The World of Materials at Georgia Tech

Academic and Research Highlights
School of Materials Science & Engineering

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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 Practicum
- Matls Science & Eng; Bio-Eng.
MSE Education and Research Paradigm

Creating the Next® in materials
The World of Materials Research in MSE @ GT

Controlling Light

Communications

Security

Energy

Environment

Health & Human Welfare

Infrastructure

Mimicking Nature

Transportation

Materials Informatics & Machine Learning
Bio-enabled and Bio-inspired Materials

Vladimir Tsukruk

Valeria Milam

Mohan Srinivasarao

John Reynolds

Optics & physics of polymeric fluids & nematic liquid crystals

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

Oligonucleotides as reagents

Polymer Thin Film for Organic Electronics

Applications of Conducting Polymer

Operation of Organic Electronics

Optics & physics of polymeric fluids & nematic liquid crystals

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

Oligonucleotides as assembly tools

Photovoltaic Cells

Emission

Electron

Hole

Light Emitting Diodes

Flexible Solar Cell

Electronic Paper

Light Emitting Diode

John Reynolds

Valeria Milam

Mohan Srinivasarao

Vladimir Tsukruk
Materials For Health & Human Welfare

Bio-compatible Nano-platforms

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

Data-Value Transformation Paradigm

Value → Results

Knowledge → Action

Information → Insight

Data → Value Added
Materials for Energy Storage & Harvesting

Fuel cells, Batteries, Supercapacitors for efficient storage & conversion

Polymer-based nanocomposites, block copolymers, conjugated polymers

Hollow C-CNT composite fiber with tailored interphases

Impact Strength (kJ/sq.m)

Polymer-based nanocomposites, block copolymers, conjugated polymers

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

Natalie Stingelin

Zhong Li Wang

CREATING THE NEXT® in materials

Georgia Tech School of Materials Science and Engineering
**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

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**New Synthesis Methods**

**Chemical Vapor Deposition of MoS$_2$**

**Flexible/transparent MoS$_2$ transistors**

**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

Wenshan Cai
Engineered nanostructures for light manipulation

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

HF-H₂O₂ Solution

Silver flakes

Carbon Nanotube paste, Nano Thermal Materials

Heat flow

Cooler

Chip 1

Chip 2

Thermally conductive Underfills
Infrastructure and Transportation
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.
- 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 - 100 nm
  - Molecular Dynamics

Seung Soon Jang

Collagen Mineralization

- Short-ranged Electrostatic Interactions
- Collagen fibril: selectively permeable membrane
- Maintain Intrafibrillar volume
- Long-ranged Osmosis
- Liquid-liquid phase separation
- Intrafibrillar unbound water
- Water molecule

Rampi Ramprasad
Computational Aided Materials Discovery

Karl Jacob
Experimental & computational approach to study material behavior

Mo Li
Electromigration in Nanoscale

Materials Informatics & Machine Learning

Funding from NSF, DOE NEUP, ONR, NAWC-D, Grant IIA-0201162
Ultra-hard ceramics ($B_4C$ and $SiC$) for lightweight armor and ultra-high temperature ceramics ($ZrB_2-SiC$) for aerospace applications.
“Materials” Research Across Georgia Tech

Chemistry and Biochemistry

Physics

Epitaxial Graphene

Daniel Guggenheim School of Aerospace Engineering

Goal-Oriented Design Methods

Material Selection Design methods are available

Processing

Structure

Properties

Cause and Effect Reasoning

Material Selection

Continuum

Woodruff School of Mechanical Engin.

Chemical and Biomolecular Engineering

Materials & Nanotechnology

Civil and Environmental

Woodruff School of Mechanical Engin.

STAMI

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**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

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The MILL - Materials Innovation and Learning Laboratory
An Open-access Make & Measure Space

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3M
Art and Patricia Cox
HOREL 3D

Georgia Institute of Technology
Georgia Tech College of Engineering

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Thank You
We look forward to seeing you in Atlanta