# The World of Materials at Georgia Tech

## Academic and Research Highlights
## School of Materials Science & Engineering

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**Professor and Chair**
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# The Past - Over the Years

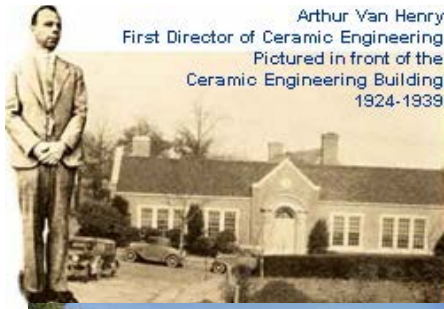
**1897** President Lyman Hall founded A. French School of Textile Engineering – 3rd School to open at GT

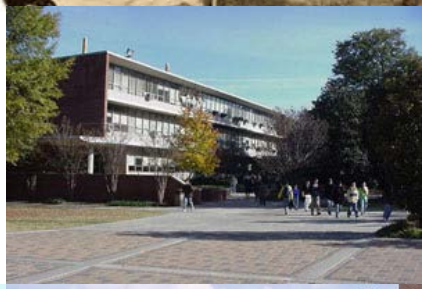
**1924** Advent of kaolin industry - School of Ceramic Engineering formed with B.S. degree program

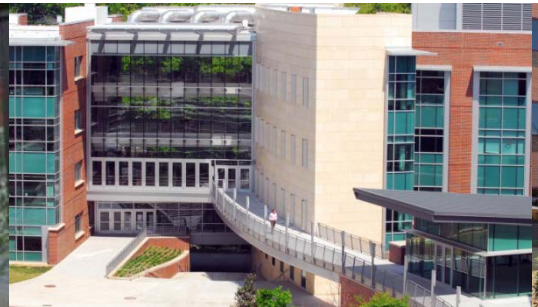
**1985** School of Materials Science & Engineering formed from merger of Ceramics and Metallurgy

**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




# The Present - By the Numbers

## FACULTY

- 40 Headcount, 8 joint appts., 35 majority Apt. in MSE, 35.6 FTE
- 18 Courtesy and Adjunct Faculty
- 10 Chair & 6 Regents' Professors
- 7 Female (1 Chaired) & 3 URM Faculty
- 13 NSF/ONR/DoE Career/YIP Awardees
- 2 NAE (US), 1 NAE China, 1 NAS China
- 39 Prof. Soc. Fellowships (22 Faculty)
- Research Expenditures: $14M (35% Ind)
- Degree Profile: 17 MSE, 8 ME, 7 Chem, 6 Poly, 6 Met, 3 Textile, 2 Elect, 2 Math, 2 Ceramics, 2 Phys, 1 Civil, 1 Chem. Eng.

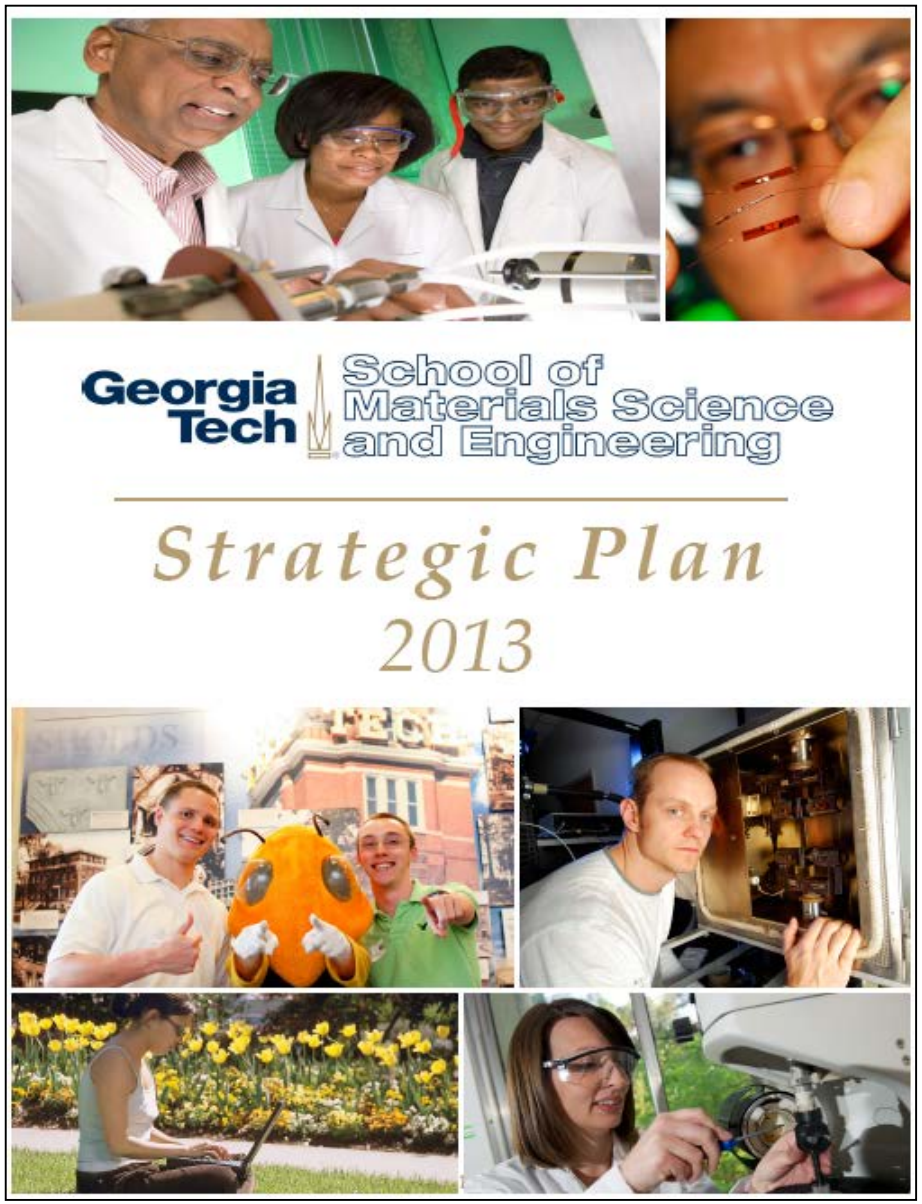
## UNDERGRADUATE STUDENTS

- 364 total: 38%Female/62%Male
- 52% GA/ 44% Out of State/ 4%Int
- 100% Co-op/Internship/Research
- 40% participate in Mentoring prog.
- USN&WR MSE Rank – 5th

## GRADUATE STUDENTS

- 192 total: 88%Ph.D./12%M.S.
  69%Male / 31%Female
  61%Domestic / 39% International
- 20-25 Non-MSE students
- 10% Internships (Industry+Natl.Labs)
- 10% Federal Fellowship Recipients
- USN&WR MSE Rank – 7th

# The MSE Strategic Vision & Mission




## Vision

***MSE at Georgia Tech will define the materials science and engineering program of the 21st century and be recognized globally as the preeminent leader in materials education, innovation, and research***

## Mission

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

# Materials Science & Engineering (MSE) – The Present

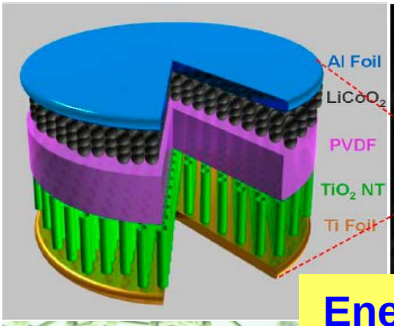
- **UG - B.S. Degree:** 132 hours
  - 21 hours in concentration and 6 hours of capstone design
  - Conc: Bio-Materials, Polymer & Fiber Materials, Structural and Functional Materials
  - Options: Co-op, Research, Study-abroad, Business
- **GRAD – Ph.D.**
  - 2 core + 5 elective + 3 Minor + Seminar, Qualifier, Proposal, Dissertation defense
  - Internship, Entrepreneurship, Teaching Practicuum
  - Matls Science & Eng; Bio-Eng.


Materials Certificate Programs

Computational Materials Science & Engineering

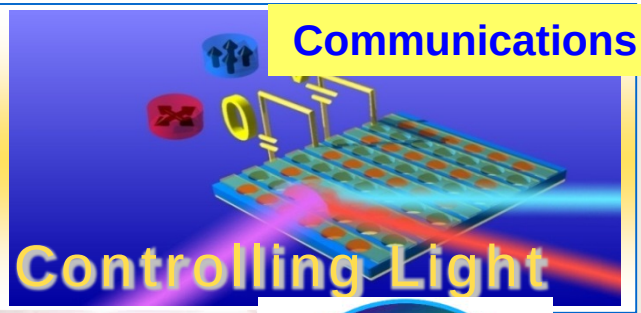
# MSE Education and Research Paradigm

# The World of Materials Research in MSE @ GT



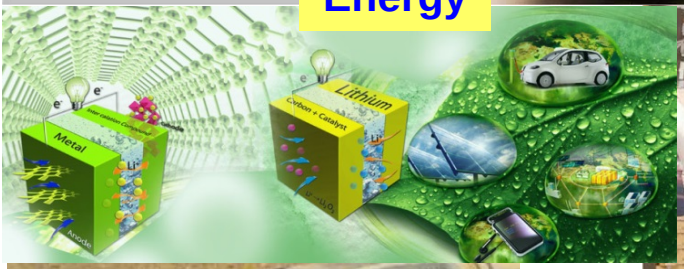


**Energy**



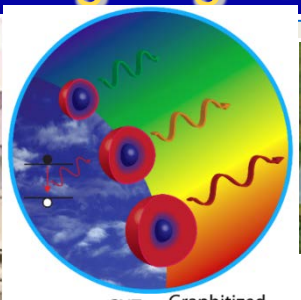

**Communications**

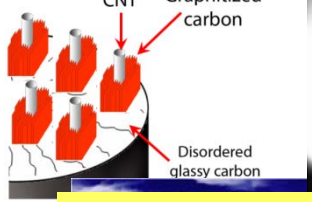
**Security**

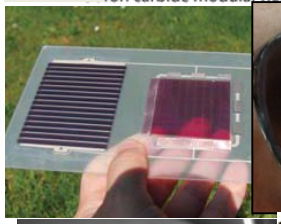


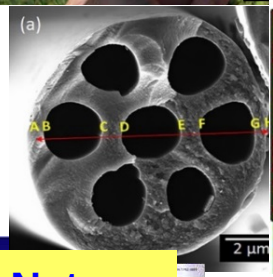


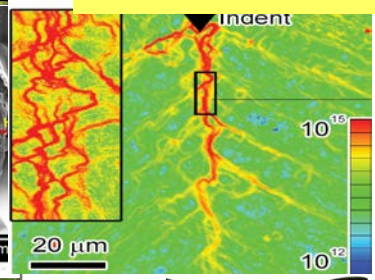
**Health & Human Welfare**





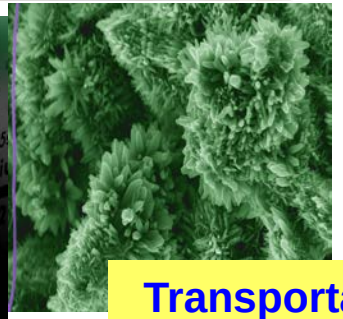


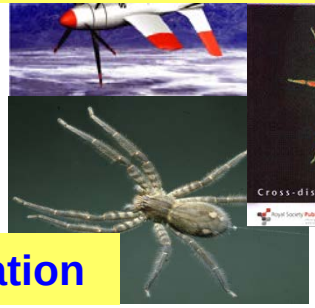

**Environment**

**Infrastructure**

**Mimicking Nature**

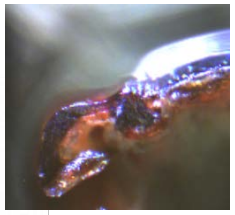



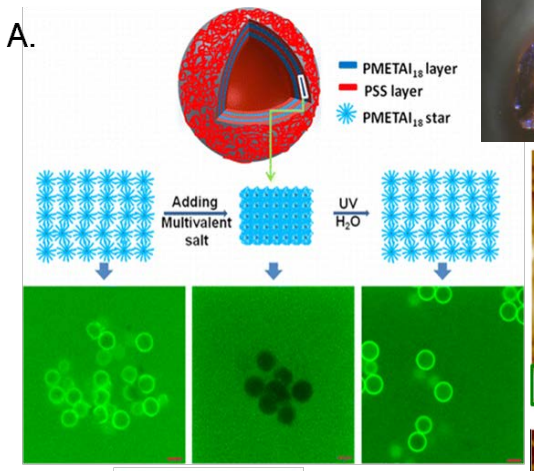
**Transportation**

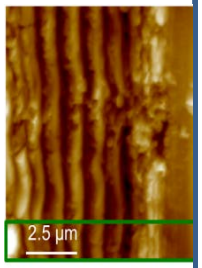


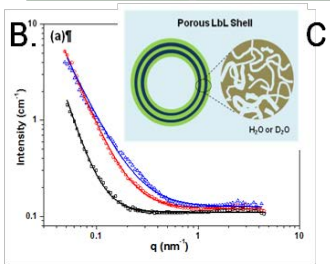
# Bio-enabled and Bio-inspired Materials

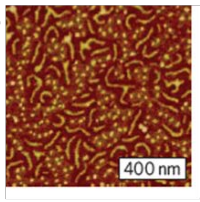

Vladimir Tsukruk

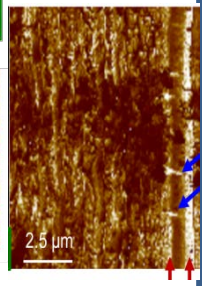




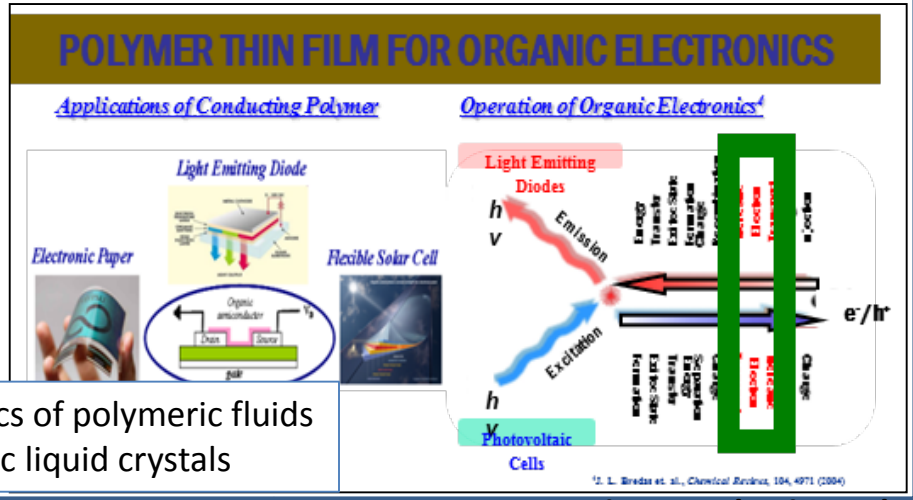



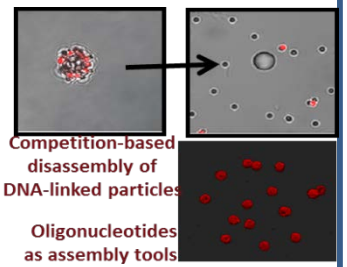




Mohan Srinivasarao

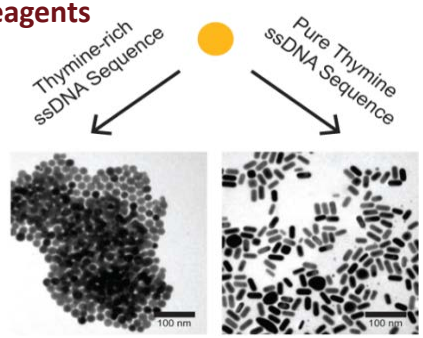



Optics & physics of polymeric fluids & nematic liquid crystals

Valeria Milam

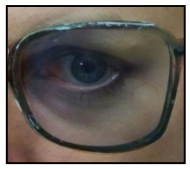


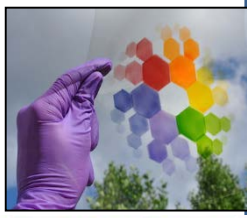

**Oligonucleotides** Gold Seed as reagents

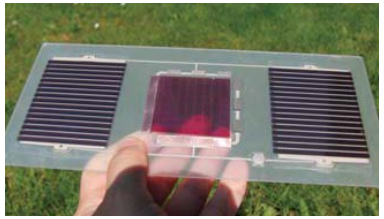



**Design, synthesis, and processing of soluble conjugated organic molecules and polymers for electrochemical an solid-state applications**

John Reynolds



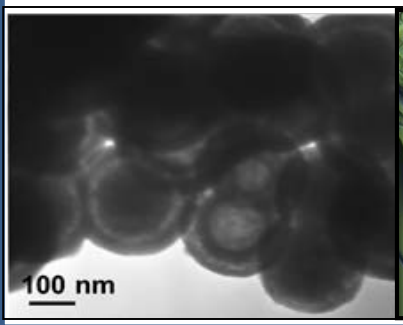




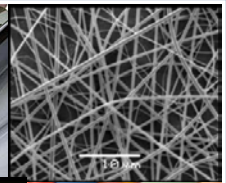
# Materials For Health & Human Welfare

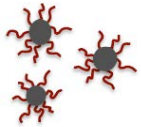
Paul Russo

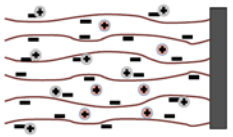
Therepeutic drug delivery



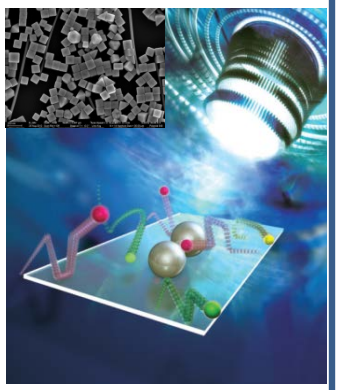

Blair Brettmann

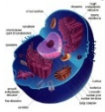


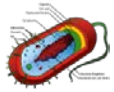


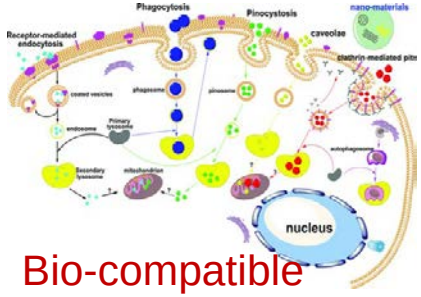


Dong Qin







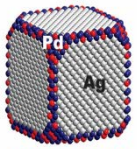



Bio-compatible Nano-platforms

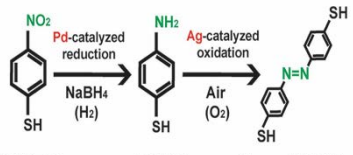
**Bimetallic nanocrystals with plasmonic and catalytic properties for applications in surface-enhanced Raman scattering (SERS)**

CHEMNANOMAT

**In-Situ SERS Monitoring**
**Stepwise Reduction and Oxidation Reaction**

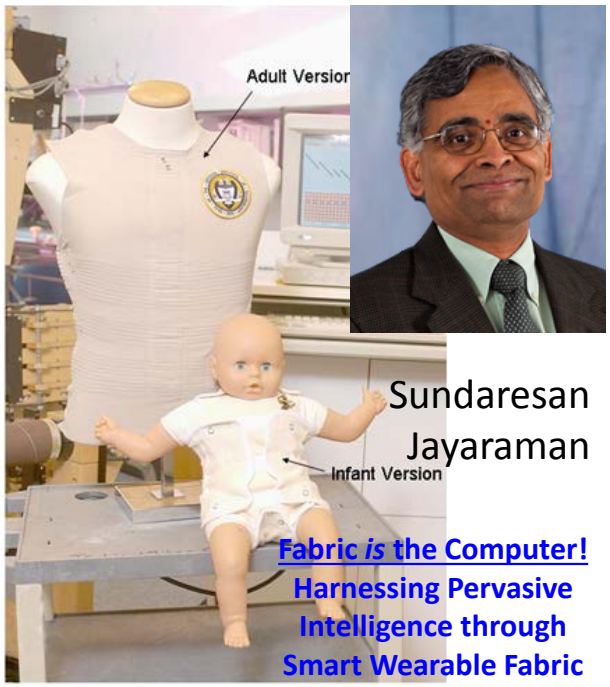



Dual Catalyst




(4-NTP) (4-ATP) (*trans*-DMAB)

2016 CHEMNANOMAT

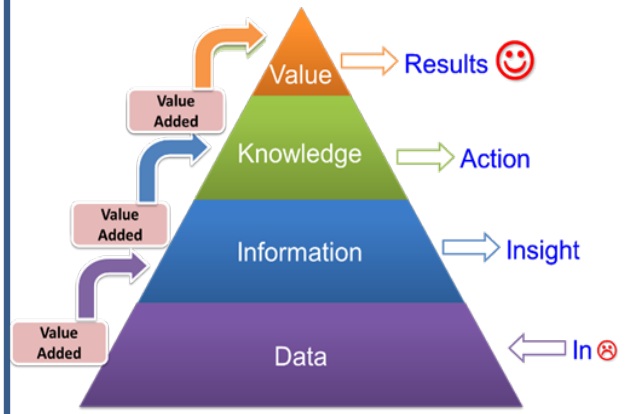





Sundaresan Jayaraman

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

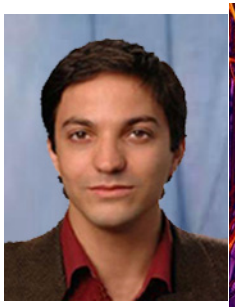
**Data-Value Transformation Paradigm**



# Materials for Energy Storage & Harvesting

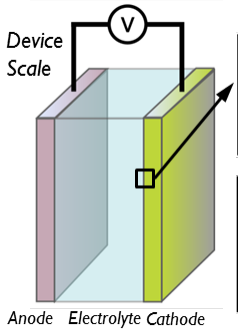
Meilin Liu

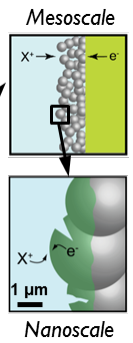
**Fuel cells, Batteries, Supercapacitors for efficient storage & conversion**

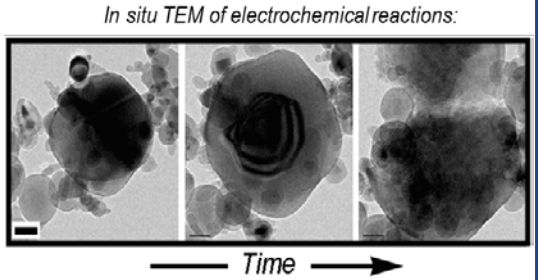



Gleb Yushin

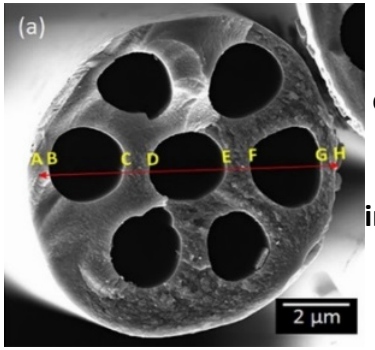
Matt McDowell



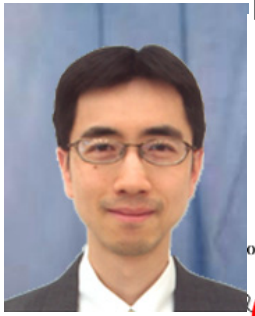




Satish Kumar

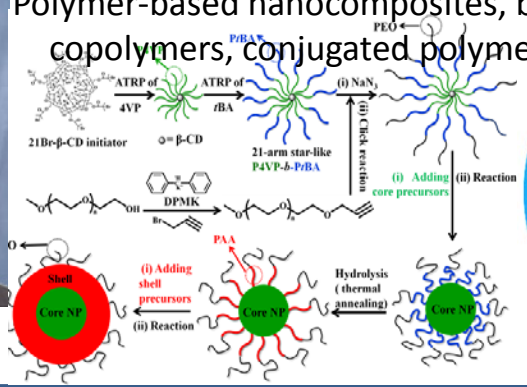


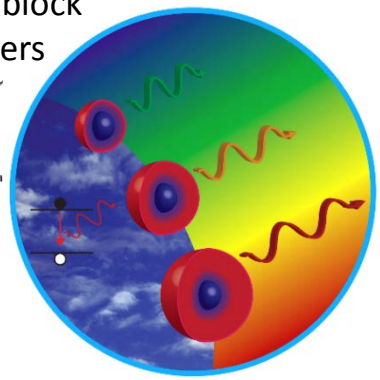

**Hollow C-CNT composite fiber with tailored interphases**

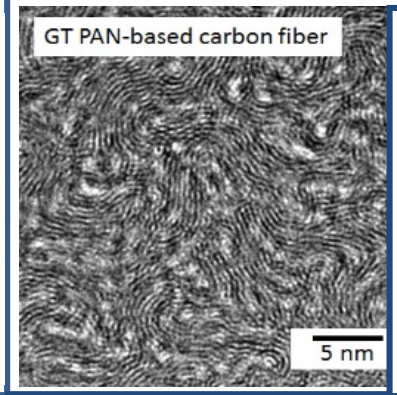


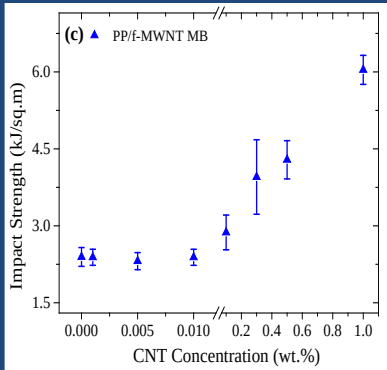
Zhiqun Lin

**Polymer-based nanocomposites, block copolymers, conjugated polymers**



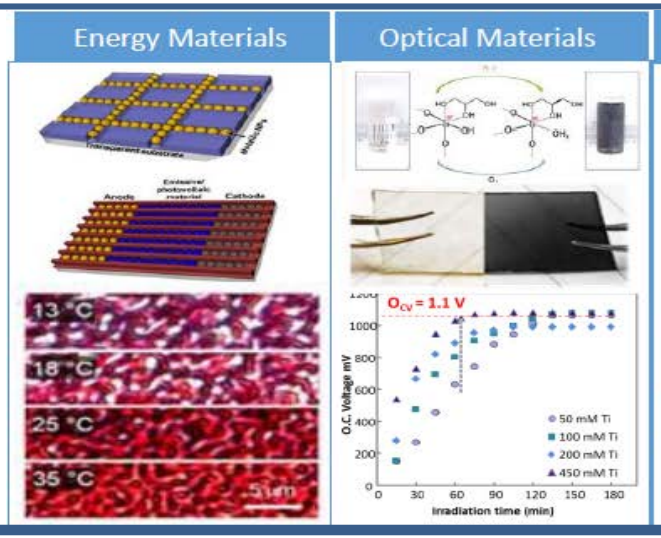





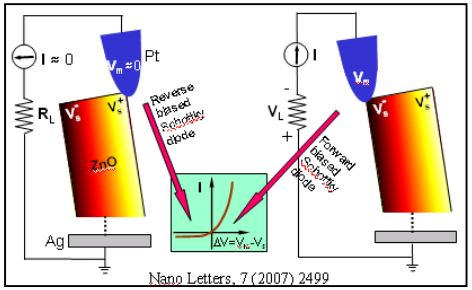



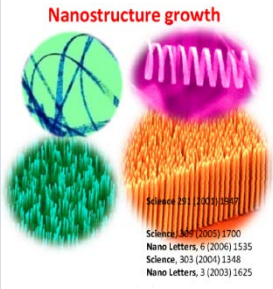
# Active Materials & Self-powered Devices

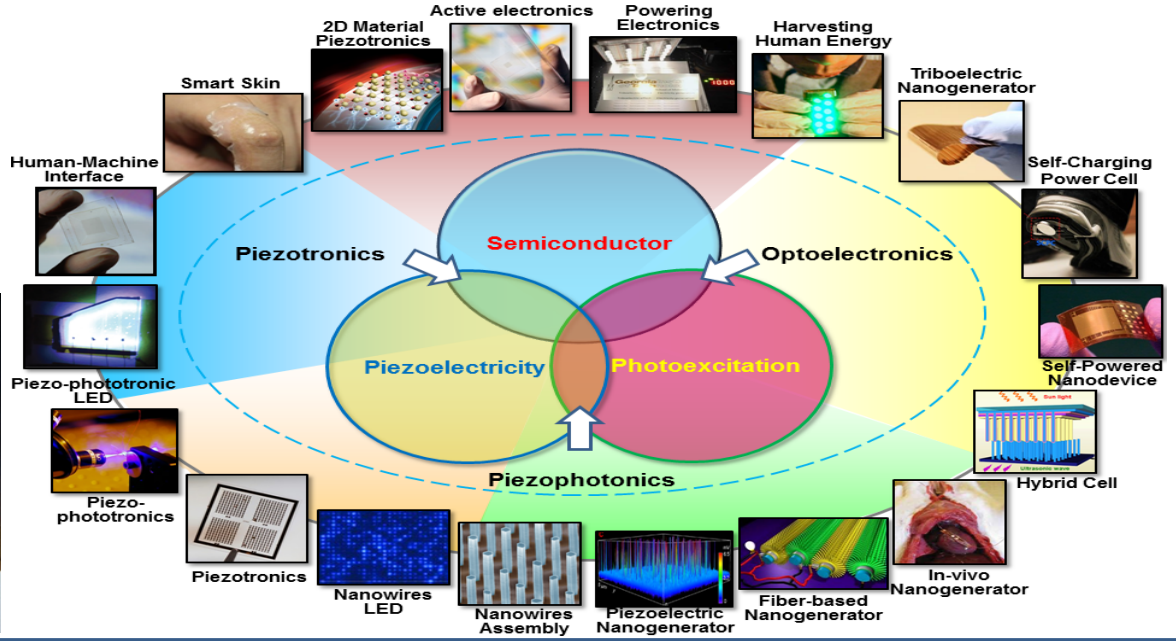
Natalie Stingelin




Zhong Li Wang



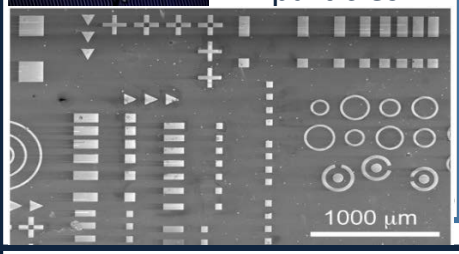



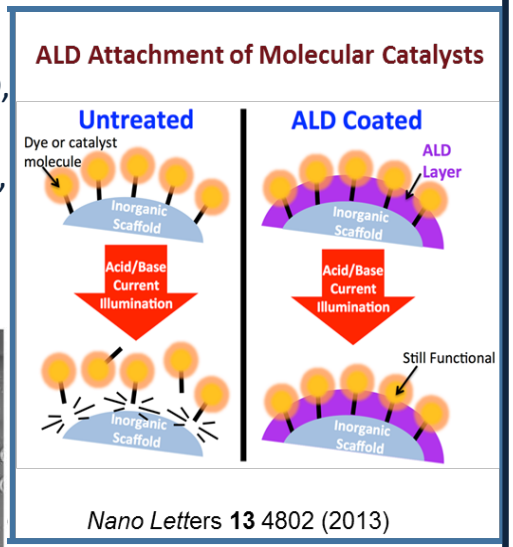



# Electronic Devices: Synthesis & Fabrication

## Mark Losego

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

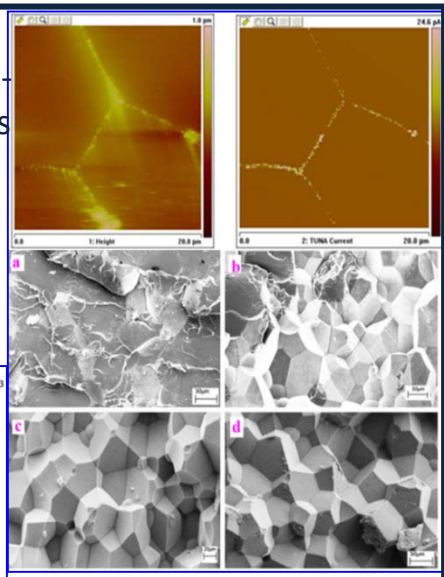


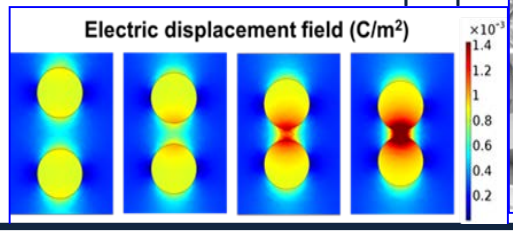




*Nano Letters* **13** 4802 (2013)

## Rosario Gerhardt

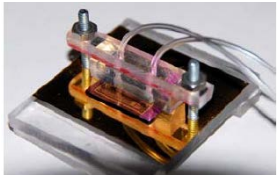
Process-structure-property relations in electronic materials, impedance spectroscopy, dielectric props.

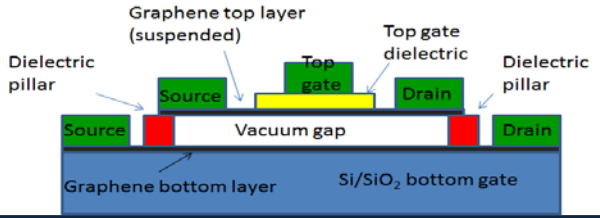


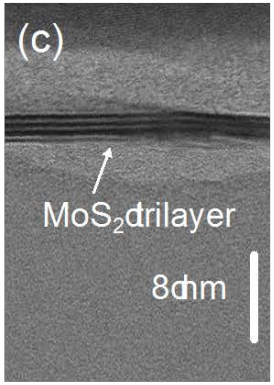

## Eric Vogel

Synthesis, structure, and properties of electronic materials and devices





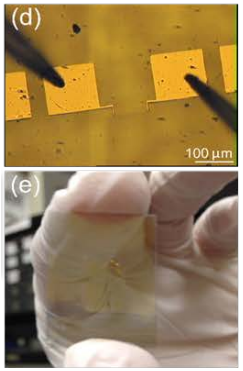

### New Synthesis Methods




Chemical Vapor Deposition of $MoS_2$

*Advanced Functional Materials* **24**, 6389 (2014)

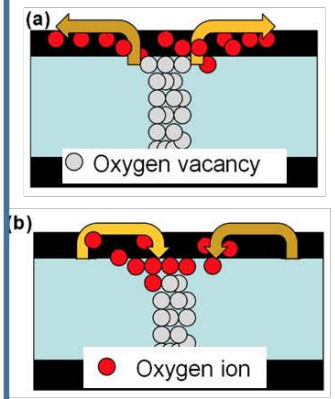
### Novel Device Fabrication




Flexible/transparent $MoS_2$ transistors

*ACS Applied Materials & Interfaces* **7**, 12850 (2015)

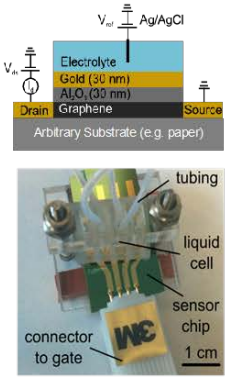
### Atomic Scale Mechanisms




Filament formation in metal oxide memory

*IEEE Electron Device Letters* **35**, 750 (2014)

### Applications




Graphene-based biosensor

*2D Materials* **2**, 044008 (2015)

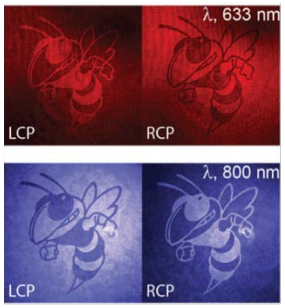
# Electronic, Optoelectronic, Packaging & Devices

Wenshan Cai

**Engineered nanostructures for light manipulation**

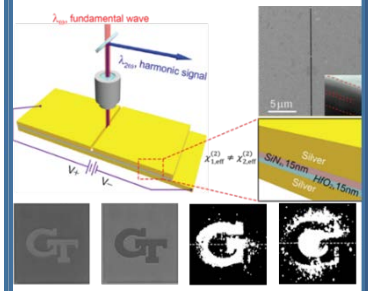
**Nanophotonics, optoelectronics, plasmonic nanodevices, optical metamaterials, integrated photonics, optical sensing**

**Metamaterials with exotic properties**




*Advanced Materials* **27** 1124 (2015)

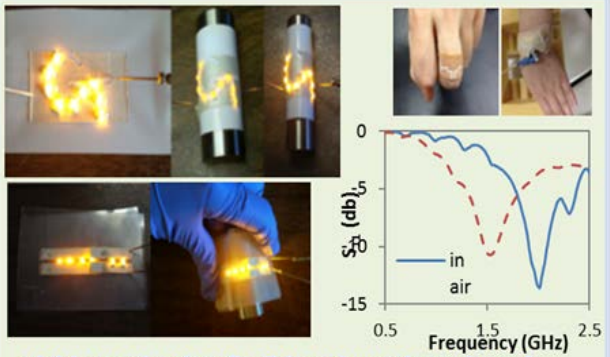
**Nonlinear optics with plasmonics**



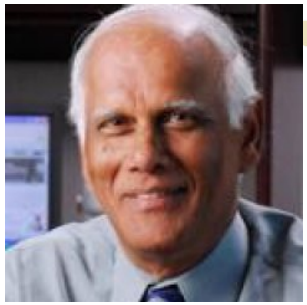

*Nature Materials* **14** 807 (2015)

C.P. Wong

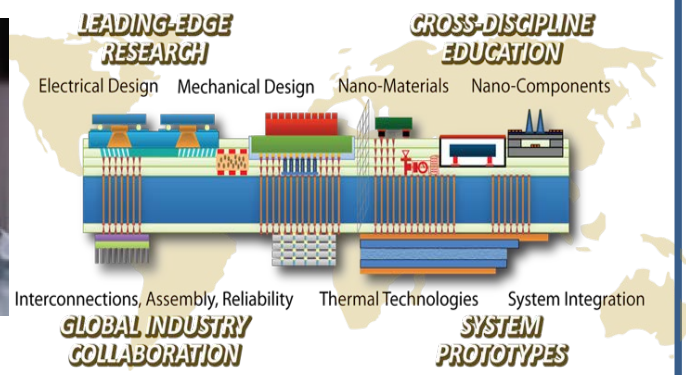
**Wearable and printable devices**

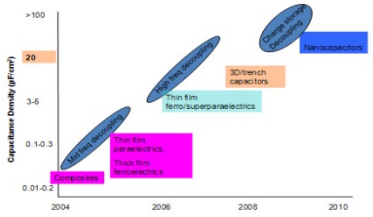


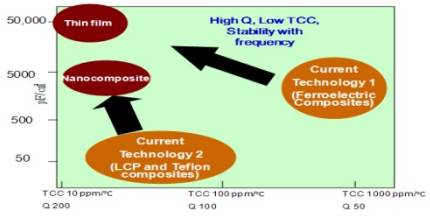

**Highly conductive, flexible polyurethane-based adhesives for flexible and printed electronics**



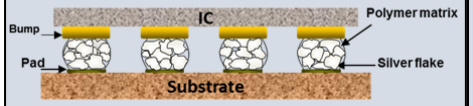
Rao Tummala



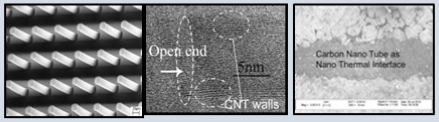



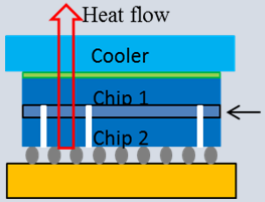

**Electrical Interconnects**




**Nano Thermal interface materials (carbon nanotubes)**

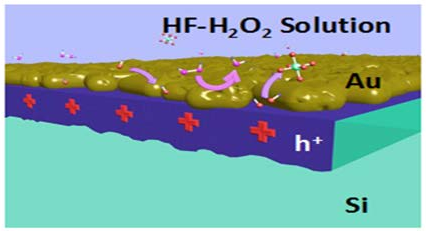


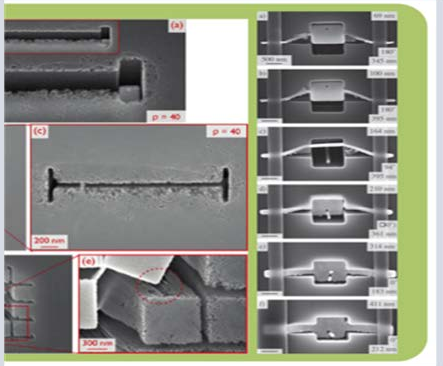

**Thermally conductive IC Encapsulant Underfill**




**Thermally conductive Underfills**

**3D Nanomanufacturing**

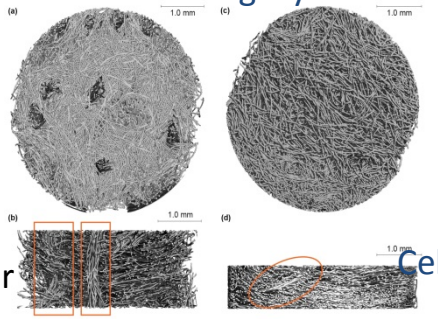


# Infrastructure and Transportation

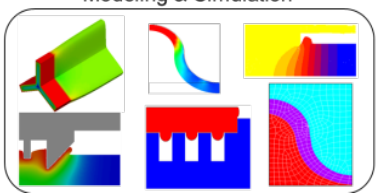
Meisha Shofner

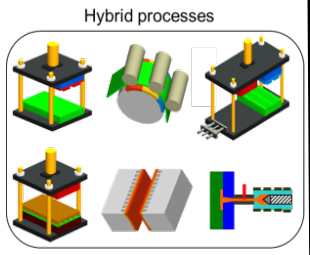
Auxetic & Tensegrity Structures



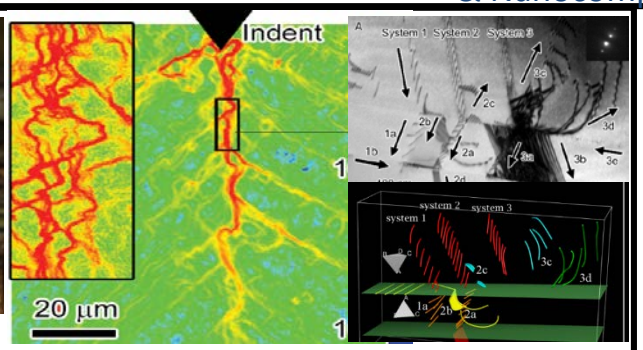
Cellulosic Nanomaterials & Nanocomposites

Donggang Yao

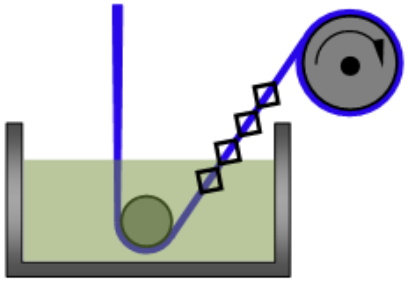


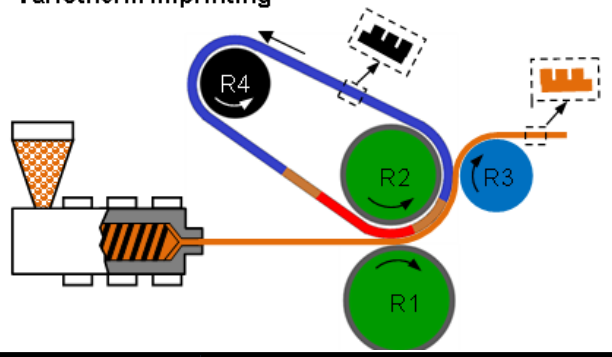

Josh Kacher



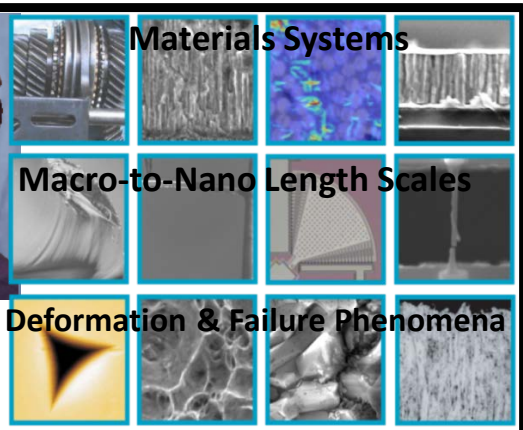

Twist-Gel Spinning



Variotherm Imprinting



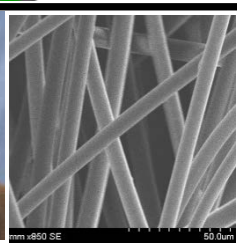

Chris Muhlstein



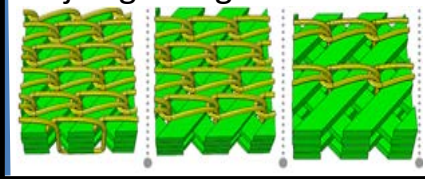

Preet Singh



Stress Corrosion Cracking



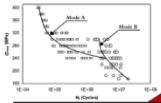
Youjiang Wang



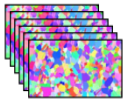
# Computational Materials Science and Design

Dave McDowell

- Multiscale modeling approaches can be used to inform models at high scales with data generated using sub-models simulated at finer scales

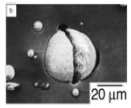


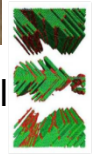
**Macroscale**
Scale: >1mm

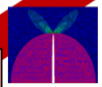


- Empirical Models (e.g. Paris law)
- Microstructure-sensitive plasticity macro models
- Informed

**Mesoscale(s)**
Scale: ~100 nm – <1mm



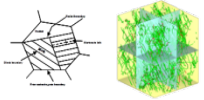





- Dislocation dynamics using Coarse Grained MD
- Crystal Plasticity

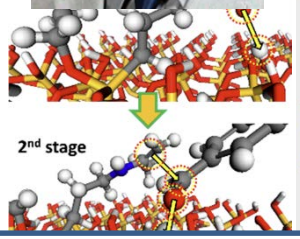
**Nanoscale**
~1-100nm

- Molecular Dynamics

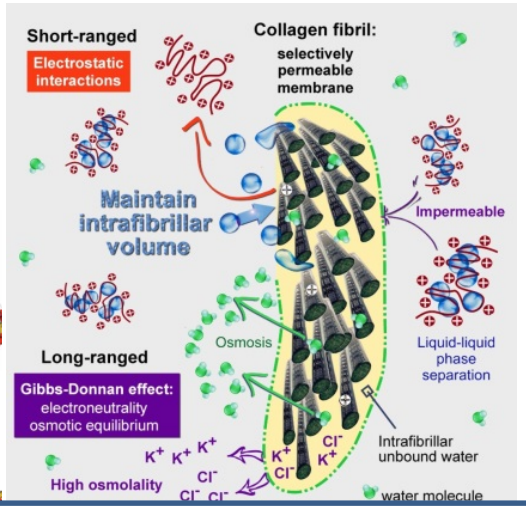


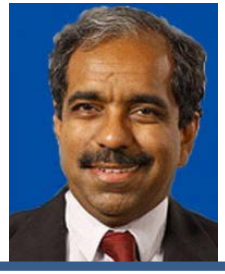
Funding from NSF, DOE NEUP, ONR, NAVAIR

Seung Soon Jang



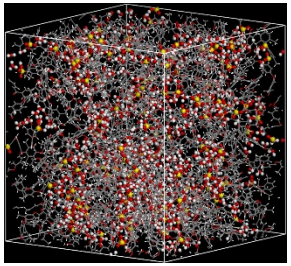

## Collagen Mineralization



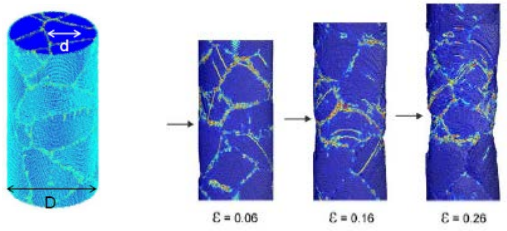



Karl Jacob

Experimental & computational approach to study material behavior

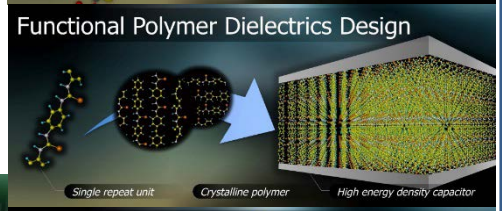


Mo Li Electromigration in Nanoscale

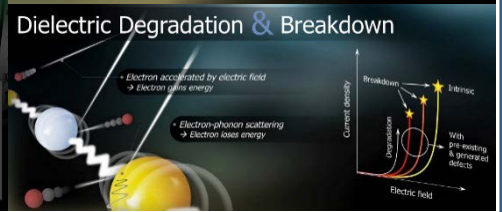



Rampi Ramprasad

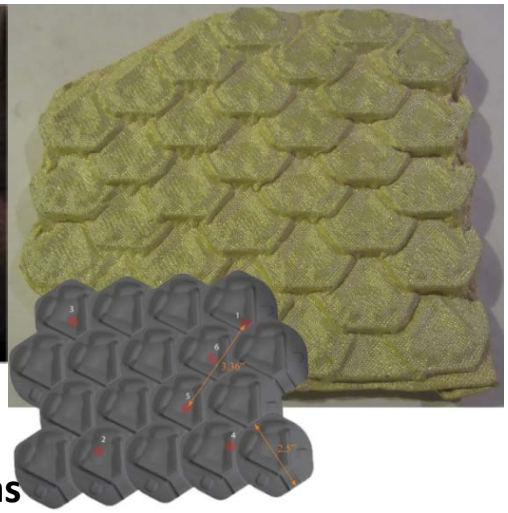
Computation Aided Materials Discovery

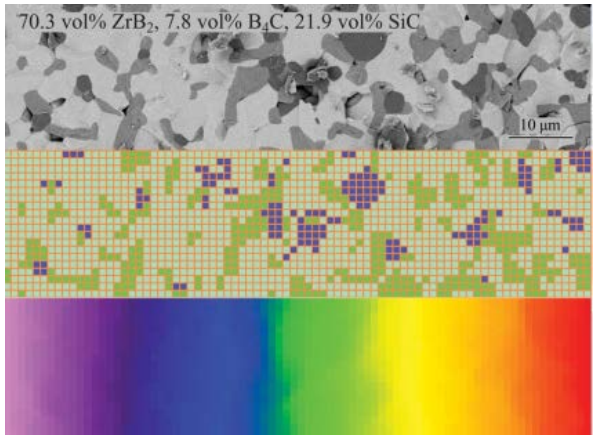




# Security: Materials Under Dynamic Extremes

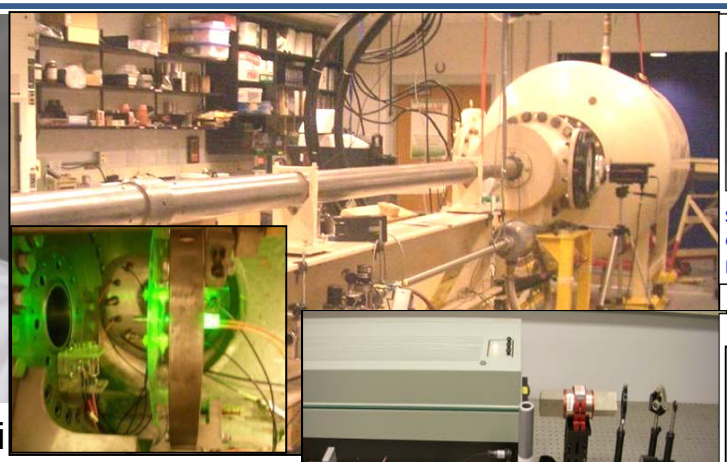



**Ultra-hard ceramics ($B_4C$ and SiC) for light-weight armor and ultra-high temperature ceramics ($ZrB_2$-SiC) for aerospace applications**



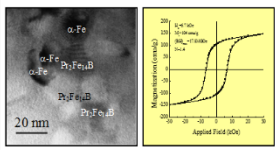

***Thermal conductivity and emissivity***

Naresh Thadhani



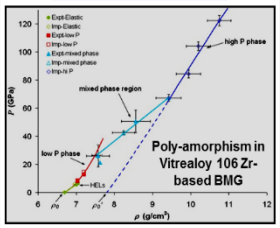
Probing and processing materials under extreme conditions of dynamic high pressure & HSR

**MATERIALS PROCESSING**



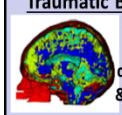

Shock-consolidated (Nd-Fe-B/α-Fe) exchange-coupled nanocomposite permanent magnet ($BH_{max}$~18MGOe)

**PHASE TRANSITIONS**



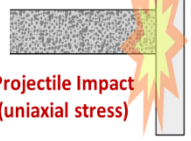

Measurement of change in compressibility provides indication of phase transition in metallic glass

**Traumatic Brain Injury**



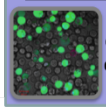
Short and long term diagnostics & modeling

**High-pressure Shock-Compression**



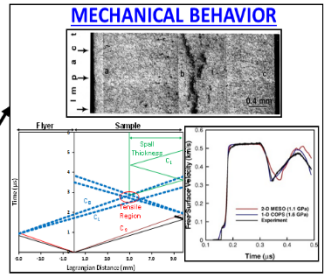
**Projectile Impact (uniaxial stress)**

**Targeted Drug Delivery**

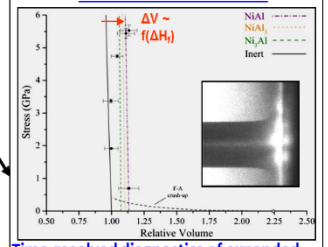


Laser activation of nano-C allows drug permeation in cells

**MECHANICAL BEHAVIOR**




**CHEMICAL REACTIONS**




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

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Georgia Tech School of Materials Science and Engineering

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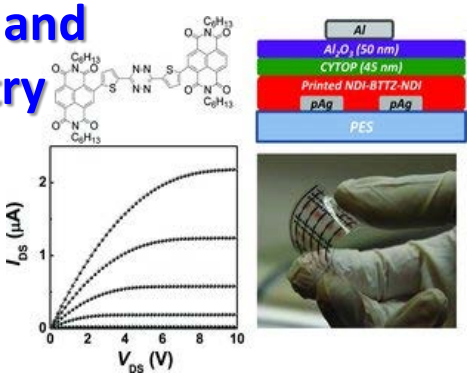
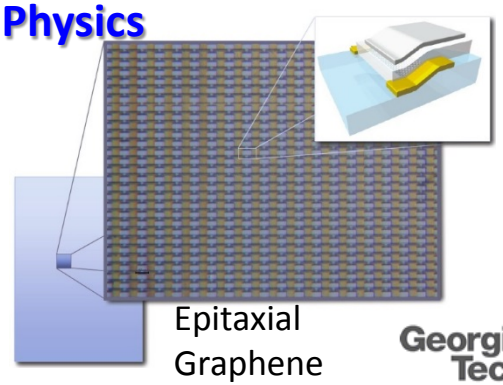
EVOLUTION, ECOLOGY & BEHAVIOR

Integrative & Systems Biology @ Georgia Tech

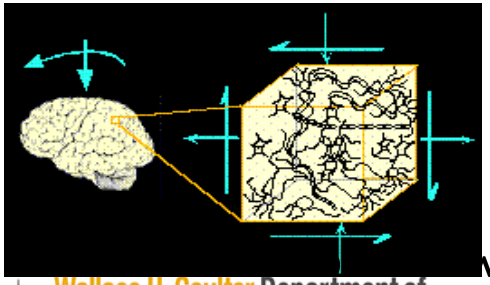
## Chemistry and Biochemistry




## Physics



Epitaxial Graphene



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

EMORY UNIVERSITY

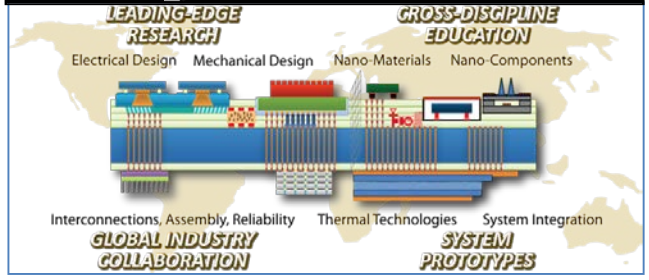
Daniel Guggenheim School of Aerospace Engineering

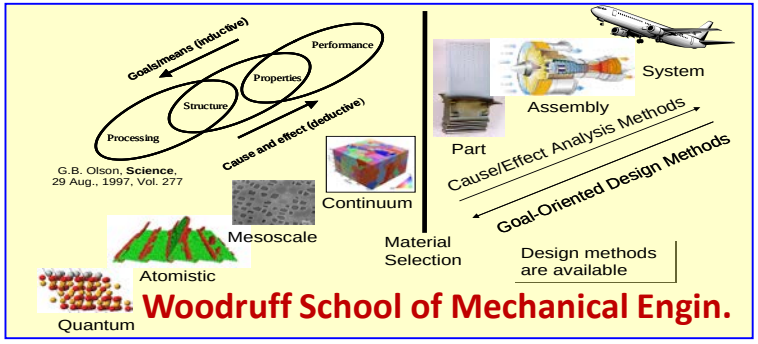

## Chemical and Biomolecular Engineering

Materials & Nanotechnology

## Civil and Environmental

Georgia Tech School of Electrical and Computer Engineering




Woodruff School of Mechanical Engin.

Georgia Tech Institute for Materials

Georgia Tech STAMI

Georgia Tech Manufacturing Institute

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Georgia Tech Research Institute

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# Georgia Tech Materials Characterization Facility

## *Prof. Eric Vogel, Director*

### 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

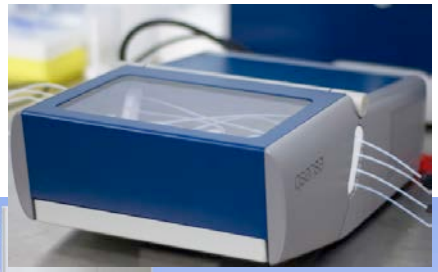
*Loc. in basement of Marcus*

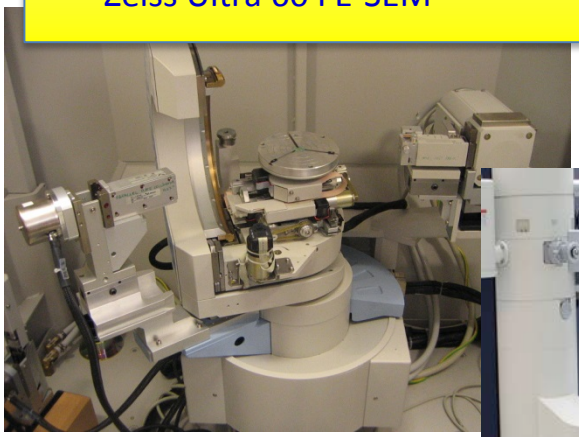
- Empyrean – Multipurpose XRD with SAXS
- X'Pert Alpha-1 MPD
- X'Pert PRO MRD XRD

### CNC Electron Microscopy

*Located in PTB*

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





Empyrean Multipurpose XRD

Hitachi HD2700 STEM

**Contact: walter.henderson@ien.gatech.edu**

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# The MILL - Materials Innovation and Learning Laboratory

## *An Open-access Make & Measure Space*

THE MILL
*Materials Innovation & Learning Laboratory*

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

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**HEADQUARTERS**
Erskine Love Manufacturing Building
Room 176
For more info, email:
themillgt@gmail.com

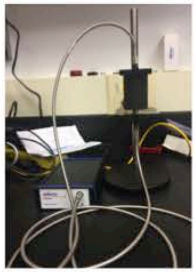


Ceramic Processing


SEM/EDX

XRD


ATR-FTIR


UV/Vis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# *Thank You*
# *We look forward to seeing you in Atlanta*