Academic and Research Highlights of The School of Materials Science and Engineering

Spring 2018

Naresh Thadhani
Professor and Chair

www.mse.gatech.edu
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
### FACULTY
- **38** Headcount, **8** joint appts., **33** majority Apt. in MSE, **33.6** FTE
- **3** Assistant (2M/1F); **7** Associate (3M/4F)
  - 23 Full (21M/2F)
- **18** Courtesy and Adjunct Faculty
- **9** Chair & **5** Regents’ Professors
- **7** Female (1 Chair) & **2** URM Faculty
- **10** NSF Career Awardees
- **2** NAE (US), **1** NAE China, **1** NAS China
- **35** Professional Society Fellowships
- **Degree Profile:** 15 MSE, 8 ME, 7 Chem, 6 Poly, 5 Met, 3 Textile, 2 Elect, 2 Math, 2 Ceramics, 2 Phys, 1 Civil, 1 Chem. Eng.

### UNDERGRADUATE STUDENTS
- **354** enrolled: **62%** Male / **38%** Female
- **52%** State/44% OutofState/14% Int
- **100%** Co-op/Internship/Research
- **40%** participate in Industry-Student Mentoring program
- **USN&WR MSE Rank – 5th**

### GRADUATE STUDENTS
- **193** enrolled: **93%** Ph.D. / **7%** M.S.
  - 67% Male / 33% Female
  - 55% Domestic / 45% Int.
- **20-25** Non-MSE students
- **10%** Internships (Industry+Natl.Labs)
- **10%** Federal Fellowship Recipients
- **USN&WR MSE Rank – 8th**
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 – Degree Programs

**UG - B.S. Degree:** 132 hours
- Core MSE courses emphasizing fundamentals of all materials
- 21 hours in concentration
- Bio-Materials, Polymers & Fibers, Structural and Functional
- 3 hours design fundamentals, 3 hours capstone experience
- Co-op, Research, Study-abroad, and Business Options

**Graduate – Ph.D.:**
- 2 core courses (Thermodynamics & Structure of Materials)
- 9 free elective courses (including 3 courses in Minor)
- Graduate seminar and technical communication course
- Qualifier, Oral Proposal and Dissertation defense
- Materials Science & Engineering, Bio-Engineering
MSE Education and Research Paradigm
Bio-enabled and Bio-inspired Materials

Mohan Srinivasarao

Optics & physics of polymeric fluids & nematic liquid crystals

Valerio Milam

Oligonucleotides as reagents

John Reynolds

Design, synthesis, and processing of soluble conjugated organic molecules and polymers for electrochemical and solid-state applications
Materials For Health & Human Welfare

Bio-compatible Nano-platforms

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

In-Situ SERS Monitoring
Stepwise Reduction and Oxidation Reaction

Dual Catalyst

Value Results
Knowledge Action
Information Insight
Data Value Added

Fabric is the Computer!
Harnessing Pervasive Intelligence through Smart Wearable Fabric
Materials for Energy Storage & Harvesting

Fuel cells, Batteries, Supercapacitors for efficient storage & conversion

Polymer-based nanocomposites, block copolymers, conjugated polymers

Hollow CNT composite fiber with tailored interphases

Impact Strength (kJ/sq.m) vs. CNT Concentration (wt.%)
Active Materials & Self-powered Devices

Catalysts and Engineered Nanomaterials for Energy Conversion and Storage

Zhong Li Wang

Piezotronics, Semiconductors, and Optoelectronics
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
- MoS₂ trilayer
- Chemical Vapor Deposition of MoS₂

Novel Device Fabrication
- Flexible/transparent MoS₂ transistors
  - ACS Applied Materials & Interfaces 7, 12850 (2015)

Atomic Scale Mechanisms
- Filament formation in metal oxide memory

Applications
- Graphene-based biosensor
  - 2D Materials 2, 044008 (2015)
Electronic, Optoelectronic, Packaging & Devices

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

Engineered nanostructures for light manipulation

Wenshan Cai

LEADING-EDGE RESEARCH
Electrical Design
Mechanical Design
Nano-Materials
Nano-Components

CROSS-DISCIPLINE EDUCATION
Interconnections, Assembly, Reliability
Thermal Technologies
System Integration

GLOBAL INDUSTRY COLLABORATION

SYSTEM PROTOTYPES

C.P. Wong

Wearable and printable devices

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

Electrical Interconnects

Nano Thermal interface materials (carbon nanotubes)

3D Nanomanufacturing

Thermally conductive IC Encapsulant Underfill
Computational Materials Science and Design

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

Dave McDowell

- Macroscale: Scale > 1 mm
- Mesoscale(s): Scale ~ 100 nm - < 1 mm
- Nanoscale: ~ 1-100 nm

- Dislocation dynamics using Coarse Grained MD
- Crystal Plasticity
- Molecular Dynamics

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

Seung Soon Jang

- Collagen Mineralization
- Short-ranged
- Electrostatic interactions
- Collagen fibril: selectively permeable membrane
- Maintain intrafibrillar volume
- Long-ranged
- Gibbs-Donnan effect: electrochemically osmotic equilibrium
- Intracellular unbound water
- Liquid-liquid phase separation

Karl Jacob

- Experimental & computational approach to study material behavior

Rampi Ramprasad

- Computational Aided Materials Discovery

Mo Li

- Electromigration in Nanoscale

- $E = 0.06$
- $E = 0.16$
- $E = 0.26$

Materials Informatics & Machine Learning

- Prediction: Interfacial design
- Device properties: New material
- Dielectric degradation & breakdown
Ultra-hard ceramics ($B_4C$ and $SiC$) for lightweight armor and ultra-high temperature ceramics ($ZrB_2-SiC$) for aerospace applications.

Thermal conductivity and emissivity

Probing and processing materials under extreme conditions of dynamic high pressure & HSR.
“Materials” Research Across Georgia Tech

Chemistry and Biochemistry

Physics

Epitaxial Graphene

Daniel Guggenheim School of Aerospace Engineering

Materials & Nanotechnology

Chemical and Biomolecular Engineering


Part Cause/Effect Analysis Methods

Woodruff School of Mechanical Engr.
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

Contact: walter.henderson@ien.gatech.edu
MILL Equipment – Simple, Robust, Common (not S-o-t-A)

**Processing**

- **Hyrel 3D Printers (5x)**
  - Support up to 4 heads and various extruders.
- **Filament Extruder**
  - Ideal for making 3D printer filaments
- **Furnaces (5x)**
  - Heat to 1500°C
- **Uniaxial Press**
  - with heated plattens; dies available.
- **Rolling (Ball) Mill**
  - Communion

**Characterization**

- **Benchtop SEM with EDX**
  - Excellent resolution to 0.5 μm, capable of elemental mapping, “high-pressure” holder for non-conductive samples.
- **Benchtop XRD**
  - θ-2θ scans ideal for polycrystalline samples.
- **ATR-FTIR**
  - FTIR with ATR crystal for rapid analysis. Database for polymer identification.
- **XRF**
  - Elemental analysis above Mg; ppm resolution; many calibrations; also measures coating thickness

**Measurement**

- **Mechanical Measurement**
  - 500 N load cell; attachments for doing tension, compression, and 3-point bend.
- **Hardness Tester**
  - Automated; measures Vickers and others...
- **ATR-FTIR**
  - Measuring dielectric properties from 20 Hz – 300 kHz
- **Density**
  - Archimedes Method

- **Fiber-Optic UV/Vis**
  - Transmission, reflection, and integrating sphere with color analysis software
- **LCR Meter**
  - Measure DC resistance
- **Multimeter**
  - Small volume viscometer