

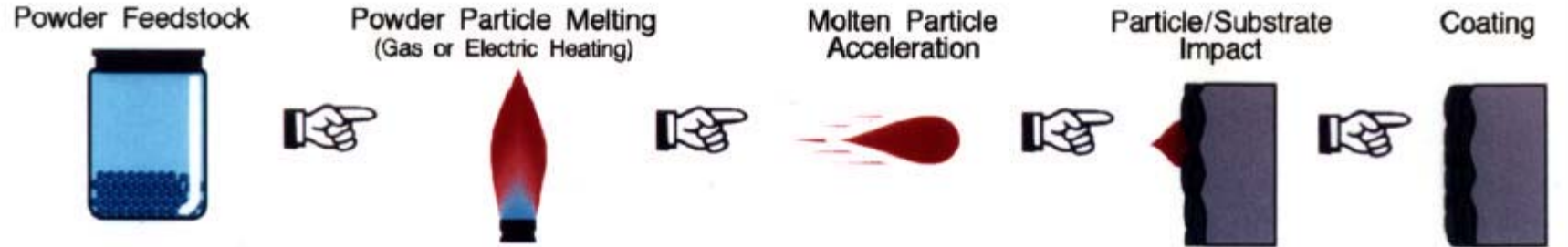
Direct Write Thermal Spraying of Mesoscale Electronics and Sensor Structures

Novel Approaches to Integrating Sensors on Structures

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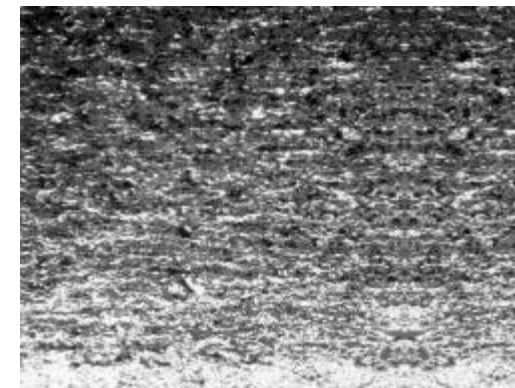
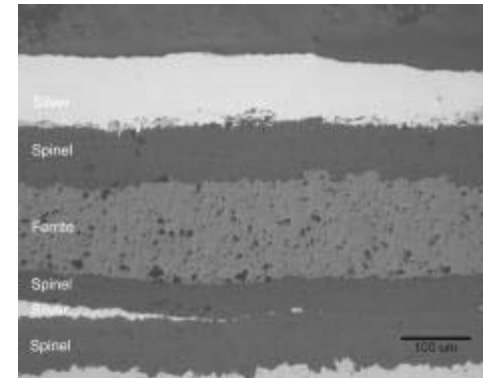
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Huntington Beach, CA

Thermal Spray Direct Write Technology



Virtues and Unique Advantages

- High through-put manufacturing
- High speed direct writing capability
- *In situ* rapid application of metals, ceramics and polymers
 - W/o thermal treatment or post processing
 - (Once we write we are done !!)
 - *In situ* incorporation of multilayers & functionally graded layers
- Useful functional material properties in as-deposited state
- Cost effective and efficient
- Process virtually in any environment
- Minimal heat input into the substrate



Thermal Spray Direct Write Deposition Capabilities

Range of Geometries

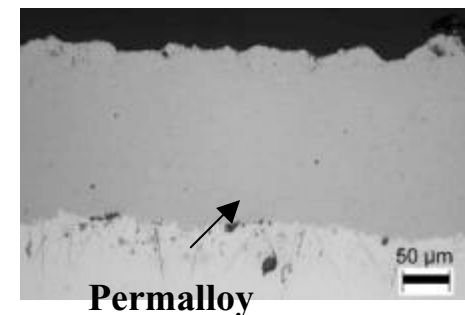
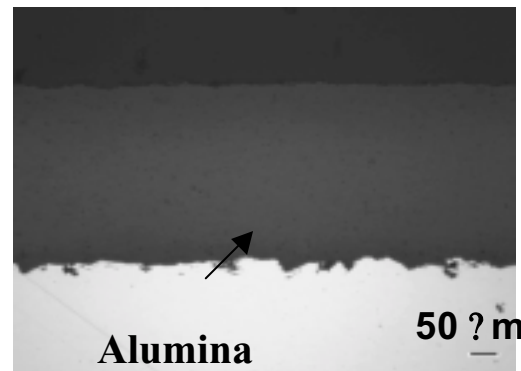
- Blanket Deposits: Films and Coatings
- Patches
- Lines
- Vias
- Thick deposits and 3-D structures
 - On plastic, metals, textile and ceramic substrates
- Conformal structures
- On pre-existing components and structures
 - Ability to overcoat with a variety of materials for harsh environment applications

Extraordinary Materials Versatility

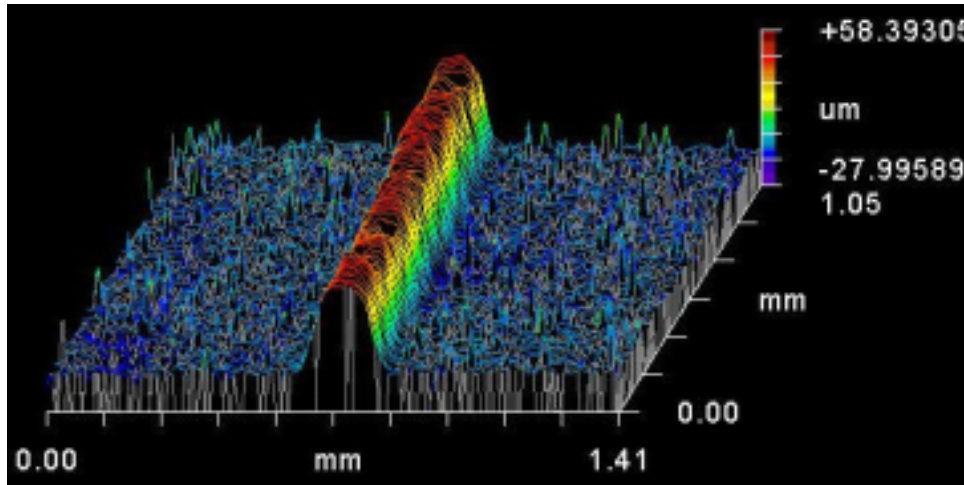
- Dielectrics and sensor ceramics
 - alumina, zirconia, yttria, BaTiO₃, BST
- Conductors
 - Cu and Ag
- Sensor materials
 - NiCr, NiAl, Mo, NiCu etc.
- Magnetics
 - Permalloy) and MnZn ferrites
- Polymers
 - Range of thermoplastics
- Semiconductors
 - Si and Ge



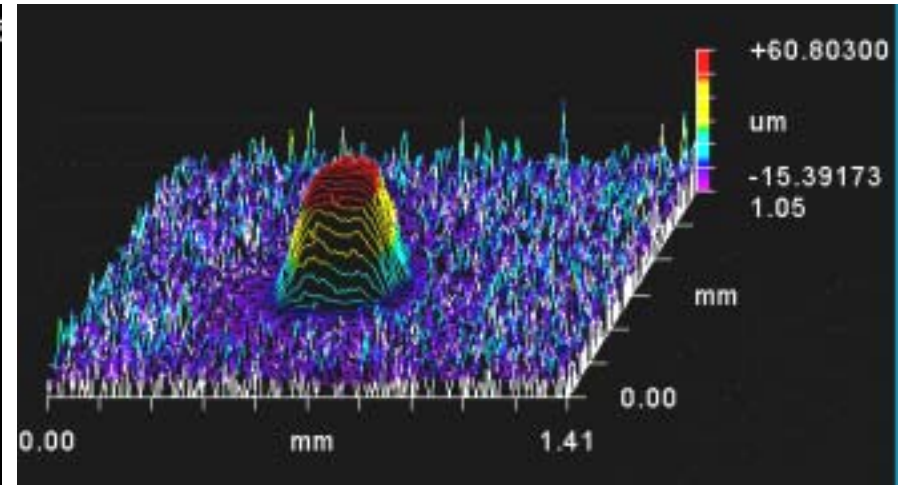
Antenna on Concrete
With Polymer overcoat



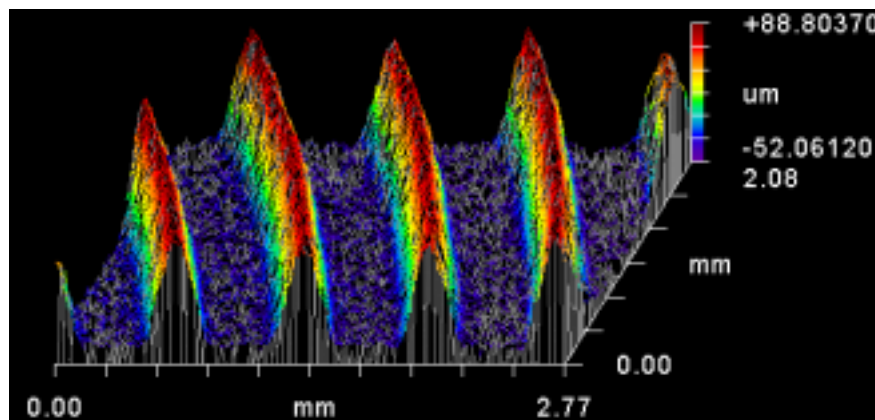
Mesoscale Direct Write Capability



Height ~ 60 ? m
Base Diameter ~ 350 ? m



Height ~ 60 ? m
Base Diameter ~ 350 ? m

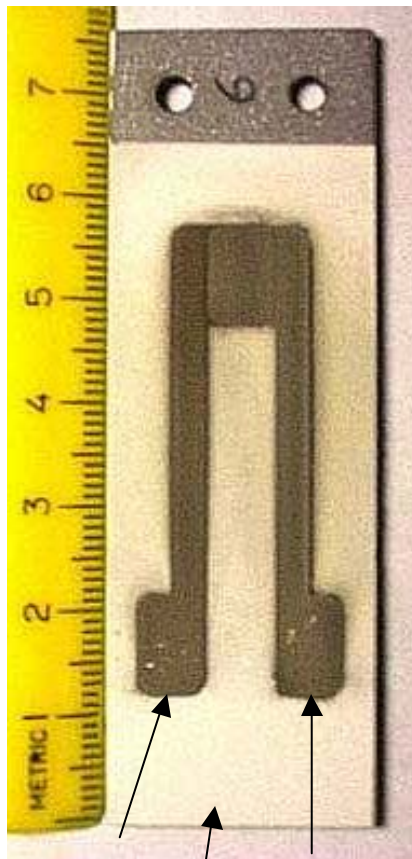


Direct-Write Sensors for Harsh Environments

- **Harsh Environments**

- high temperatures ,corrosive
- high vibration, wear, strain, thermal/load cycling, etc.

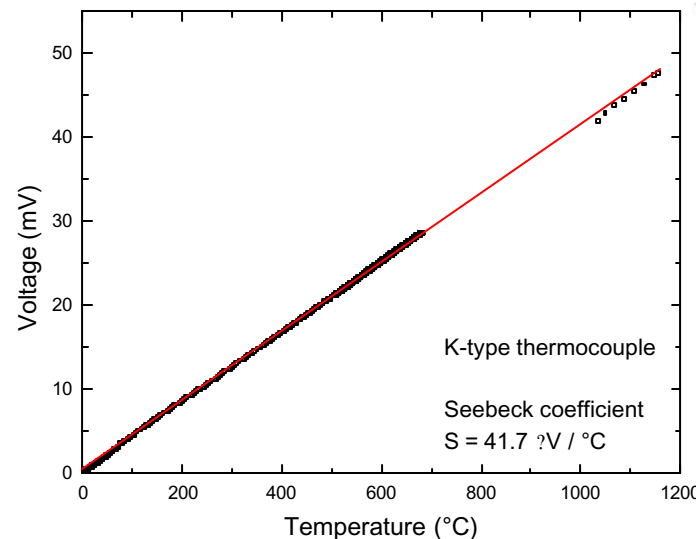
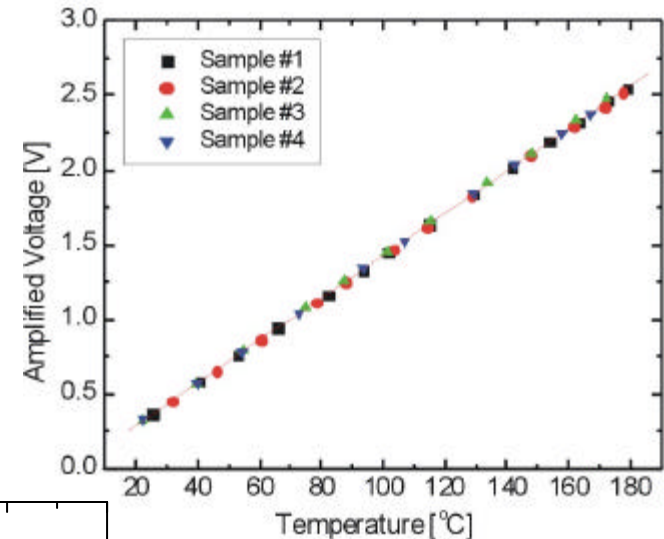
=> Intrinsic capability due to nature of thermal sprayed material and its application



NiCu
Alumina
coating
NiCr

E-type thermocouple By direct write

- chromel/constantan
- up to 900+ °C
- high sensitivity (> 45 mV/°C)
- High reproducibility

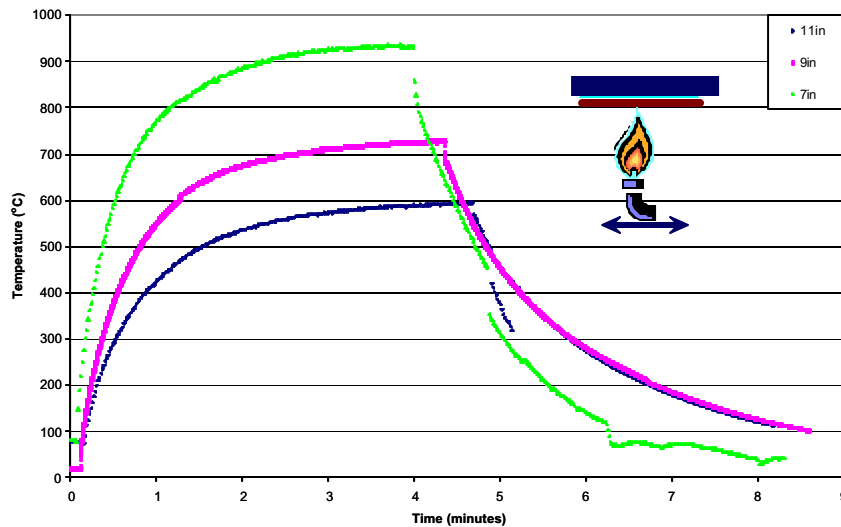
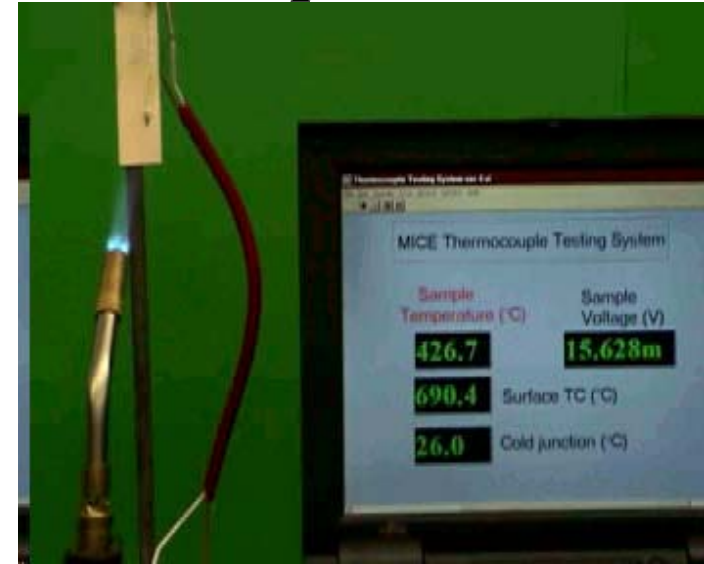
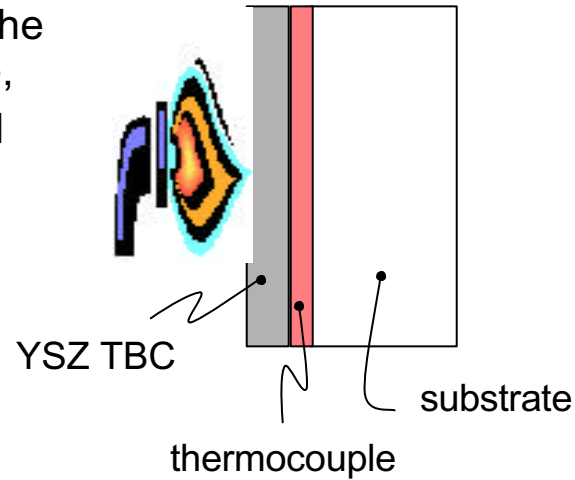


K-type thermocouple By direct write

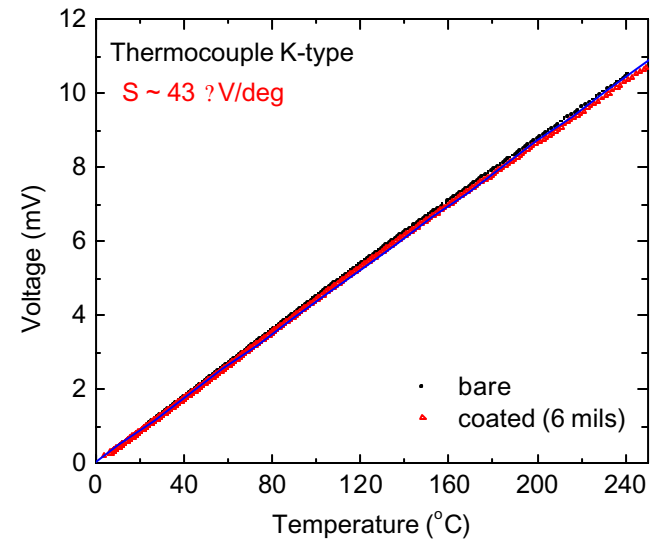
- chromel/alumel
- up to 1200+ °C
- good sensitivity
- robust performance

Flame Impingement Test for Exposed and Embedded Direct Write Thermocouples

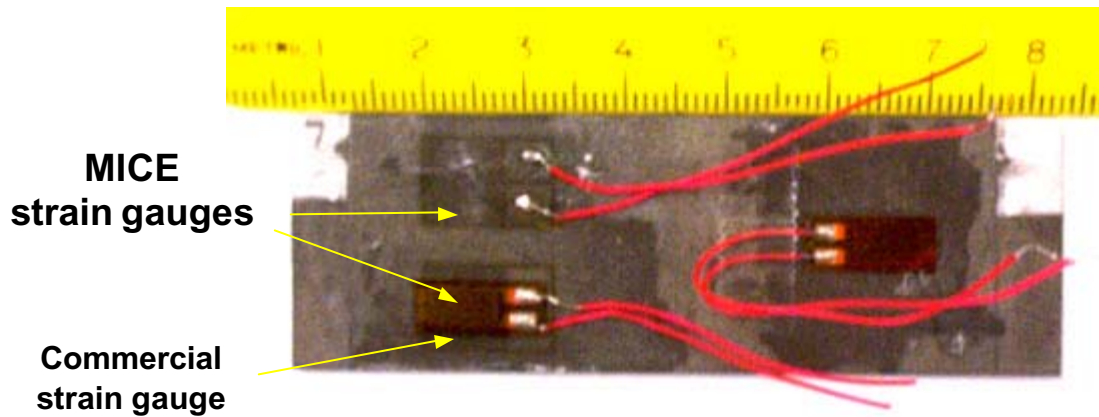
- MAPP flame on front of the embedded thermocouple, coated with YSZ thermal barrier coating
- Surface TC: 700 °C
- Embedded TC: 435 °C



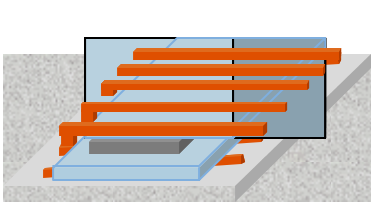
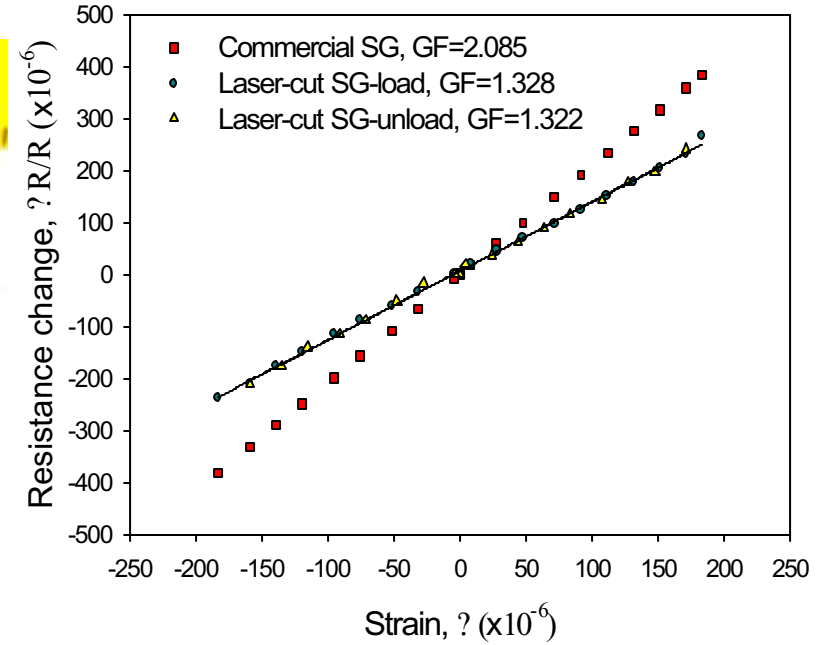
Response as a function of standoff distance



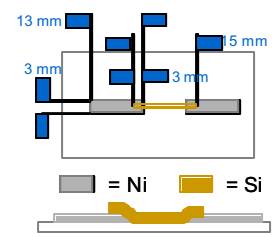
Embedded Strain Gauge and Other Devices



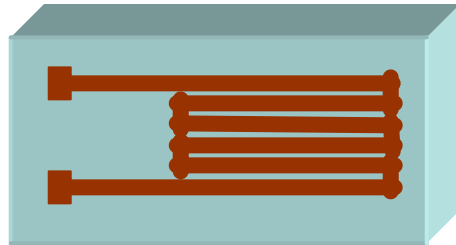
- Good repeatability
- Good linearity
- Negligible hysteresis



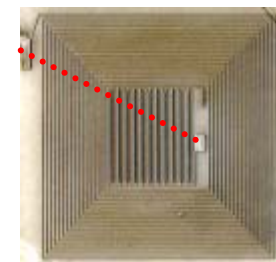
**Inductors/
Transformers**



Thermistors



Magnetic Sensors



RF Elements



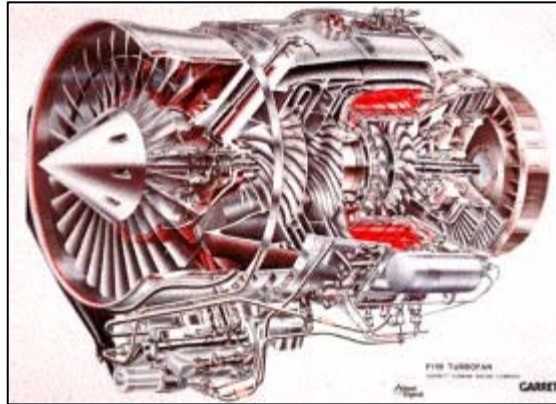
Microheaters

Applications in a wide range of industries

Thermal Spray MICE allows sensor integration onto variety of structures embedded within structural coatings



Infrastructure



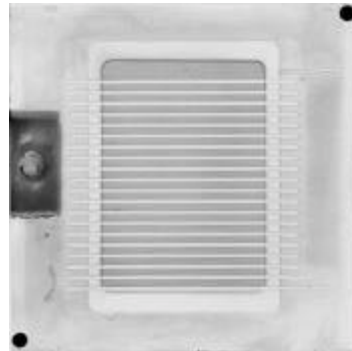
Aerospace



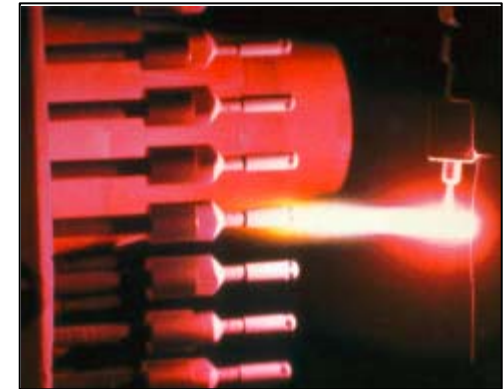
Automotive



Paper, Textile & Printing Industry

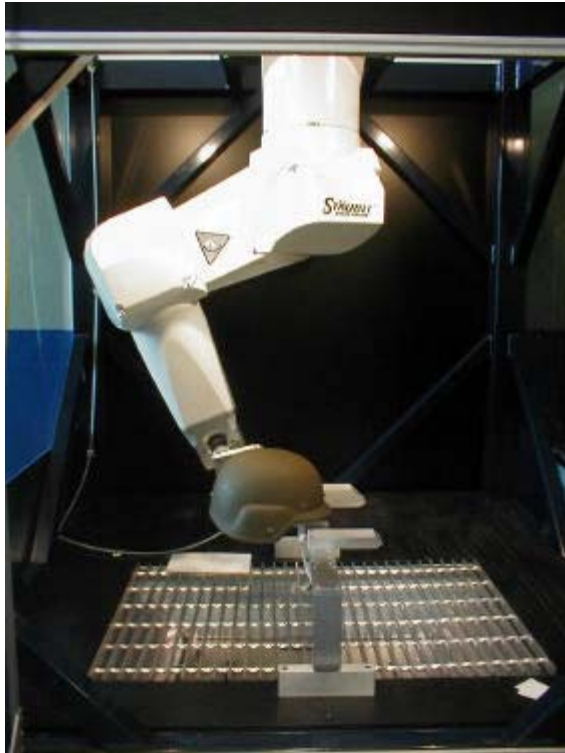


Mesoscale Electronics and Sensors

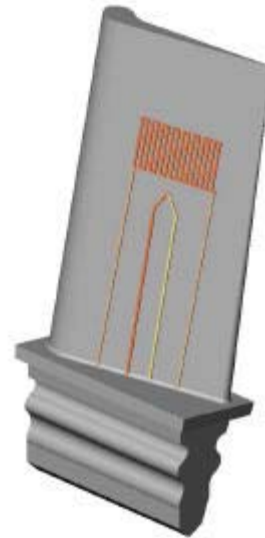


Dental Implants/Prosthetics

Conformal Direct Write Capability (Prototype Tool and System)



**Direct write antenna
On helmet**



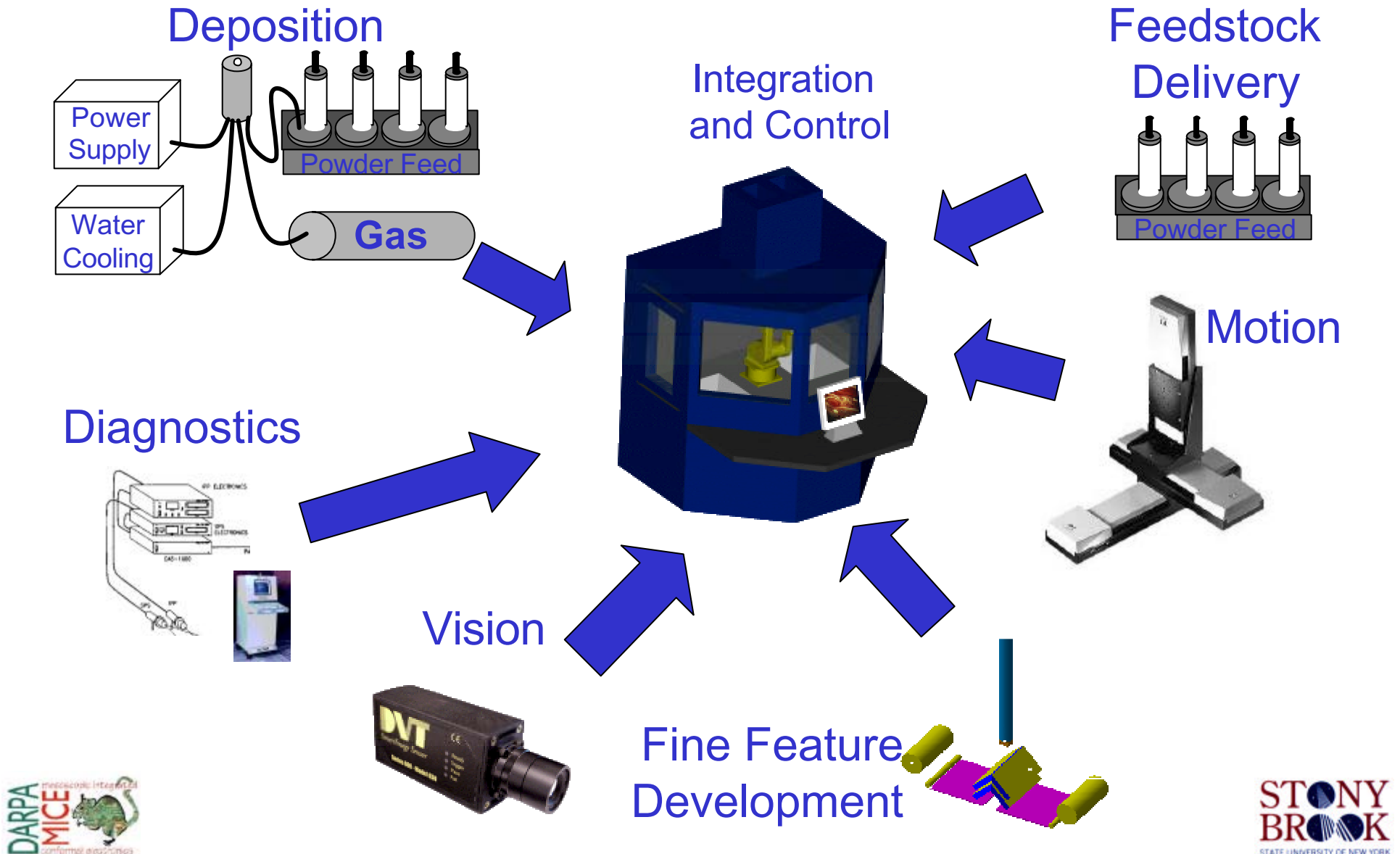
**Possible Direct-written
multisensor configuration
on a turbine blade**



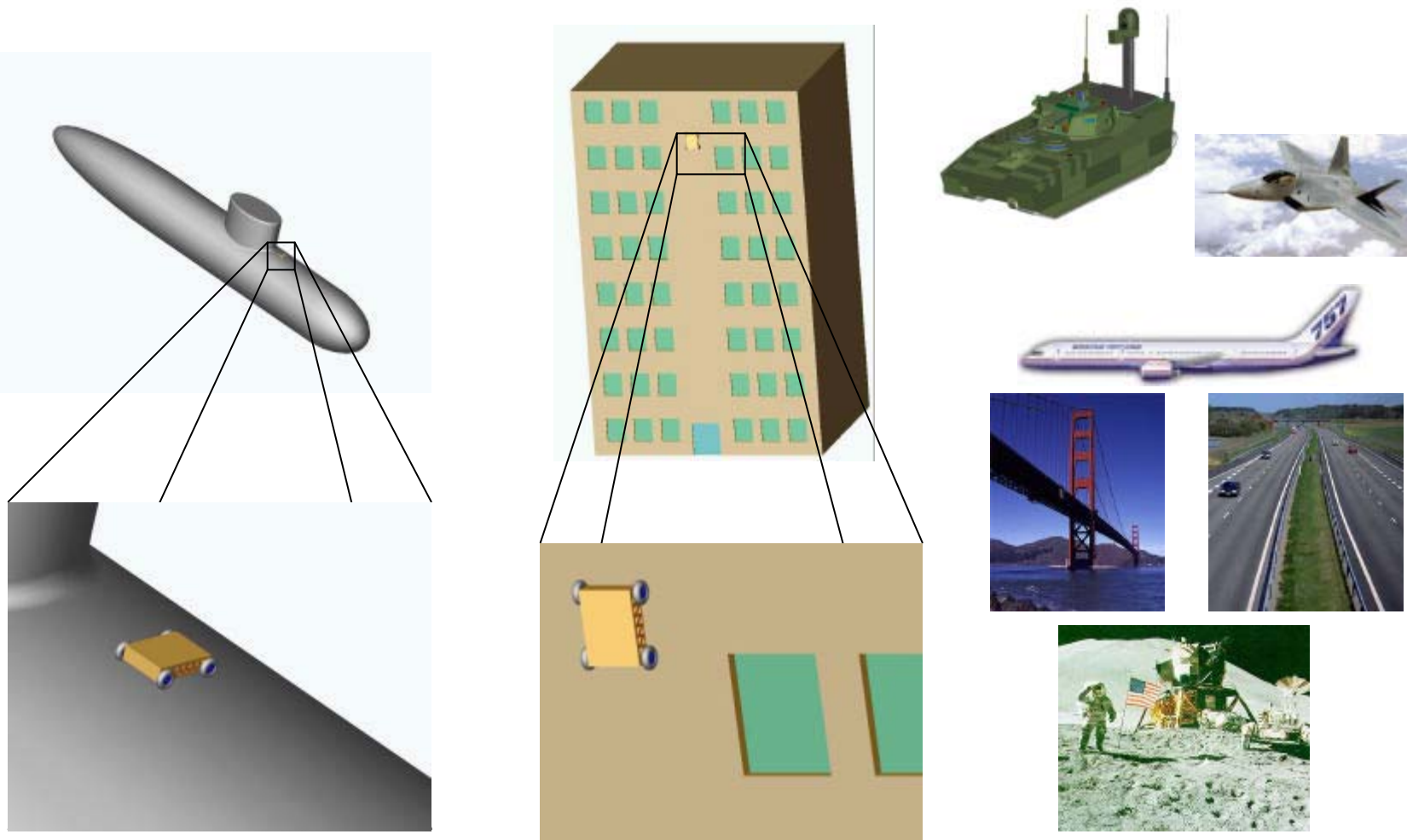
**Conformal direct
Write cell**



Stony Brook Prototype Direct Write Tool



Direct Write Sensors Mobile Application Possibilities



*Support equipment, tethered lines, and effects of gravity omitted for simplicity