FlexTech Alliance
for Displays & Flexible, Printed Electronics

Flexible Electronics Development Supported by NASA

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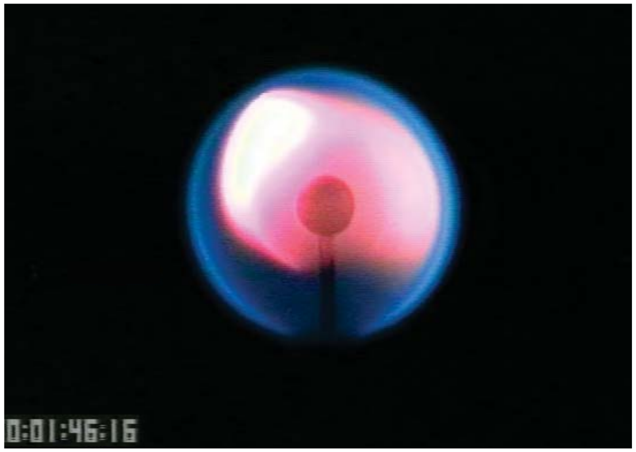
Flexible Electronics Sector Manager

NASA's Vision

To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.

Some basic questions:

- What is out there in space?
- How do we get there?
- What will we find?
- What can we learn there, or learn just by trying to get there, that will make life better here on Earth?



Diffusion Flame

Requirements for Space Operations

Space operations are often more constraining than terrestrial activities

- Low mass & volume
- Structural load environments
  - -Ground transportation
  - -Launch -Landing
- Natural Environments
  - -Thermal -Microgravity
  - -Radiation -Vacuum
- Off gassing and toxicity concerns
- Equipment calibration / stability
- Lifetime / Storage

Composite Cryo Tank
30% wt. 25% cost reduction

Space Technology Roadmaps*

TA01 Launch Propulsion Systems
TA02 In-Space Propulsion Systems
TA03 Space Power and Energy Storage
TA04 Robotics, Tele-Robotics and Autonomous Systems
TA05 Communication and Navigation Systems
TA06 Human Health, Life Support and Habitation Systems
TA07 Human Exploration Destination Systems
TA08 Science Instruments, Observatories and Sensor Systems
TA09 Entry, Descent and Landing
TA10 Nanotechnology
TA11 Modeling, Simulation, Information Technology and Processing
TA12 Materials, Structures, Mechanical Systems and Manufacturing
TA13 Ground and Launch Systems Processing
TA14 Thermal Management Systems

Shuttle Main Engine Test

* See the National Aeronautics Research and Development Plan for Aeronautics R&D challenges and goals

NASA's Flexible Electronics Needs

- Flexible solar arrays
  - -Solar electric vehicles (400kW)
  - -Conforming to habitats and mobile platforms
- Electronics systems with reduced mass and volume
  - -Power processing units
  - -Sensors / sensor systems
  - -Space suits
  - -Controllers
  - -Cameras
  - -Radios
  - -Data storage
  - -Antennas
  - -Displays

Z-2 Spacesuit

Flexible Electronics Needs (cont.)

- Compact, low power, radiation dosimeter and monitoring sensors
- Sensors and instruments sensitive to
  - Electromagnetic radiation including photons
  - Charged, neutral and dust particles
  - DC and AC electromagnetic fields
  - Gravity waves
  - Acoustic and seismic energy
  - Chemical, mineralogical, organic, and in-situ biological samples
  - Pressure, temperature, winds
  - Other physical phenomenology required by science

Monkey Head Nebula

Flexible Electronics Needs (cont.)

- Smart wiring systems
  - -Reduce mass
  - -Decrease volume
  - -Detect wire damage
  - -Self heal insulation
  - -Sense connectivity issues
  - -Reconfigure power and data to maintain connectivity in response to changing mission conditions
  - -Increase reliability
  - -Sustainable over long periods
- Electronic systems operating above 500°C to eliminate
  - -Active cooling systems
  - -Heat pipes
  - -Heat sinks
  - -Mass
  - -Volume

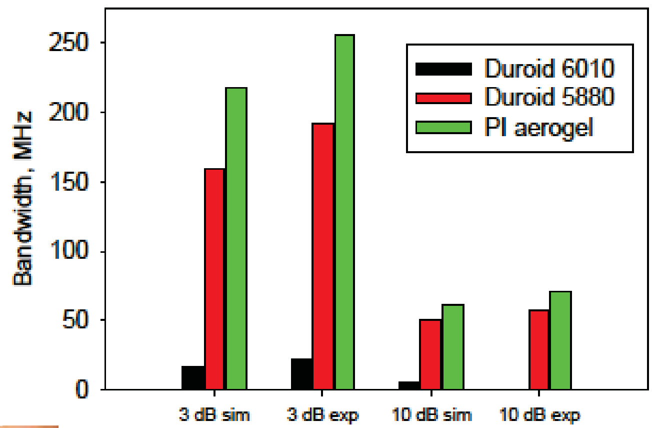
Flexible Electronics Biomedical Needs

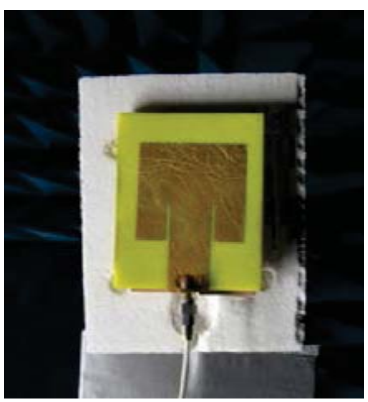
- Biomedical sensors
  - Easily donned/doffed and comfortable to wear
  - Minimally-invasive to the eye and skin
  - Noninvasive to the brain
  - Microfluidics to deliver samples to sensors
  - Attentional state monitoring
  - Biomarkers
  - Nutrient absorption
  - Wireless data communication vs. quick disconnect
  - Subcranial, interocular, and spinal fluid pressure
- Surface sensors

Pulse/Ox	Blood pressure	Dry electrodes
Temperature	Sweat	Electromyography (EMG)
GSR	Plantar pressure	

Flexible Electronics at NASA GRC

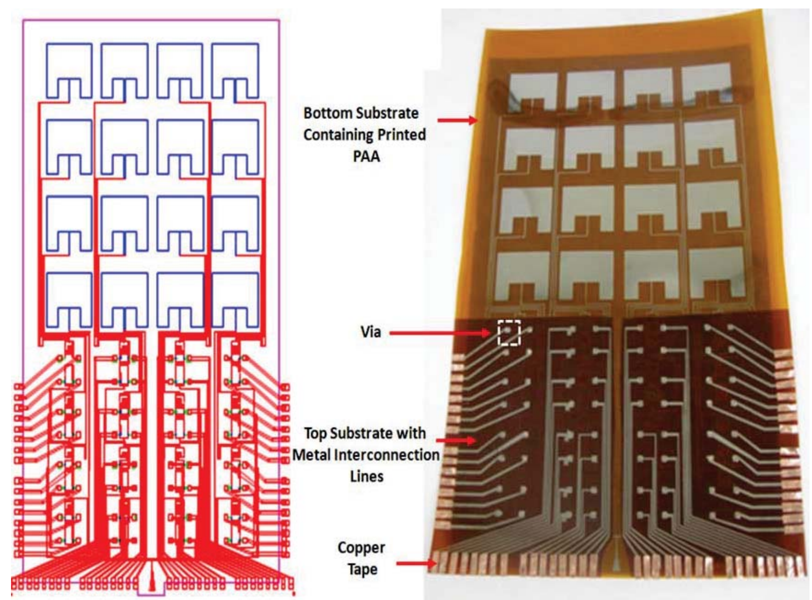
- Aerogels
  - Flexible, porous, lightweight, high surface area, good thermal insulator
  - Low density = low dielectric properties (1.008 at 0.008g/cm^3)
  - Potential dielectric for capacitors, flexible capacitors, super-capacitors
  - Substrate material in sheet form
- Antennas
  - Patch antenna on polyimide aerogel
  - Wide bandwidth antennas
  - Conformal antennas





Flexible Electronics at NASA GRC

- Inkjet-printed two-dimensional 2-bit 4 x 4 phased-array antenna
- Multilayer interconnection scheme used to fabricated the subsystem
- 64 carbon nanotube thin-film transistors form the phase shifter
- Switching controlled by mainframe computer
- 5-GHz RF signal at four steering angles were experimentally demonstrated



- Maximum steering angle: elevation (θ) of 34°, azimuth (φ) of -26.5°

Flexible Electronics at NASA JPL

- Eliminate structure, spacecraft on a substrate
- Printable Spacecraft

  A two dimensional "sheet" that contains all of the functional subsystems of a typical spacecraft - science measurement through data downlink.
- Task elements

  Design, build and demonstrate an end to end spacecraft platform

  Define a scientific reference mission to evaluate the programmatic benefits of infusing printed spacecraft.

  Develop roadmaps for multiple applications and focused mission infusion.

  Test printed electronics coupons in space environments and evaluate compatibility
- Program objectives are to investigate technology that might be achievable in a ten year horizon
- Eliminate structure, spacecraft on a substrate

Glenn Analytical Capabilities

Advanced analytical capabilities available to NASA researchers as well as academia, industry and other government agencies

- Analytical Chemistry
  - Atomic Absorption Spectrophotometry
- Electron Optics
  - Scanning electron microscopes
  - Transmission electron microscopes
  - Electron microprobe
  - Focused ion beam / scanning electron microscope
- X-ray diffraction
  - Crystallographic characteristics of metals, ceramics, and polymer specimens
- Metallography laboratory
  - Sample preparation (metals, ceramics, and matrix composites thereof)
  - Interference layering
  - Plasma etching surface preparation
- Optical Microscopes
  - MEF3 Reichert metallographs
  - Nikon Optiphot binocular microscopes
  - Olympus and Wild stereo macroscopes

Glenn Sensors and Electronics Capabilities

- Micro-ElectroMechanical Systems (MEMS)
- Microfabricated thin film sensors
  - Temperature
  - Strain
  - Heat flux
  - Flow measurements
- Chemical species sensors
- Nanotechnology
  - Sensing systems
  - Wireless and embedded communications
  - Large area flexible electronic displays
  - Active matrix light-emitting diode (LED) displays
  - Antennas and Radio Frequency identification (RFID) devices
  - Smart keys and smart cards

NASA Glenn Applicable Expertise

- Power management and distribution
- Nano technology
- Energy conversion and storage
  Solid-state lithium battery
- Advanced control algorithms
- Thin film solar arrays
- Shape memory alloys (actuators)
- Materials development and assessment
- Systems integration
- Problem solving from a different view point
- Aerospace applications

Flexible Electronics Technology Development

- The commercial electronics industry is leading development in most areas of electronics for NASA applications
- NASA is focused on improving technology and partnering with industry to secure electronics capability for a wide range of aerospace missions

Partnering

- The NASA Glenn Research Center is interested in identifying opportunities to partner with the private sector and academia to advance flexible electronics technology for the NASA mission and, beyond aerospace, to help the spur economic growth in the community.

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