Wearable Technology Workshop

ISM Multi Material Fabrication Flexible Sensing Development

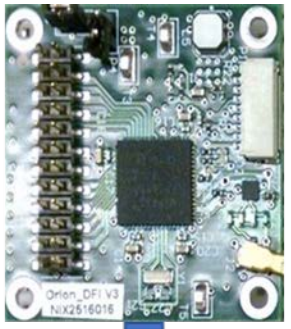
Curtis W. Hill
NASA MSFC
EM42/ESSCA

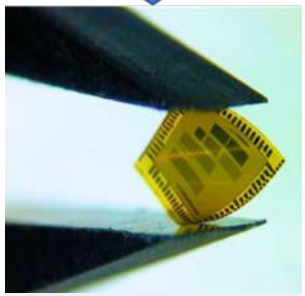
NASA MSFC Materials & Process Development
Flexible Sensing Technology

Background and requirement

ISM Multi Material Fabrication Key Areas:

- **Development of Flexible Sensing Technology:**
  - Development of next-generation flexible sensor platforms and printed sensors for Crew Health Monitoring on International Space Station.
  - Development of materials and processes for printed sensors.
  - Evaluation and incorporation of new component technologies (flexible components, wireless communications, etc.)
- **Energy Storage Technology Development:**
  - Develop triboelectric power in order to build a self-contained sensor system.
  - Further maturation of an all-printed supercapacitor.
  - Developing very high energy density supercapacitors for battery replacement with several commercial companies.
  - Developed an Al-air battery with University of Tennessee & ORNL for scalable battery replacement applications.





Flexible Electronics Sensors

NASA MSFC Materials & Process Development Background on In Space Manufacturing

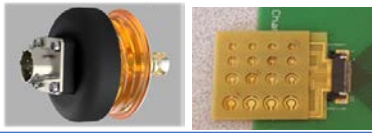
ISM Objective: *Develop and enable the technologies, materials, and processes required to provide sustainable on-demand manufacturing, recycling, and repair during Exploration missions.*

- ***In-Space Manufacturing Technology & Material Development:*** *Work with industry and academia to develop on-demand manufacturing and repair technologies for in-space applications.*
- ***In-Space Recycling & Reuse Technology & Material Development:*** *Work with Industry and academia to develop recycling & reuse capabilities to increase mission sustainability.*
- ***In-Space Manufacturing Digital Design & Verification Database (i.e. WHAT we need to make):*** *ISM is working with Exploration System Designers to develop the ISM database of parts/systems to be manufactured on spaceflight missions.*

Made in Space, Inc. ISS Additive Manufacturing Facility (AMF)

NextSTEP Multi-material 'FabLab' Private Public Partnership

Design Database Development
Printed Life Support System (LSS) Retaining Plate (Left); Urine Funnels (Right)



Printed Electronics:
LSS Pressure Switch (Left); UV Radiation Sensor (Right)

ISS Refabricator Demo with Tethers Unlimited, Inc.

Collaborative *Leveraging with Industry and Academia*

NASA MSFC Materials & Process Development Laboratory Capabilities

Nanomaterials Development & Processing

Powder Processing

Ceramic Powder Processing

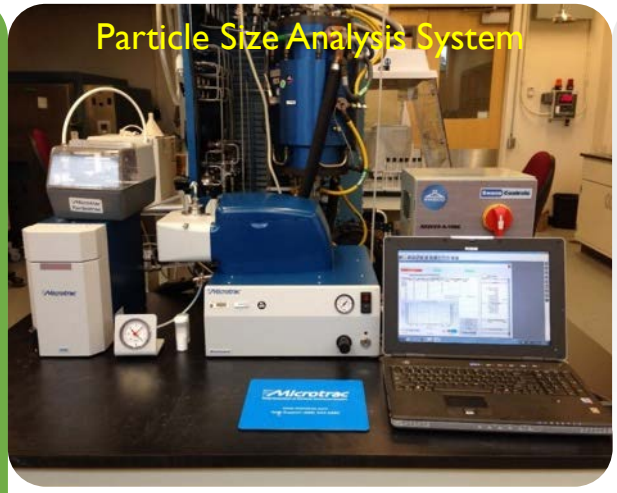
- Powders can be reduced in sized and homogenized
  - Vibratory Mill utilizes 3-axes grinding action
  - Micro-mill provides fast-grinding for small batches, and can achieve < 50nm particle sizes
- Powder treatment with forming gas inside fluidized bed furnace produces desired dielectric properties for ultracapacitors
  - Current process is DOE-optimized

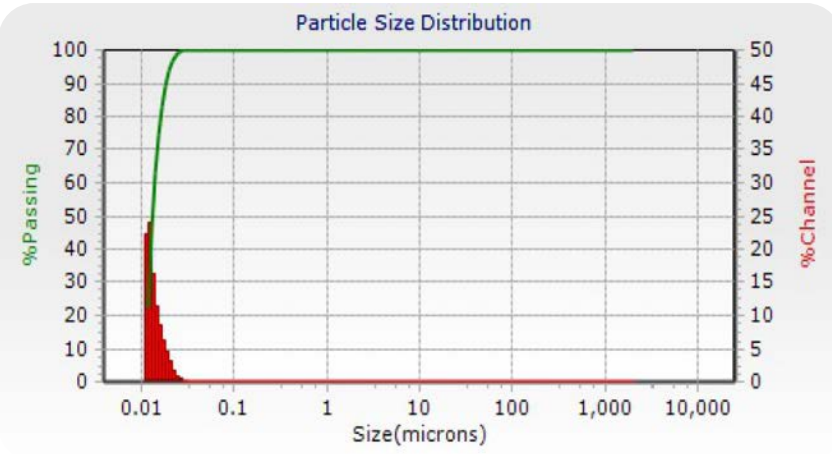
Particle Size Analyses

Particle Size Measurements

Understanding of mean particle size and distribution aids in powder milling for uniform sizing.

Sample preparation is critical in gathering accurate data, as data collection (air bubbles can skew results dramatically).

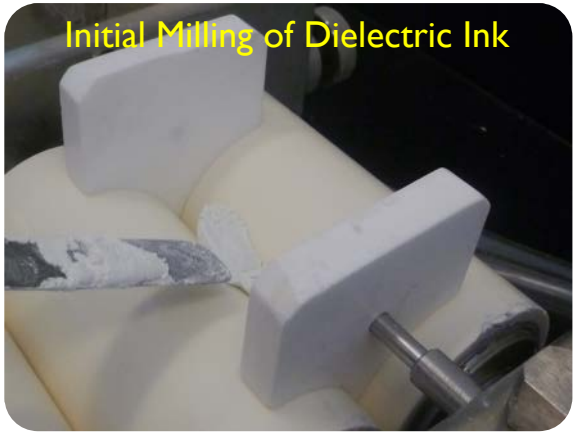


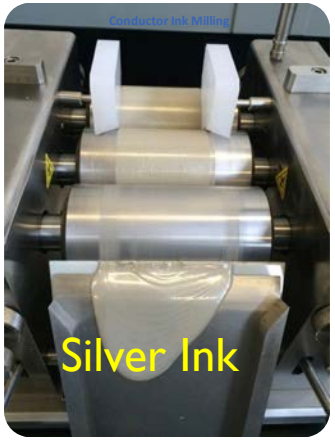


NASA MSFC Materials & Process Development Laboratory Capabilities

Nanoinks Development & Processing

Ink Formulation





Ink Formulation

- The combination of ceramic (dielectric) or metallic (conductor) powders with vehicles, dispersants, and other additives creates **inks** which can be printed with a variety of different deposition processes.
- **Thick film ink** formulations are produced via 3-roll mills, which disperse particles though out the mixture via a combination of compression and shear between tightly spaced rollers. Roller speed and spacing are both controllable and are key factors in the final product
- **Thin film** inks require fewer additives (typically the powder material and a vehicle) and are used in direct write deposition systems. Therefore lower viscosity is necessary, which can be achieved using a high-shear dispersion mixer.

Strategic Advantages

- While initially developed to support Ultracapacitor research, capabilities in the Nanoelctric Materials Lab can be used for a variety of research (ultracapacitors, conductor inks, electroluminescence, radio-frequency identification (RFID)).
- Particle Size Analysis system can be used to support many different areas (propellant formulation, additive manufacturing)
- Equipment allows for custom development of raw materials

NASA MSFC Materials & Process Development Laboratory Capabilities

Material processing

3D Multi-Material Printers

nScrypt 3D Multi-Material Printer

nScrypt 3D multi material printer

- 4-head capability:
  - SmartPump for inks
  - 2 nFD heads for filament polymers
  - Pick & place head for discrete electronic components.
  - nMill for polishing, drilling, subtractive processing
- High precision 3D deposition in a 300x300x150mm volume. Developing materials and processes leading to a multi material FabLab for International Space Station.
- Recent addition of a laser sintering capability.

Voltera electronics printer

Voltera Electronics Printer

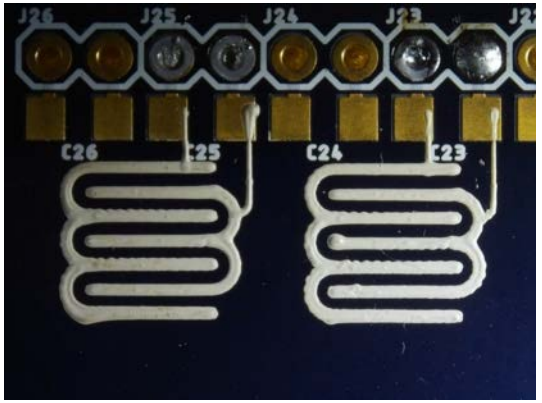
- Added in 2018 for quick-turnaround prototyping of sensors and testing of inks.
- Printing resolution is good for prototyping and general electrical circuits, but not fine pitch devices or tight line spacing.

NASA MSFC Materials & Process Development
Flexible Sensor Development

Multi Material Fabrication and Materials Development

Development of Flexible Sensing Technology:

- Development of next-generation wireless flexible sensor platforms and printed sensors for Astronaut Crew Health Monitoring on International Space Station.
- Development of materials and processes for printed sensors.
- Evaluation and incorporation of new component technologies (flexible components, wireless communications, etc.)



NASA MSFC Materials & Process Development
Flexible Sensor Development

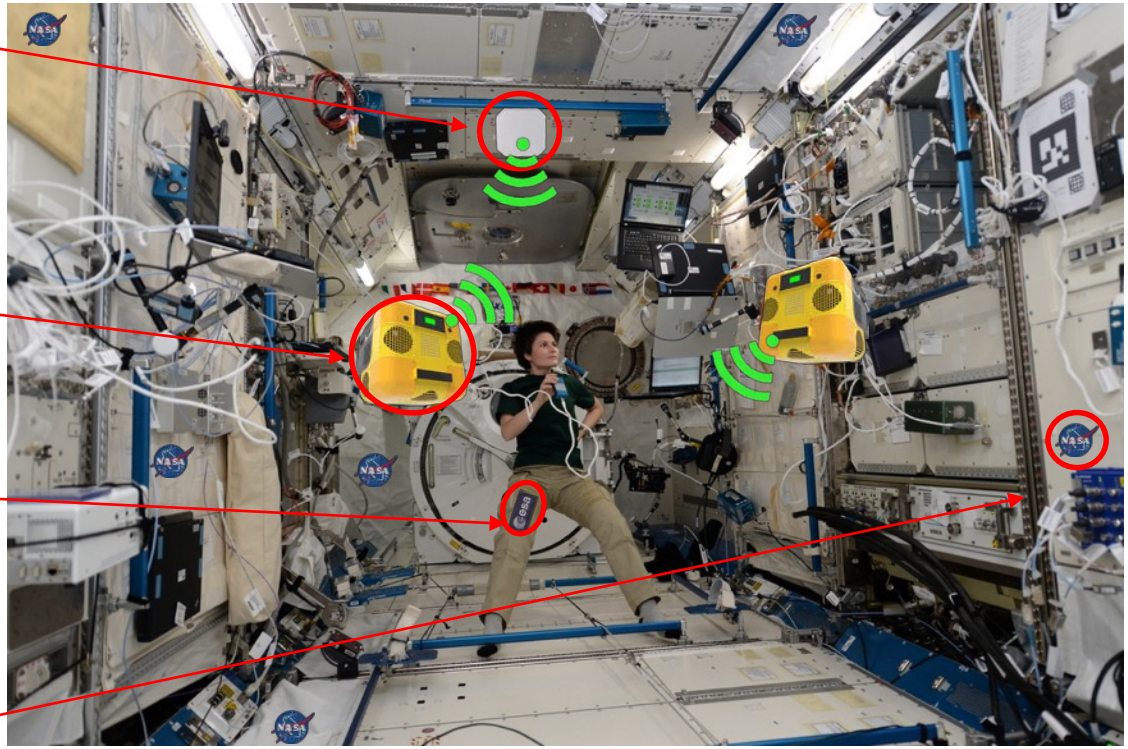
Wearable Wireless Sensors Operational Concept

fixed interrogator

mobile interrogator

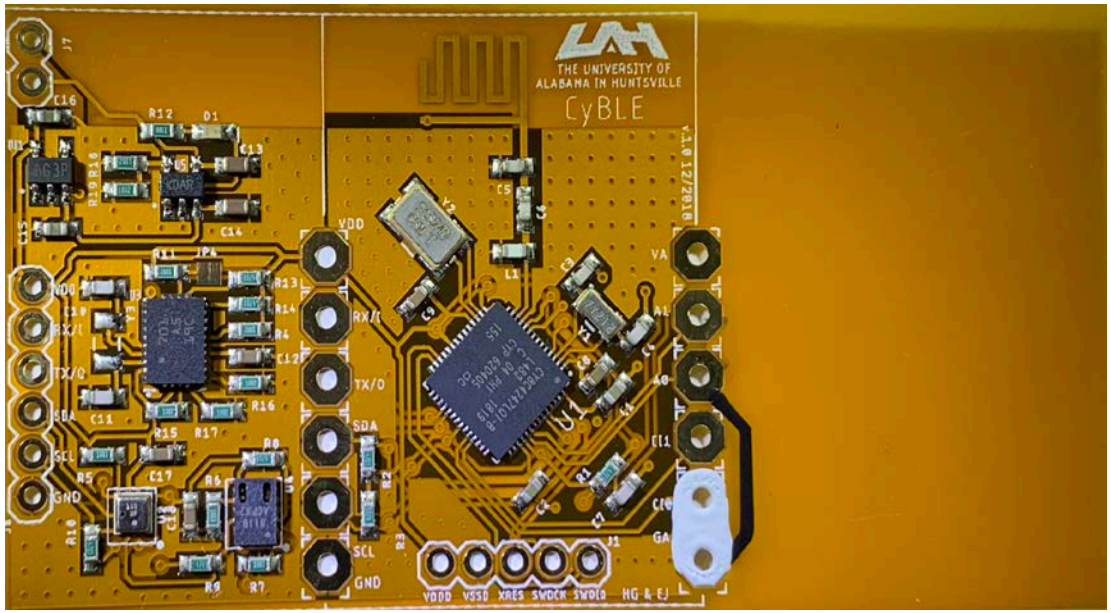
ultra-long battery life **wearable** sensor "patch"

wall-mounted ("peel-and-stick") sensor "patch"



NASA MSFC Materials & Process Development
Next-Generation Flexible Sensor Platforms

First Generation Personal CO_2 Monitors



Flexible Sensor Platform with High Speed BLE Communications with printed thermistor & respiration sensors

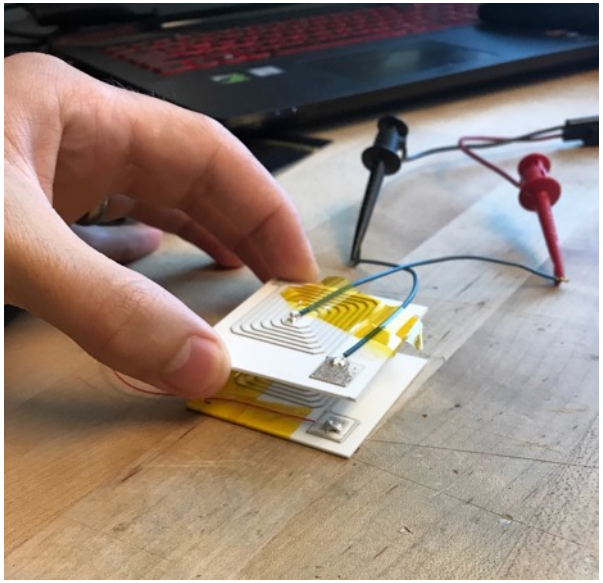
NASA MSFC Materials & Process Development
Development of Printed Sensors

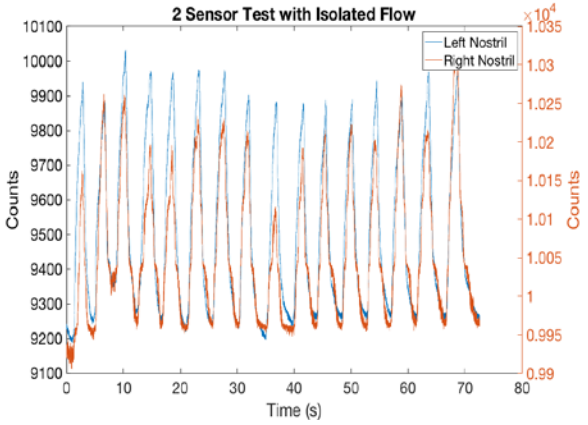
First Generation Personal CO_2 Monitors

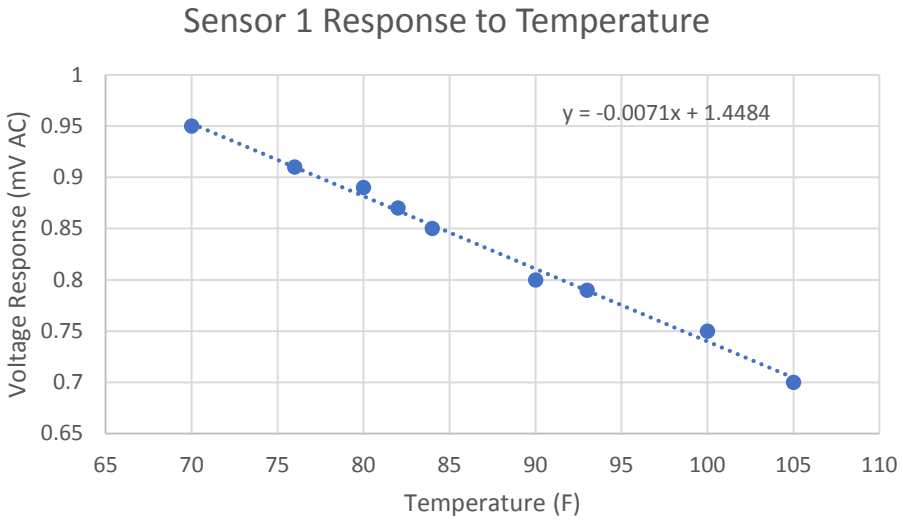
3D-Printed Al-Fe_3O_2 Nanothermite Sintered CO_2 Sensor

NASA MSFC Materials & Process Development
Development of Printed Sensors

Humidity/Respiration Sensor







Composite Temperature & Pressure Sensor