Flexible Wearable Electronics Advanced Research at the Georgia Institute of Technology is a campus-wide, multidisciplinary research and development, manufacturing, educational, and workforce-development initiative, involving a large number of faculty, graduate and undergraduate students, engineers, scientists, and staff from various schools, colleges, research centers and institutes. Team members work with other educational institutions, industry, and government agencies developing and implementing new technologies and manufacturing methods for Flexible Electronics as well as Wearable Electronics. They also actively engage in educating and growing a competitive workforce that positively impacts the economic ecosystem in addressing some of the grand challenges associated with food, clean water, health, clean energy, infrastructure, mobility, and security for the sustainable progress of humanity and society.

**RESEARCH FOCUS AREAS**

- Design, Modeling, and Simulation
- Materials and Processing
- Interconnect, Assembly, and Packaging
- Sensing and Applications
- Soft Robotics and Materials
- Test and Reliability
- Prototyping and Manufacturing Methods
- Workforce Development

www.flex.gatech.edu
**Technical Groups**

**Design, Modeling, and Simulation**
Satish Kumar, Olivier Pierron, Suresh Sitaraman, and Madhavan Swaminathan

**Materials and Processing**

**Interconnect, Assembly, and Packaging**
Muhammad Bakir, Jack Moon, P. Markondevya Raj, Vanessa Smet, Suresh Sitaraman, Rao Tummala, C.P. Wong, and Gleb Yushin

**Sensing and Applications**
Oliver Brand, Peter Hesketh, Omer Inan, Sudaresan Jayaraman, Manos Tentzeris, Eric Vogel, Z.L. Wang, W. Hong Yeo, and Chuck Zhang

**Soft Robotics and Materials – Sensing and Actuation**
Jaydev Desai, Frank Hammond, David Hu, Jun Ueda, W. Hong Yeo, and Aaron Young

**Test and Reliability**
Abhijit Chatterjee, Samuel Graham, Olivier Pierron, Suresh Sitaraman, and I. Charles Ume

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**PARTICIPATING UNITS @ GEORGIA TECH**

- Biomedical Engineering
- Chemical and Biomolecular Engineering
- Electrical and Computer Engineering
- Industrial and Systems Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Institute for Electronics and Nanotechnology (IEN)
- 3-D Systems Packaging Research Center
- Georgia Tech Manufacturing Institute
- Institute of Materials (IMAT)
- Office of Industry Collaboration

**FLEXIBLE ELECTRONICS & WEARABLE ELECTRONICS**
The ATHENA group at Georgia Tech explores the development of novel technologies for the next generation of wireless RF and mm-wave applications in telecom, defense, space, automotive, and sensing areas through robust low-cost additive manufacturing methods.

- **Low-cost Nanomaterial-Enabled Sensors and Switches**
  - Selectively functionalized CNT/graphene-based gas sensors for real-time environment monitoring (image above)
  - CNT-based RF switches for flexible, fully-printed phased arrays

- **Printed “Smart” 3D Wireless Packaging**
  - 3D ramped interconnects for application-specific wireless packages (image above)
  - Mm-wave system-in-package solutions with antenna array integration and microfluidic-based thermal management

- **Reconfigurable 4D Origami-Inspired Structures**
  - Tunable frequency selective surfaces using 3D miura folding with paper (image above)
  - Compressible/stretchable 3D antennas with liquid metal conductors and 3D scaffolding
  - Unique wideband mathematically-inspired 3D fractal-based antennas

- **Long-Range RFID and Energy Harvesting**
  - Km-range passive “smart-skin” RFID sensors with mm-wave reflectarray (image above)
  - Wearable UHF energy harvesting systems for wireless-on-body IoT devices
  - Heterogeneous power scavenging through wireless, solar, and piezo integration
Bio-Interfaced Translational Nanoengineering Group
yeolab.gatech.edu

“Smart and Connected Bioelectronic System for Advancing Human Healthcare and Wellness”

We study soft materials, flexible mechanics, and advanced manufacturing to develop wearable and implantable bioelectronics.

Research Focus

• Soft Wearable Electronics
• Low-Profile, Implantable Electronics
• Advanced Health Monitoring
• Human-Machine Interfaces
• Disease Diagnostics and Therapeutics
The Energy Storage and Conversion Lab (ESCL) at Georgia Tech focuses on designing multi-functional microscale power sources that have high power density, high energy density, long cycle life, and flexibility.

**Textile electrode**
Textile (Paper or cotton)-based electrical conductor realized by conformal coating of metal and/or metal oxide nanoparticle for flexible energy devices.

**Electrode patterning**
Functional nanoparticle-patterned flexible substrates with high resolution, packing density of nanoparticle, reliability, and reproducibility.

**Stichable 1D electrode**
Yarn-type electrical conductor capable of weaving for wearable electronics with various dimensionality.

**Elastomer-based energy generator**
Bio-friendly and scalable hierarchical surface structured elastomer-based energy generator.
The EPIC lab’s goal is to design and test human augmentation technology to improve mobility in humans performing agile and real-world tasks. We have designed a number of wearable robotic systems to improve human capability by integrating FHE technology to improve the real-time control of these systems. Our control systems use recent advances in sensor fusion, machine learning, and artificial intelligence to detect human intent and optimize wearable robotic assistance. We formally test these robotic systems in an advanced large scale human biomechanics testing facility.

Research Focus
- Robotic Exoskeletons
- Human Augmentation
- Machine Learning
- Myoelectric (EMG) Control
- Human Biomechanics
- Lower Limb Gait Assistance
- Real-time Control Systems
- Sensor Fusion Techniques
- Autonomous Systems
- Powered Prostheses
- Artificial Intelligence
Integrated 3D Systems Group
www.bakirlab.gatech.edu

The I3DS Group explores the design, fabrication, and characterization of 3D electronic systems and advanced interconnect networks.

Flexible Optimized Quilted Solar Power System
Solar cell islands integrated within a flexible substrate

Polyimide-PDMS Flexible Multi-Electrode Array
Flexible MEAs for recording in vivo EMG signals from songbirds

Bio-Sensing Interface Module
Disposable bio-system using 3D mechanically flexible interconnects

Compressible MicroInterconnects
3D flexible interconnect technology used in a variety of applications

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Mechanical and Electrical Testing and Characterization

- Stretch, bend, twist, and other mechanical tests - stretch, bend radius, and twist angle limits; in-situ resistance measurement
- Monotonic and fatigue tests
- Substrate and printed ink characterization - resistance change, cracking, thermo-mechanical properties and constitutive behavior
- High-frequency measurements and characterization with electrical group
- Interfacial fracture and adhesion characteristics
- Property-aided process enhancement
- Physics-based numerical models and analytical equations
- Computational reliability prediction
- Environmental tests and models
- Digital image correlation
- Compliant interconnects
- Customized tests and evaluation for wearables, sensors, antennas, batteries, and associated computational models

For details on this page as well as for details on Flexible Wearable Electronics Advanced Research @ Georgia Tech, please contact: Dr. Suresh Sitaraman, Regents’ Professor and Morris M. Bryan, Jr. Professor, 404-894-3405; suresh.sitaraman@me.gatech.edu, caspar.gatech.edu, flex.gatech.edu
Printed flexible microelectronics have attracted high interest due to their cost-effectiveness and scalable production. The MiNDS team endeavors to fabricate carbon nanotube (CNT) based high performance devices using aerosol jet and inkjet printing techniques.

**Research Focus**

- Printable electronics on flexible substrates
- Layer by layer printing of nanomaterials- dielectric, semiconductor, and metal
- Fully printed CNT thin film transistors, sensors
- Physically unclonable functions as security primitives

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