

High Temperature SHM/NDE

In-situ characterization of the integrity of functional gradient hybrid metal/polymer/ceramic composites

Sensors and Sensing Network

Stanford, VT

Diagnostic Algorithms

UDRI, VT, UTAM, Stanford

Modeling

VT, Stanford

Integration and Characterization

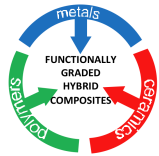
UI, Stanford, VT, UDRI, UTAM

Fu-Kuo Chang
Stanford University



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Functionally Graded Hybrid Composites

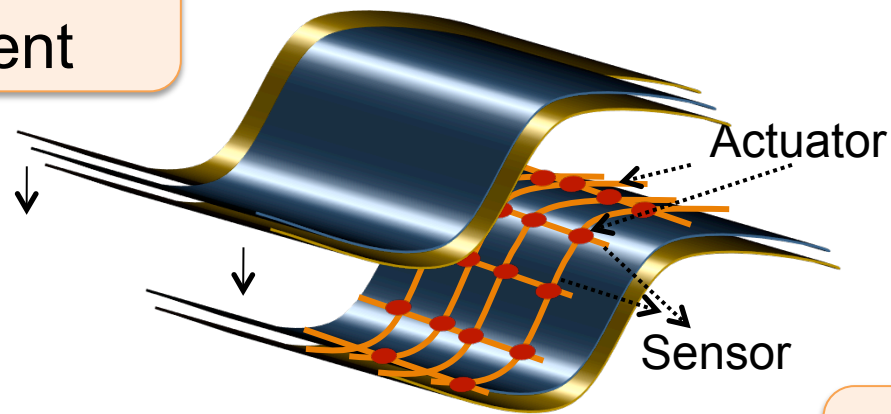




Sensors and Networks

Monitoring the health state of the hybrid composite materials during manufacturing and in service

Sensor Network development

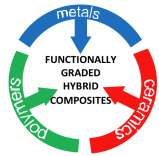


Sensors development



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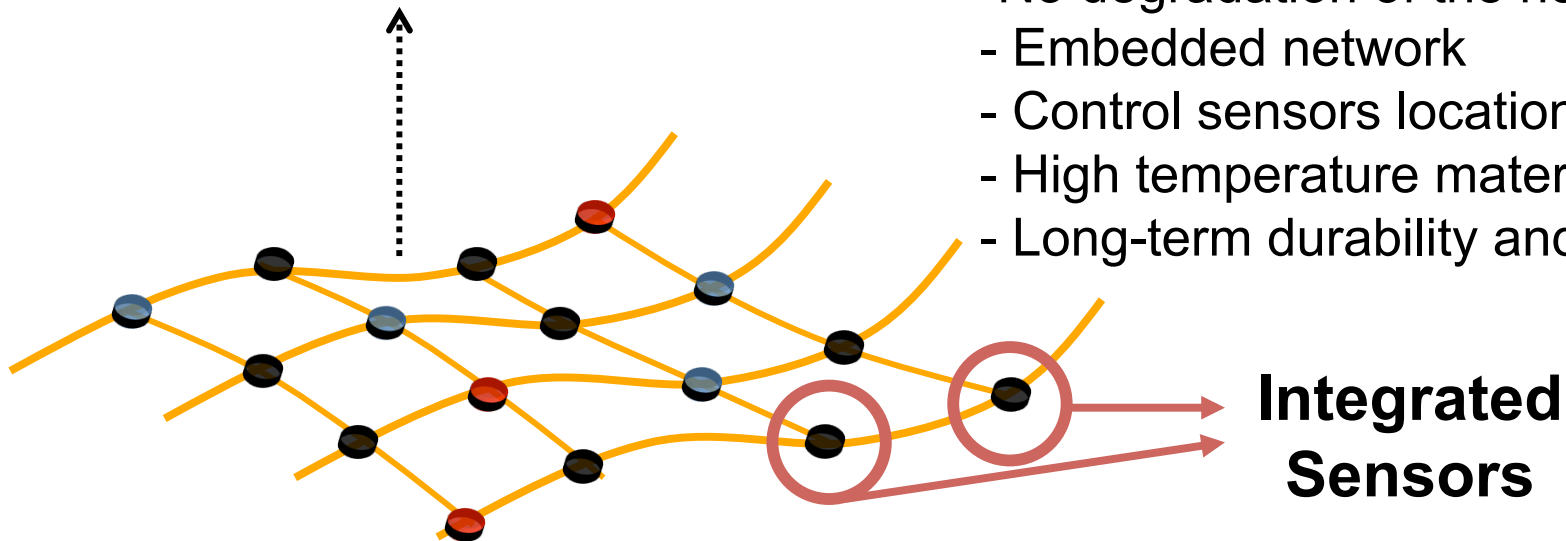
Sensor Network Development

Development of techniques to integrate sensors into:
(a) hybrid aluminum composites
(b) high T, polymer /ceramic composites

High Temperature network (e.g. silicon carbide)

Network Requirements

- No degradation of the hosting material
- Embedded network
- Control sensors location
- High temperature materials
- Long-term durability and reliability



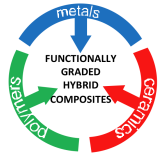
Integrated
Sensors



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Daehner et al. URETI presentation



Sensors Development: Piezoelectrics

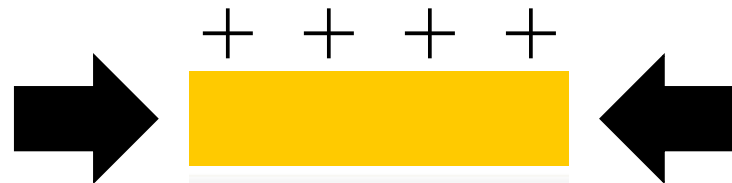
STANDARD PZTs

- Strain under voltage potential

+ + + +

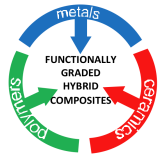


- Produce potential when strained



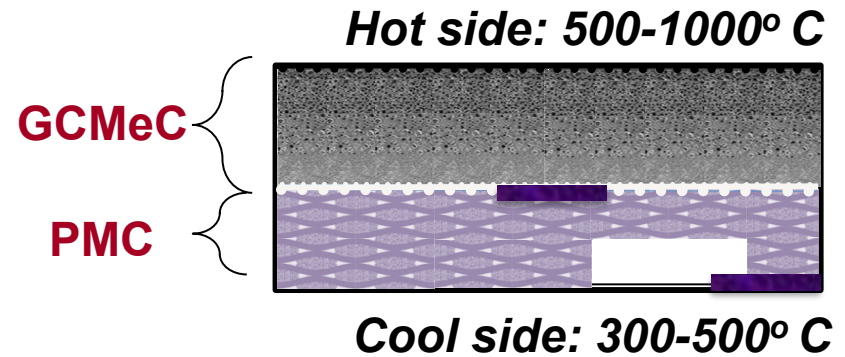
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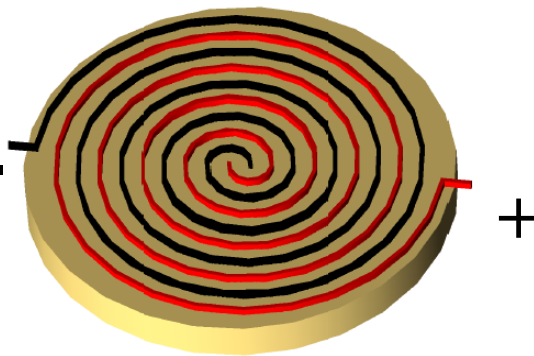


Sensors Development: Piezoelectrics

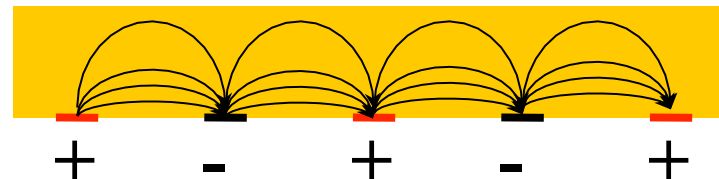
Stand-alone sensor placed at the 'cold' surface of the hybrid composite, or potentially at the GCMeC/PMC interface.



In Plane Polarization

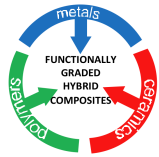


Reduced Layers



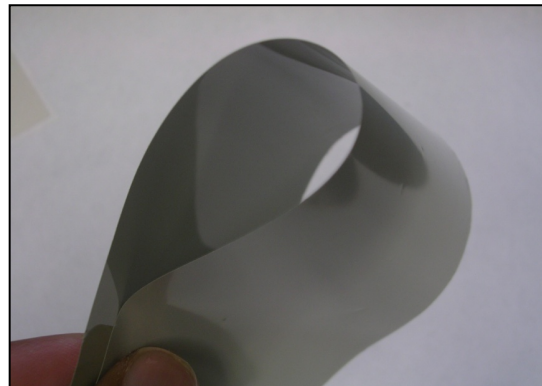
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Sensors Development: Piezoelectrics

- **High Curie Temperature piezoelectric ceramics:**
 - commercially available Bismuth titanate and BST-lead titanate with $T_c \sim 500-600^\circ\text{C}$.
 - Lead titanate-based single crystals
- **Flexible 0-3 piezoelectric composites:**
 - Piezoelectric inclusions in polymer matrix



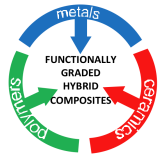
$\beta\text{CN-PI/PZT/SWNT}$

Texas A&M (SO)



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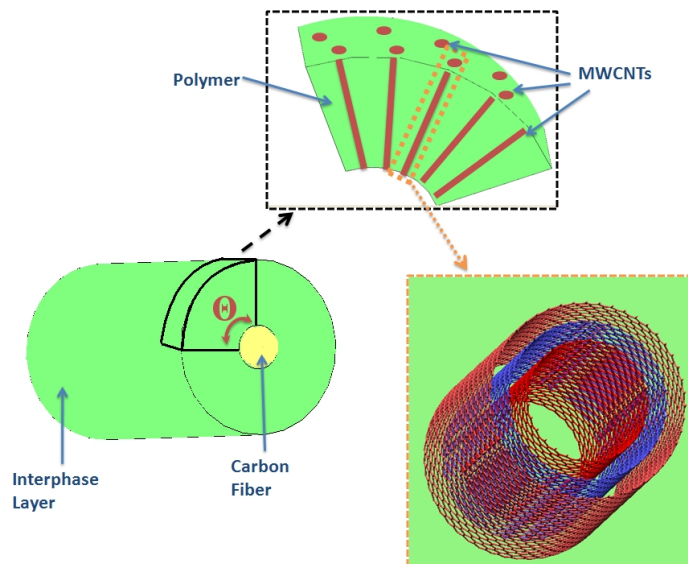


Sensors Development: Nanomaterials

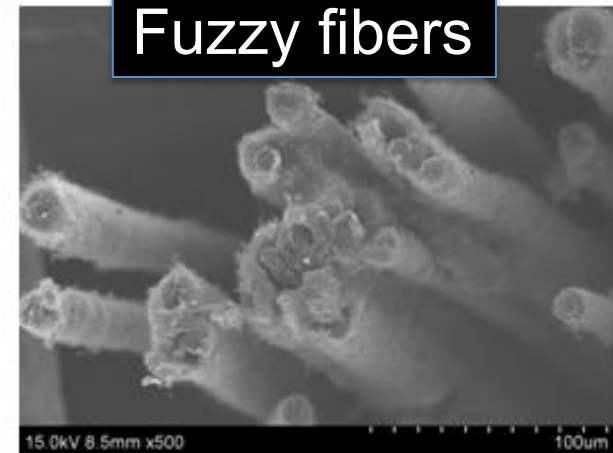
Conductivity changes



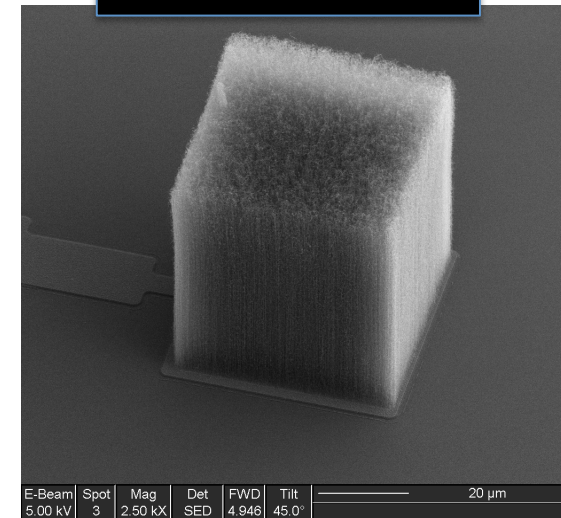
Strain, damage



Fuzzy fibers

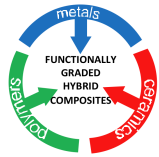


CNTs



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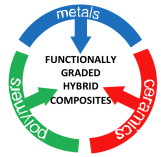
Modeling: Temperature effects

- Temperature effects on damage metrics have been addressed through experimental studies mostly for metals.
- For FGHCs temperature effects on damage metrics will be incorporated in SHM algorithms based on multi-scale modeling efforts.



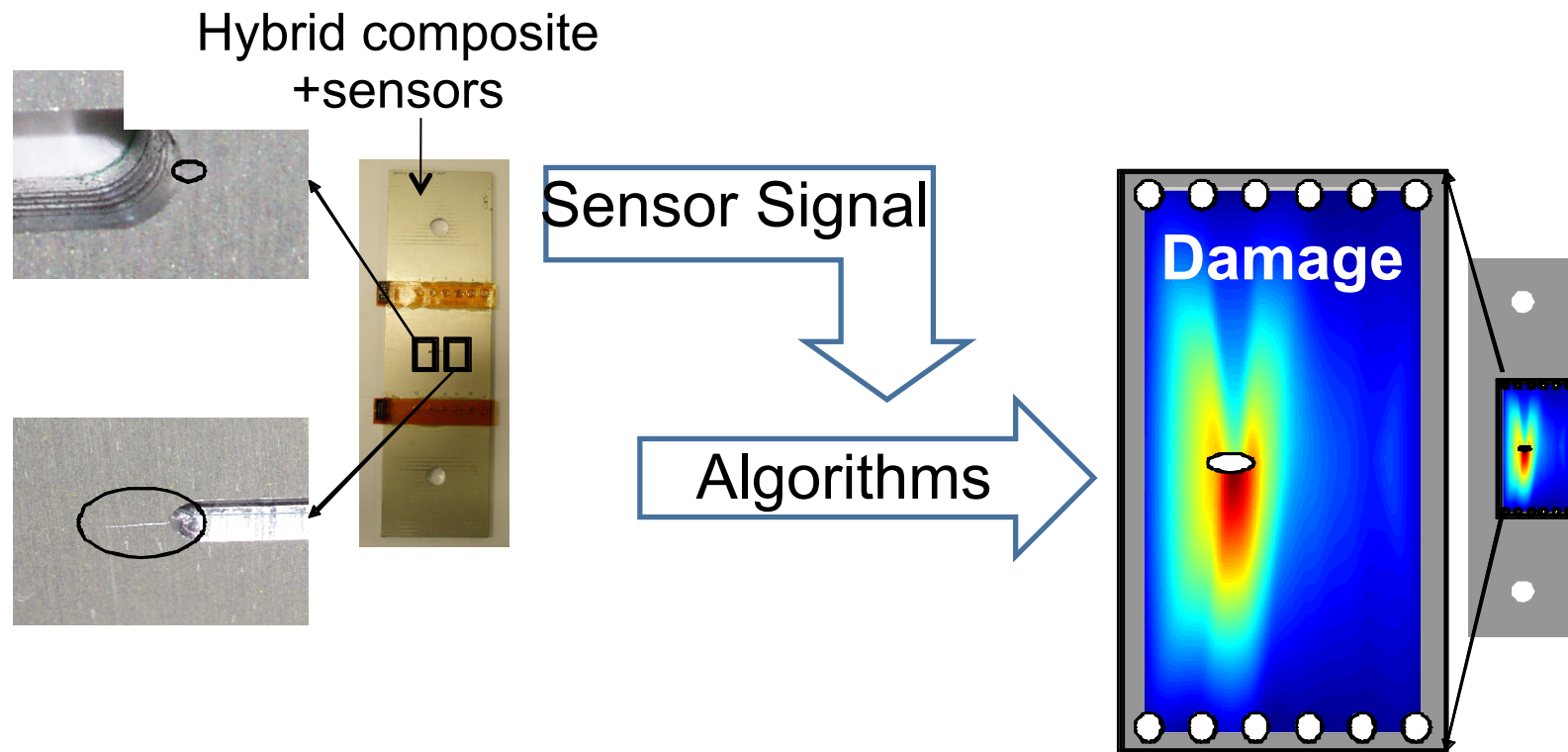
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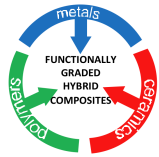
Diagnostic Algorithms

Develop Techniques to Relate Sensor Signal to Material Properties and Failure



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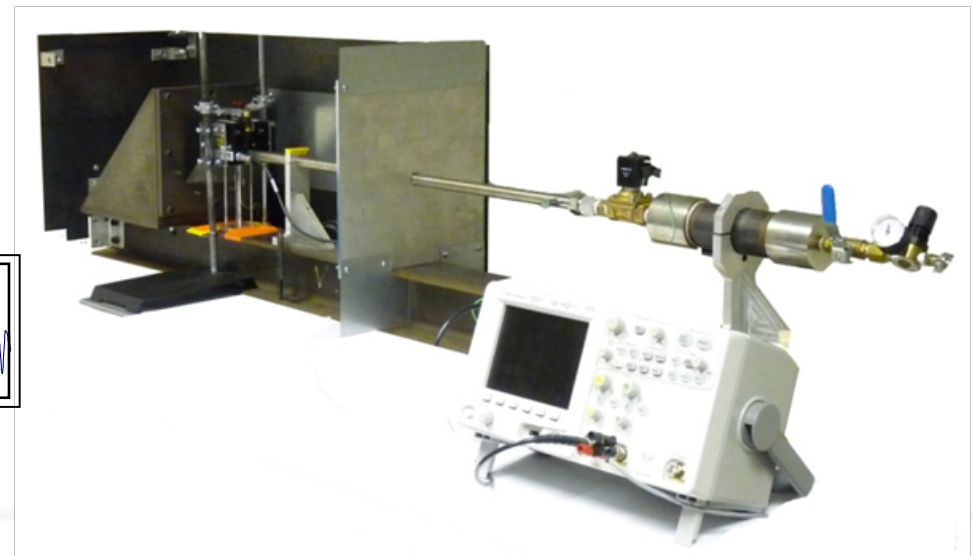
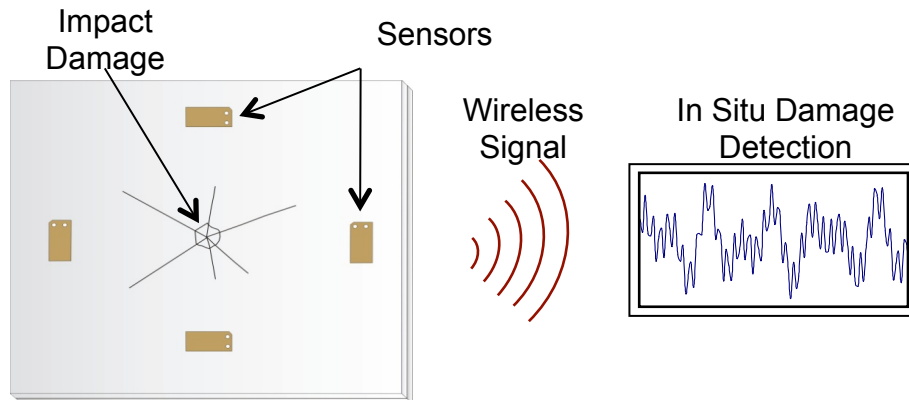




Diagnostic Algorithms: impact loading

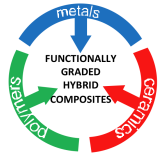
- Impact determination, location and degree of damage is an important aspect of the proposed hybrid.
- Focus is on impact force identification methods and development of a vibration based approach to determine the damage induced by impact.
- Once the failure modes of the hybrid composites are experimentally determined, correlations between health monitoring signal patterns and the stress redistribution created in the impact zone will be established.

Intermediate velocity test facility



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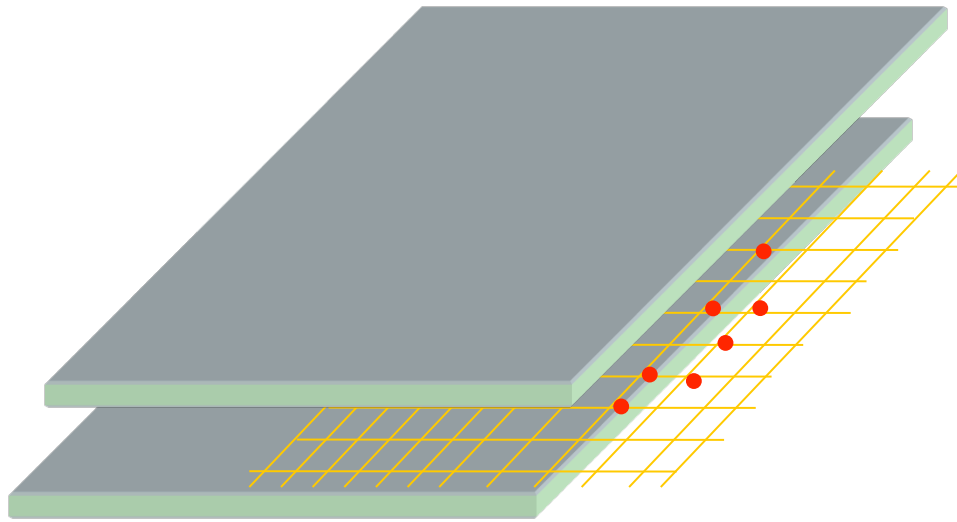




Integration and Characterization

Testing of Complete SHM/NDE System in Hybrid Composite

Complete system development

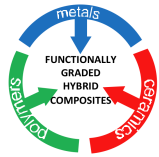


- Integration
- Evaluation
- Characterization



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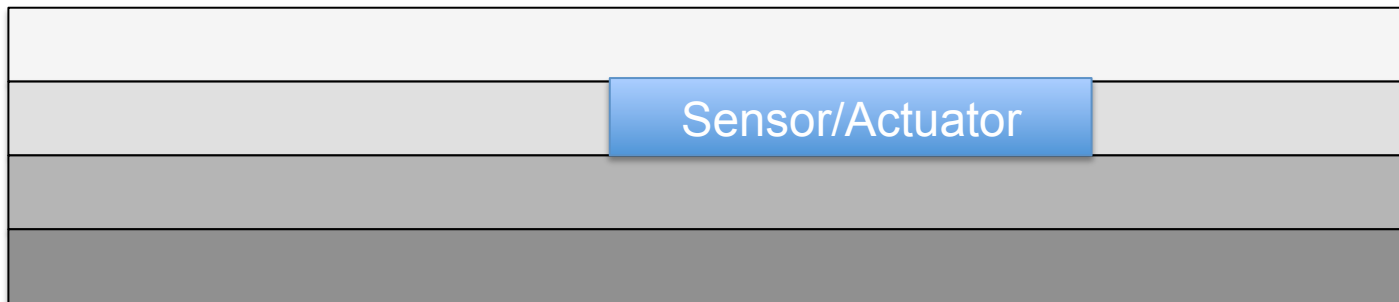


Integration: Sensor and Actuator Location

- A multi step approach:
- The *first* step is to layer the sensors according to temperature matching Curie temperature with ambient

Cool side: 300-500° C

FGHC



Hot side: 500-1000° C



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Virginia
Tech



UDRI
UNIVERSITY
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RESEARCH
INSTITUTE