dimension 3100 AFM
- Zeiss Ultra 60 FE-SEM

Panalytical X-ray Lab

Loc. in basement of Marcus

- Empyrean – Multipurpose XRD with SAXS
- X'Pert Alpha-1 MPD
- X'Pert PRO MRD XRD

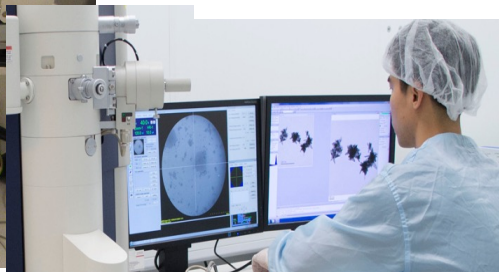
CNC Electron Microscopy

Located in PTB

- LEO 1530 SEM
- Hitachi SU8010 SEM
- JEOL 100 CX TEM
- Hitachi 2000 TEM
- FEI Tecnai F30 TEM



Hitachi HD2700 STEM



Empyrean Multipurpose XRD

Contact: walter.henderson@ien.gatech.edu



Thank you for



visiting