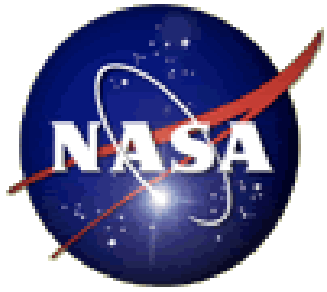

Sensor Technologies on Flexible Substrates: In-Space Manufacturing

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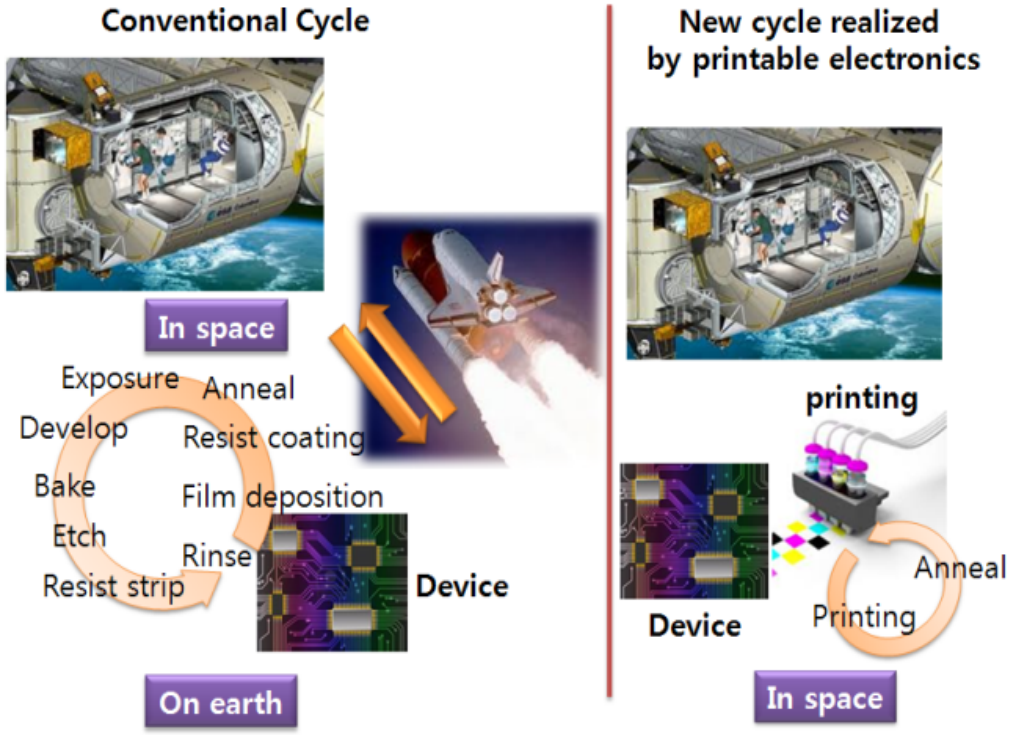
Center for Nanotechnology
NASA Ames Research Center
4/26/2016

In-Space Manufacturing

- No need to wait for resupply
- Fabrication on-demand
- Printers and Functional Inks
- Compliant or woven substrates allow easy integration into flexible or compliant surfaces
- Technologies include:
  - Energy generation & storage
  - Communication
  - Integrated circuits
  - **Sensors**



Printing Materials and Methods

Manufacturing

Roll-to-Roll
Screen Printing
Gravure
Transfer
INK JET
PLASMA JET

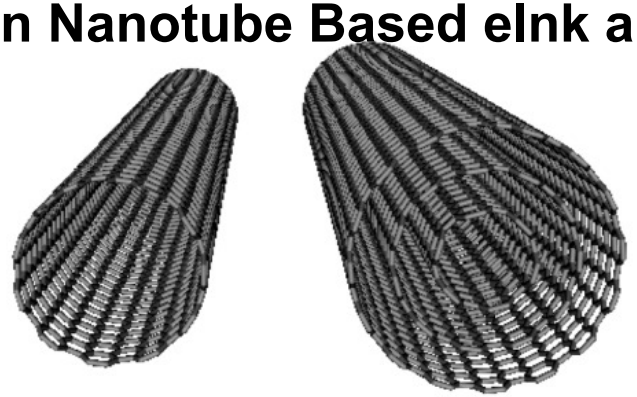
Substrates

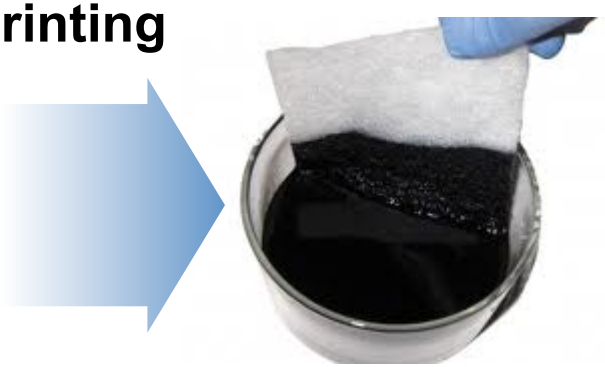
Silicon
Kapton
Metal
Glass
Ceramic
PAPER
POLYMER

Inks

Conductor
Semiconductor
Insulator
Passivation
Catalyst
Biological agent

Carbon Nanotube Based eInk and Printing





Ames Research Center

Advantages of Paper

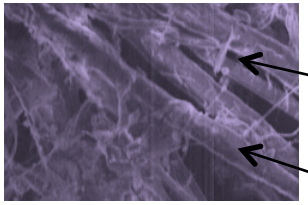
NASA

- **Sensors fabricated on paper**
  - Gas sensor, chemical sensor, bio sensor, and strain gauge
  - Detection of structural defects and cracks, structural health monitoring
  - Commercial: Intelligent packaging, advertising banner, newspaper

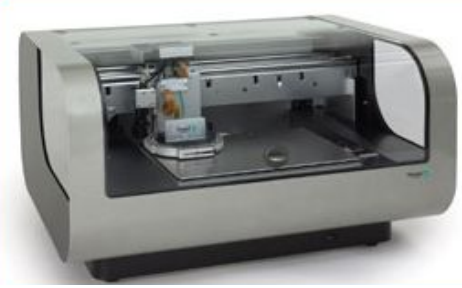
- **Features**
  - Flexible, bendable, foldable
  - Bio-degradable: green technology
  - Robust at cryogenic temperatures
  - Role-to-role printing or ink-jet printing process
  - Cheaper than solid-state sensors
  - Biomedical: Single-time use, disposable

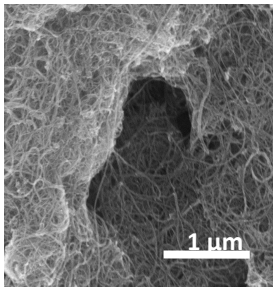
Printing Approaches

Fountain Pen:

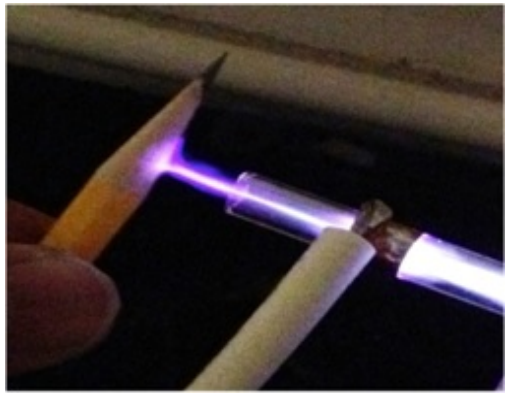


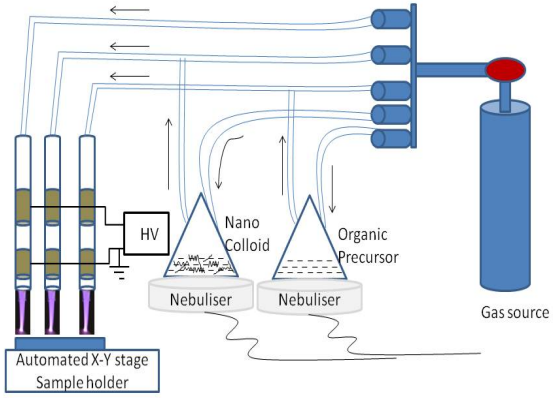
Inkjet:



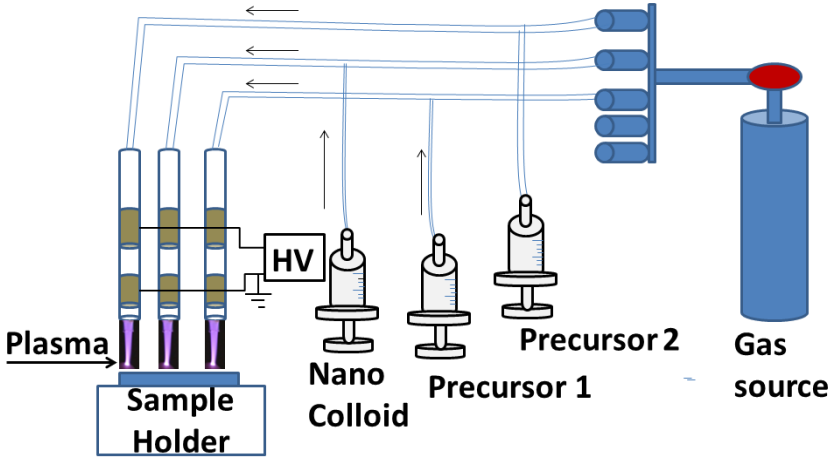


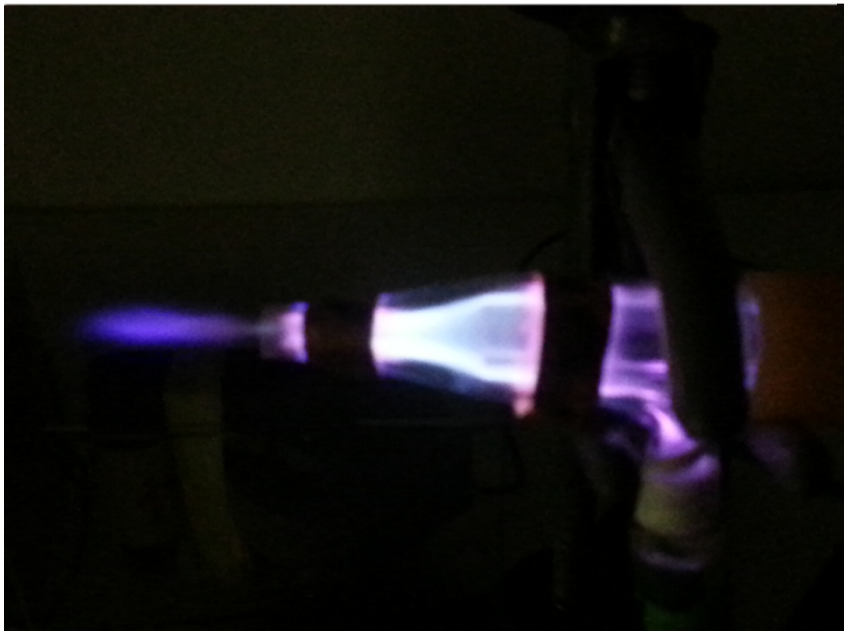
Atmospheric Pressure Plasma Jet:





Atmospheric Pressure Plasma Jet

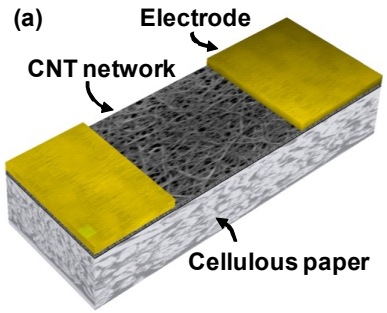


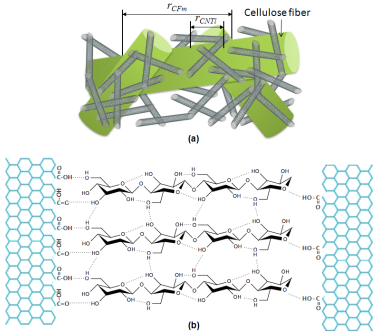


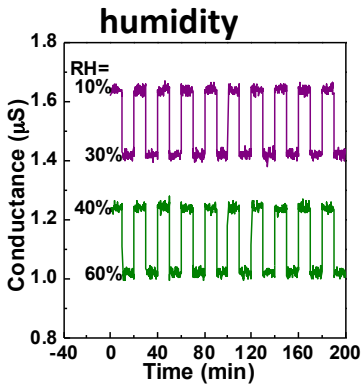
- Glass tube or nozzle; two copper band electrodes (20 mm apart)
- Helium atmospheric plasma
  - can introduce different gases for chemistry control (e.g. hydrogen for reduction)
- Nanocolloids, organic materials etc. transported as aerosol by carrier gas
- Spot size can be altered by changing print head nozzle diameter
- Multiple jets for different coatings

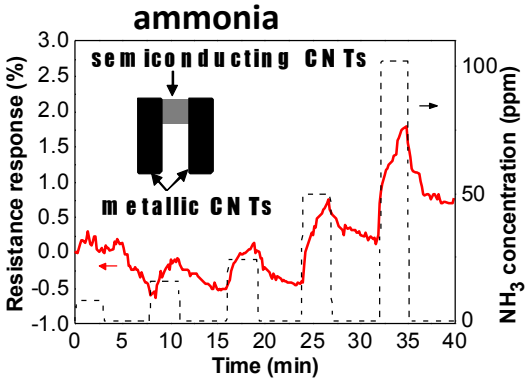
Technology Demo: Chemical Sensing

- Humidity and NH_3 Sensor on Paper





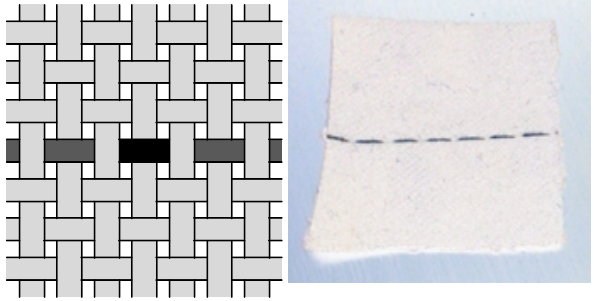


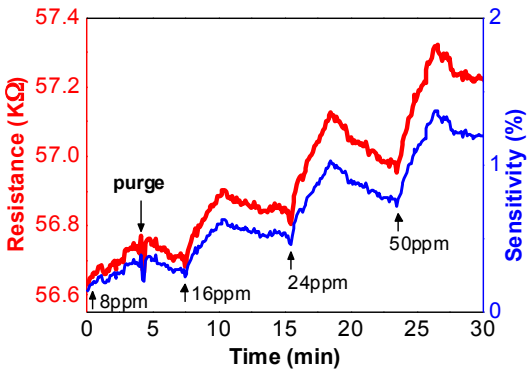


- NH_3 Sensor on Textiles

Metallic CNT

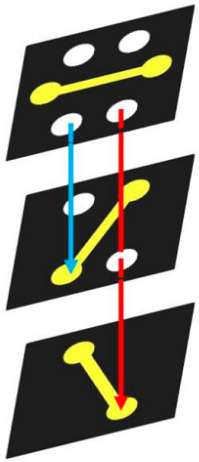
Semiconducting CNT

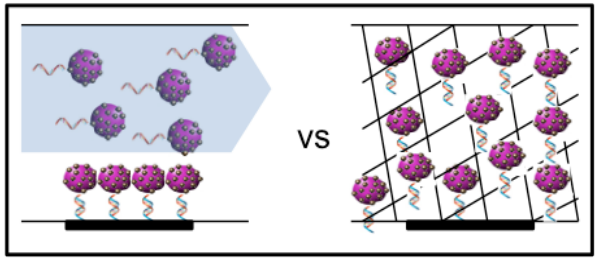


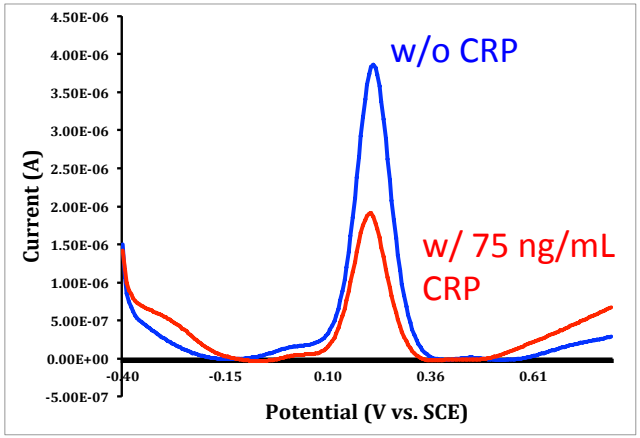


Technology Demo: Biological Sensing

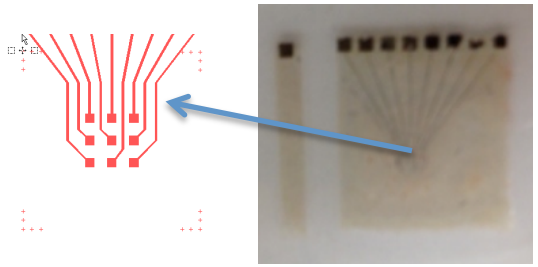
- Sensors on Paper

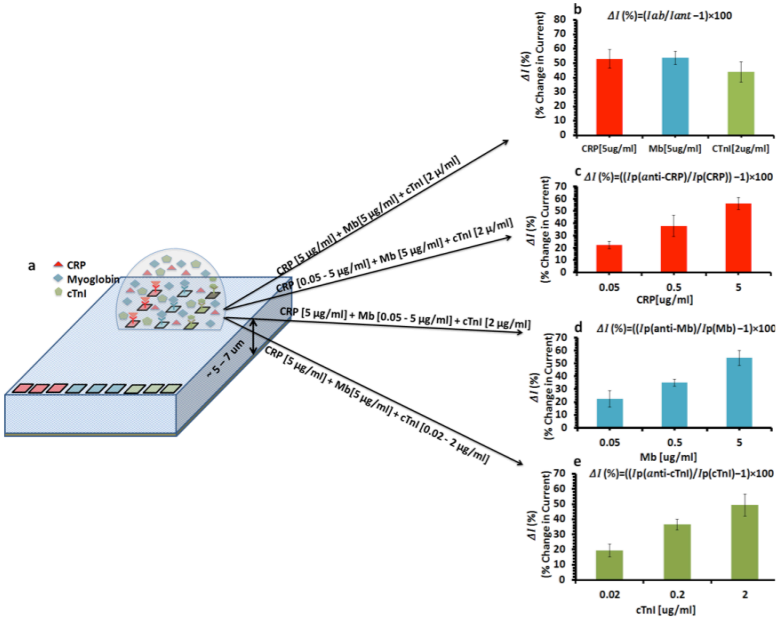






- Sensor on Polyimide





Sensors on Flexible Substrates for Next Generation EVA Suit

- Human health monitoring
  - Skin Wearable Sensors
    - Sweat, saliva, urine, blood
    - Health & human performance
    - pH, proteins, ions, etc.
  - In Suit Sensors
    - Breath
    - Health & human performance
    - O_2, CO_2, acetone, NO_2
- Environmental monitoring
  - Gas or vapor
    - CO, NH_3, hydrazine
- Structural Health Monitoring
  - Strain

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