INTEGRATED VEHICLE HEALTH MANAGEMENT

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Integrated Large – Area Sensor/Actuator Network (ILASAN) Technology for Structural Health Monitoring

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Structures and Composites Laboratory (SACL)
Stanford University

Aviation Safety Program Technical Conference
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Washington D.C.

IVHM

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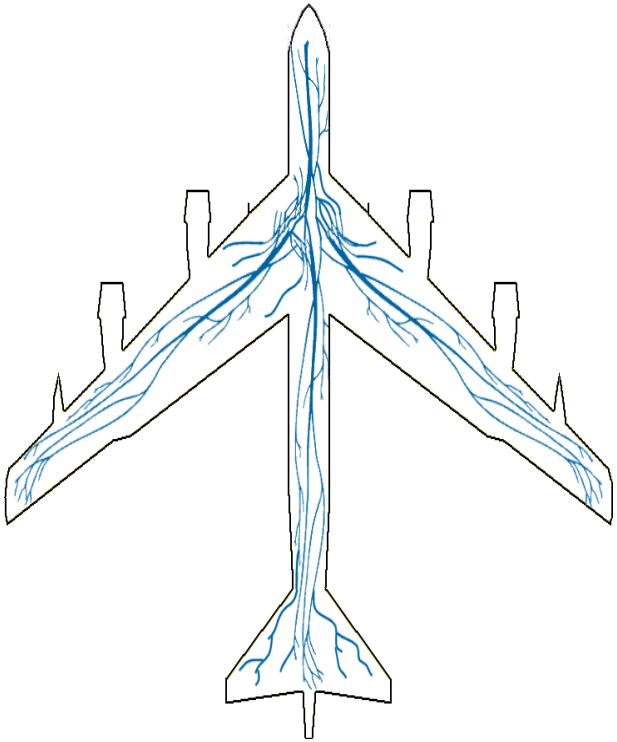
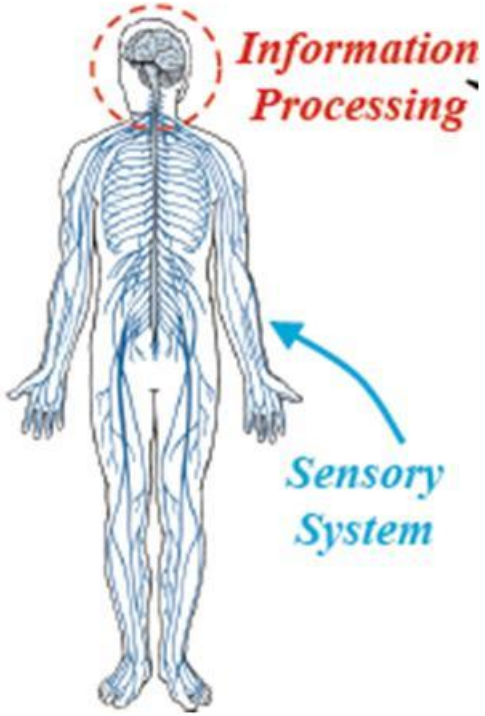
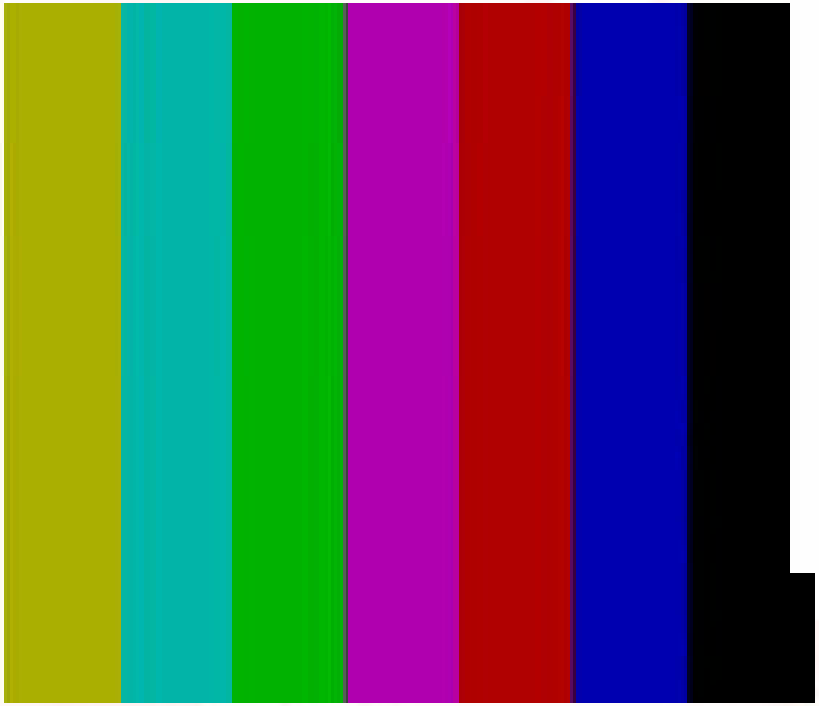


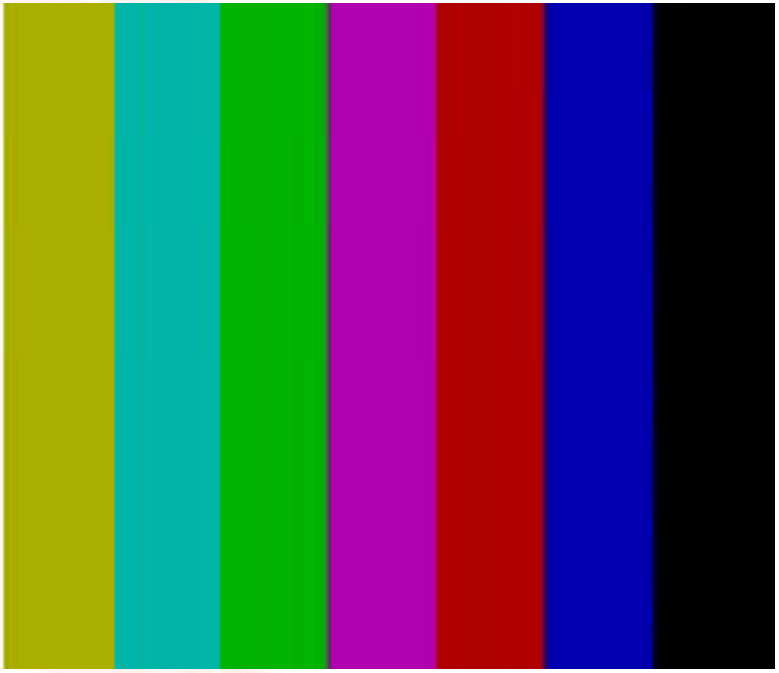


Diagnostics and Prognostics

Active and Passive Sensing



Passive Sensing



Active Sensing

SMART Layer

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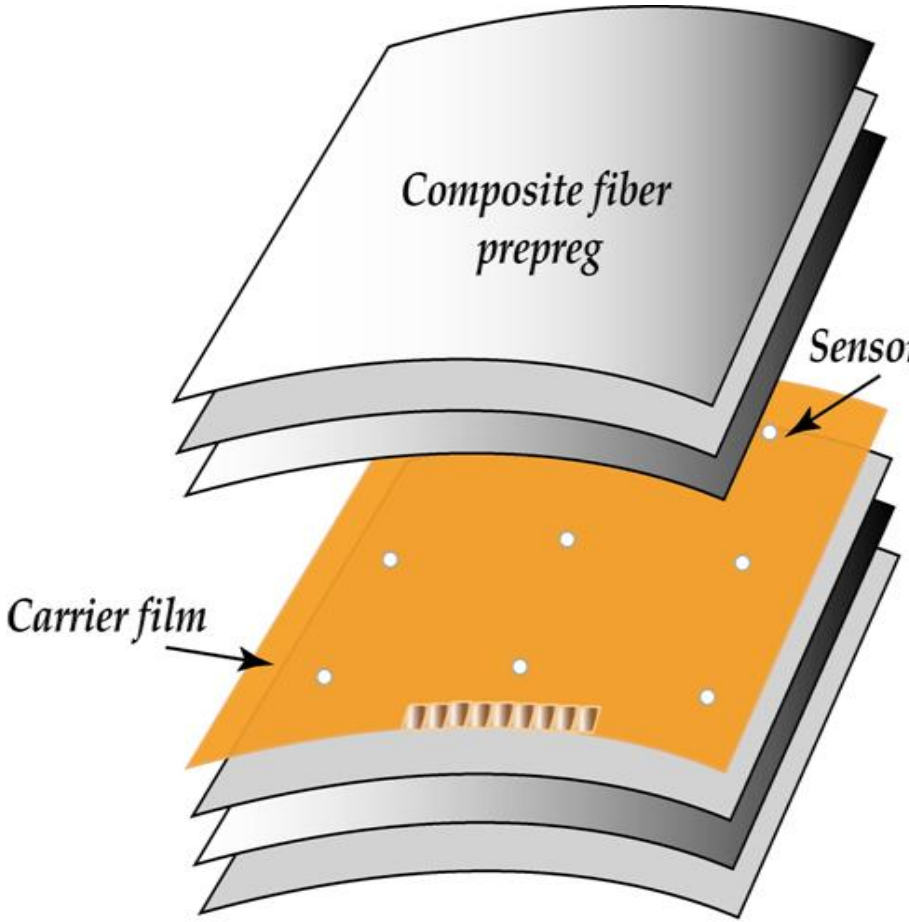
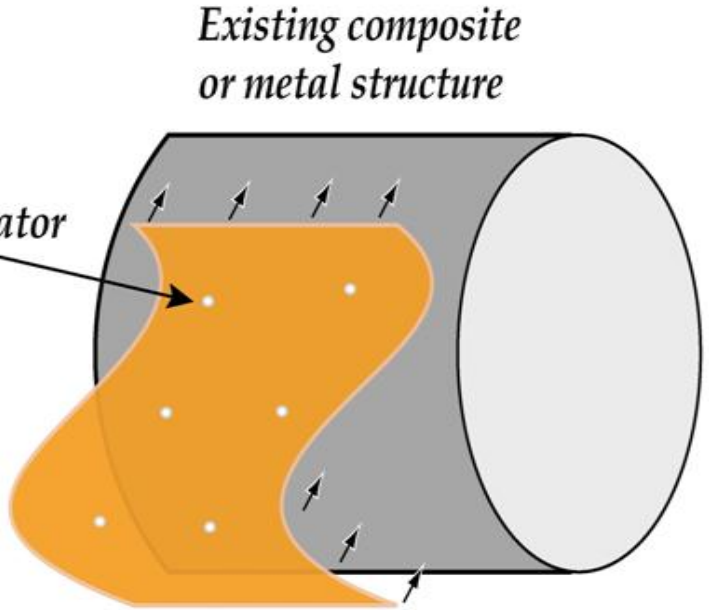


Embedded sensor network



Surface mounted sensor network

Sensors

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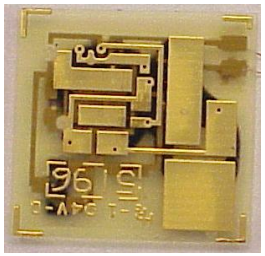
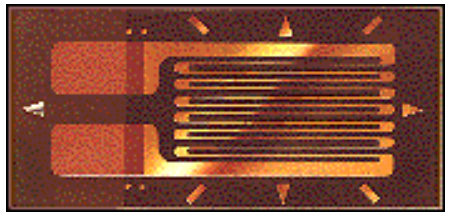
- Piezoelectric



- Fiber-optic

- MEMS

- Strain gages



- Other…

Applications

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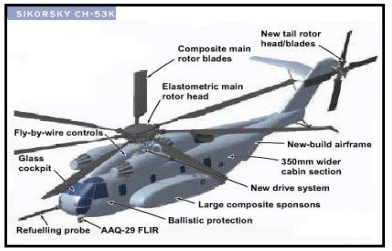
- Concerns: (advanced materials)
- Accidental impact
  - Fuselage
  - Wings
  - etc.
- Disbond/cracks
  - skin-stiffeners
  - bonded or bolted joints
  - etc.
- Overloads
  - Impact
  - Operation
  - etc.



Challenges in Sensor Network

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Key Components: Sensors, Network, Electronics and Software

- Large area coverage
- Multiple sensing capabilities (passive and active)
- Large number of sensing nodes
- Minimal weight
- Ease of installation
- Embeddable
- On-board and real-time monitoring capabilities

Problem Statement

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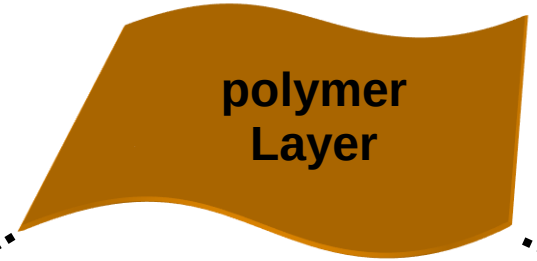
How to cover large area?



e.g. Kapton ultimate elongation: 72%

?

stretching >2000%

Related Technologies

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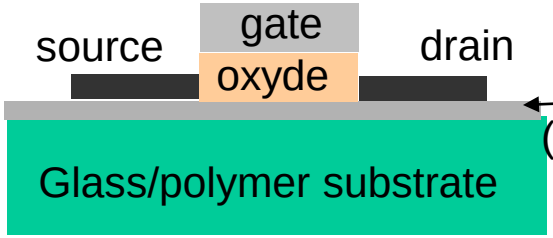
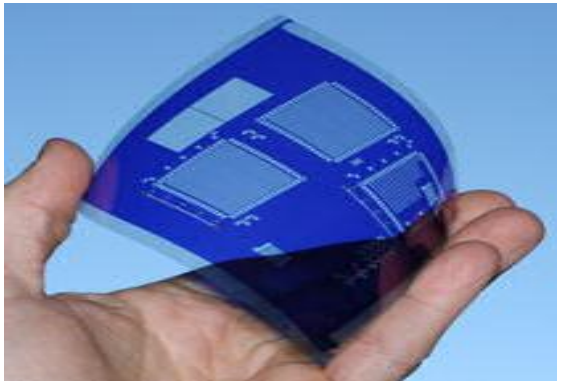
Thin film transistors (TFT)
(switch in LCD displays)



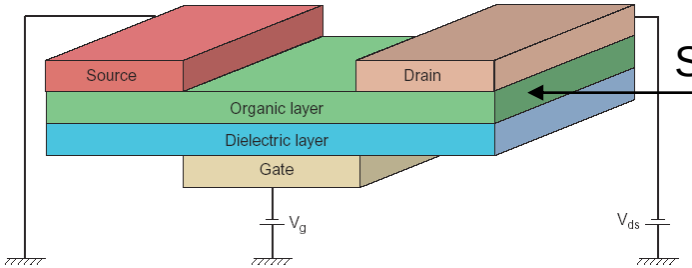
PolySi
(semiconductor)

Flexible electronics



Assembling devices and electronic circuits on plastics (e.g. Kapton)

Organic Thin film transistors (OTFT)
(e.g. electronic papers, sensors, memory devices)



Semiconducting
polymer

Our Approach

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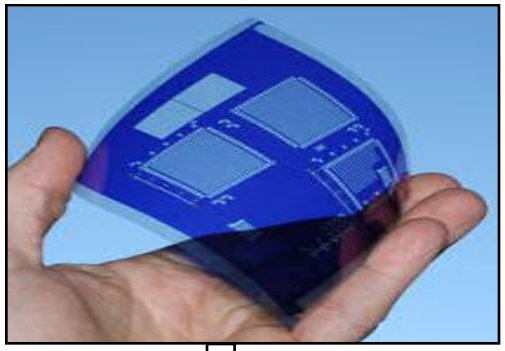
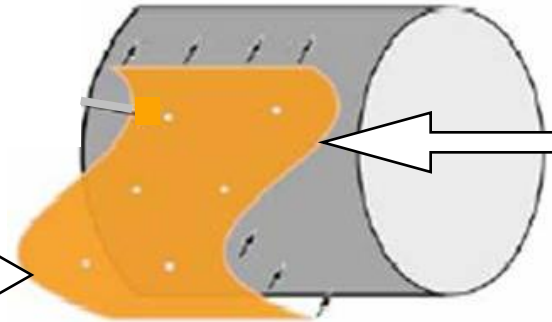


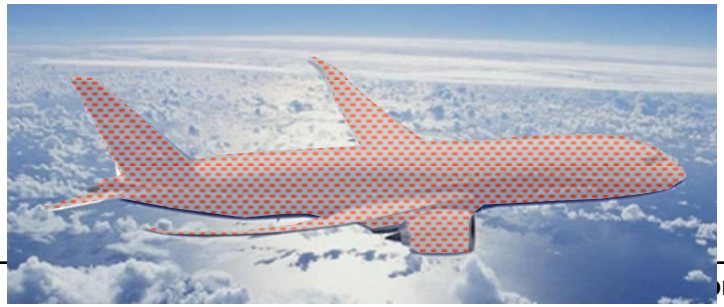
Our focus

Stretchable Polymers

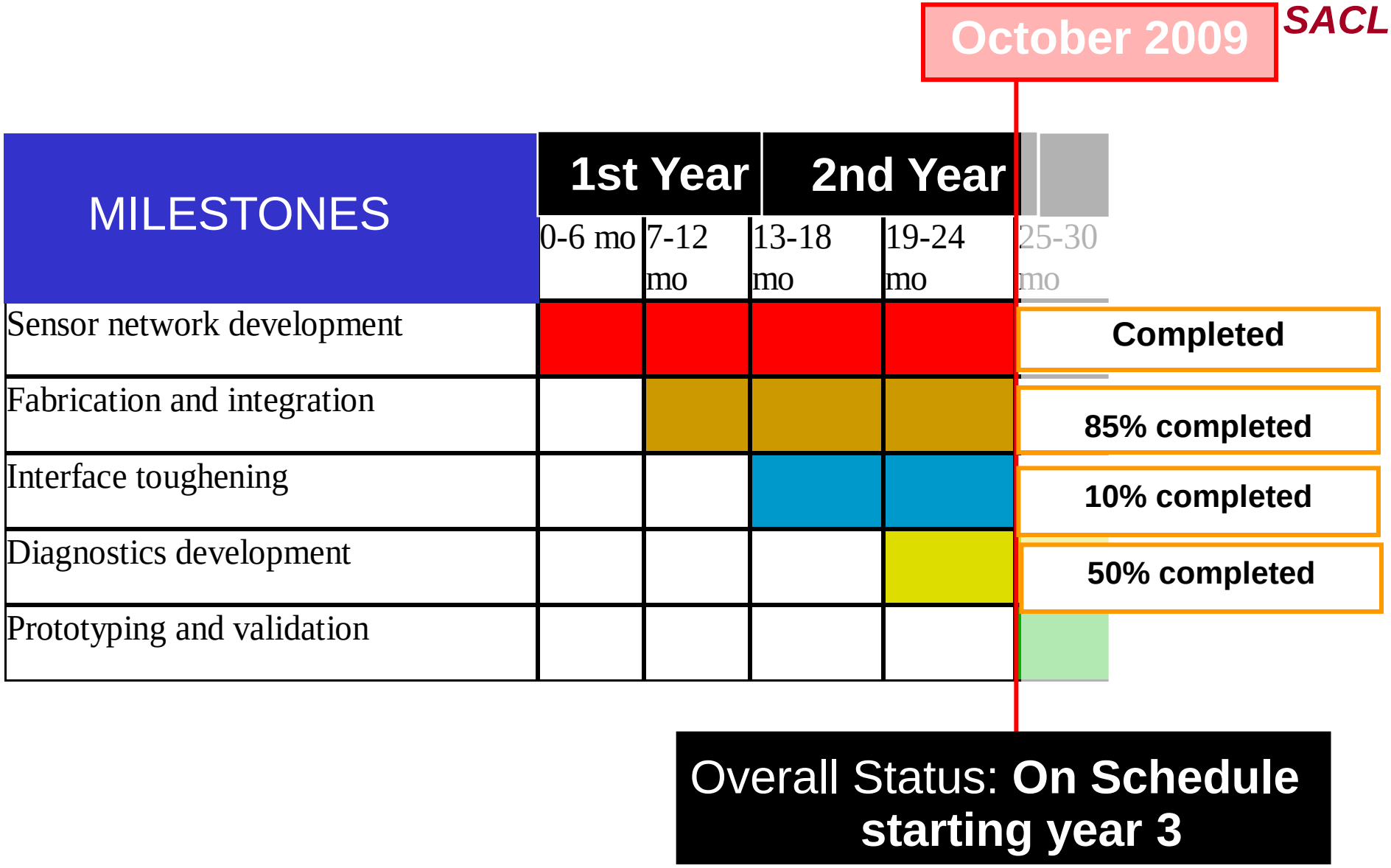
Integrate the SMART layer with advanced flexible electronics



Make the SMART layer out of a “stretchable” polymer



Overall Schedule



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NETWORK and SMART WIRE DESIGN

for Large Area Coverage

Our Approach

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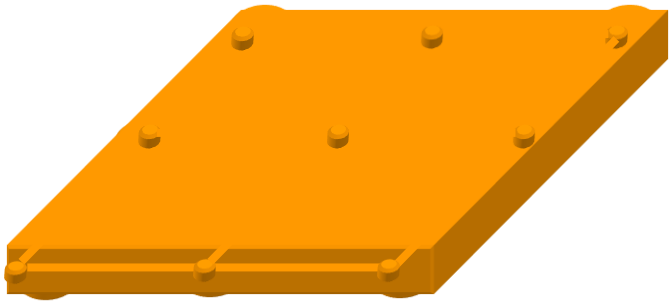
Develop a micro/nano-scale fabrication technique to create expandable infrastructure networks within polymer and silicon materials.



over 20,000% expansion!!

- Removing materials to improve network expansion capability
- Using CMOS fabrication to miniaturize the network systems

The Key Element

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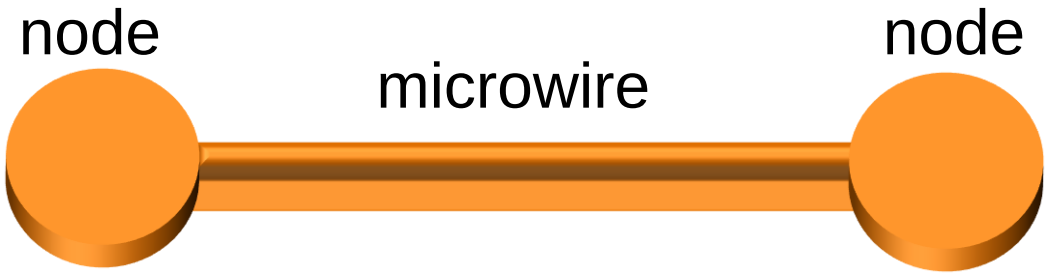

1) Allow “in-plane” “ultra-high extendibility” (>2000%)

2) Easy deployment

3) Allow extension sensing to:

- Precisely position nodes at the macroscale
- Minimize strain
- Translation only of the micronodes

4) Allow electrical connectivity between nodes

Fabrication of Polymer-based Network

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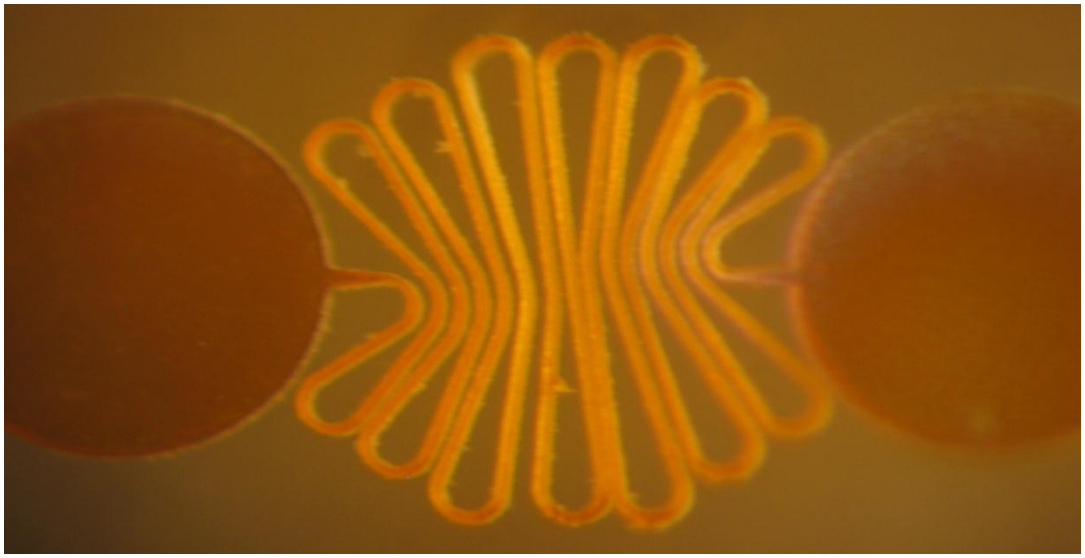
Result: top view



Optical microscope image

Results

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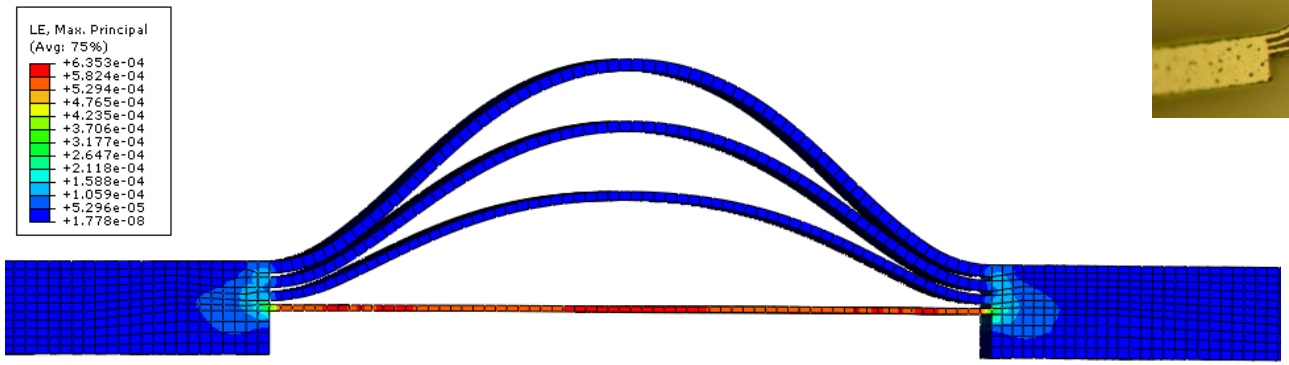
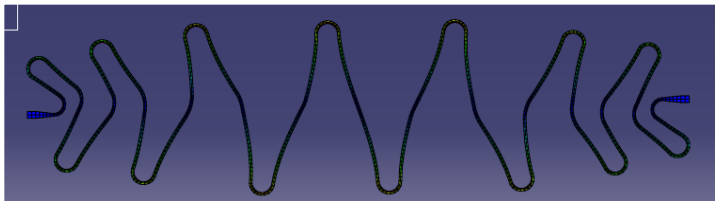
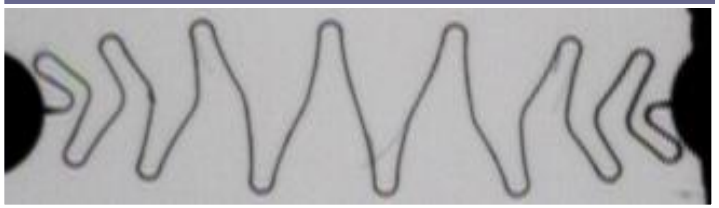


L=22231 u=20127 υm Max.Principal Strain: 0.064% no Plastic strain Elongation Ratio: 10.566

Experimental and Numerical Study

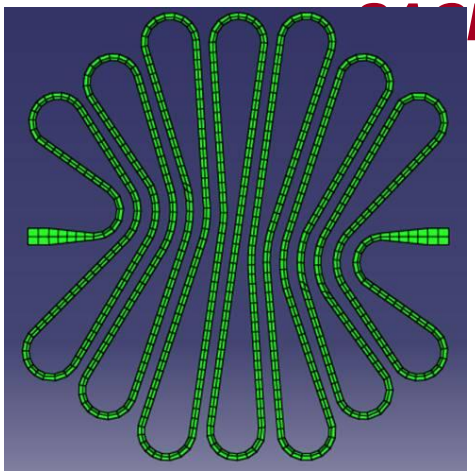


NUMERICAL



EXPERIMENTAL

L/Lo=385%



NUMERICAL

EXPERIMENTAL

L/Lo=815%

EXPERIMENTAL

L/Lo=1190%

Strain and elongation monitoring

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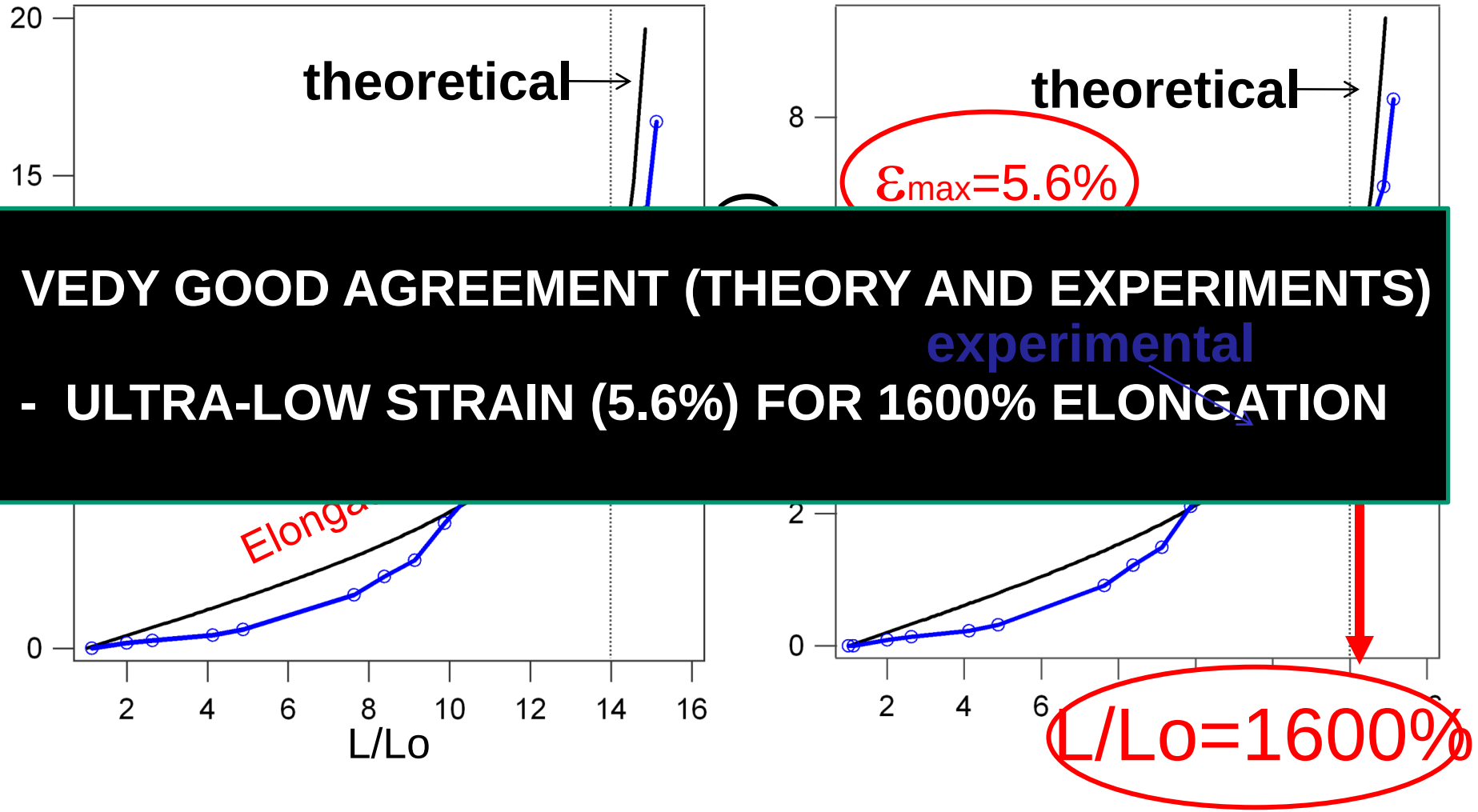

- VEDY GOOD AGREEMENT (THEORY AND EXPERIMENTS)
- ULTRA-LOW STRAIN (5.6%) FOR 1600% ELONGATION

Fatigue Tests

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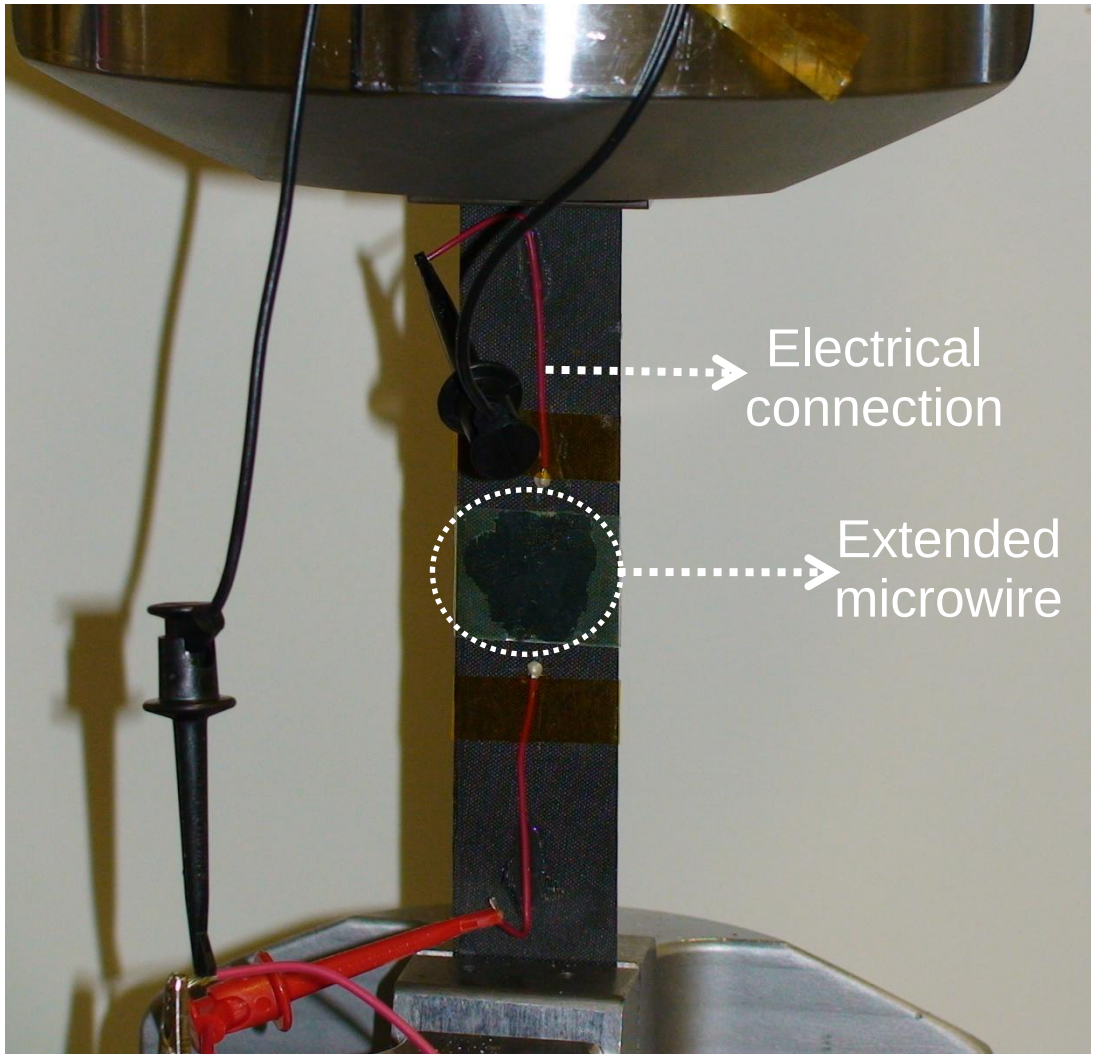

Max load:
1.9144Kips

500,000 cycles

5000 Nodes Network

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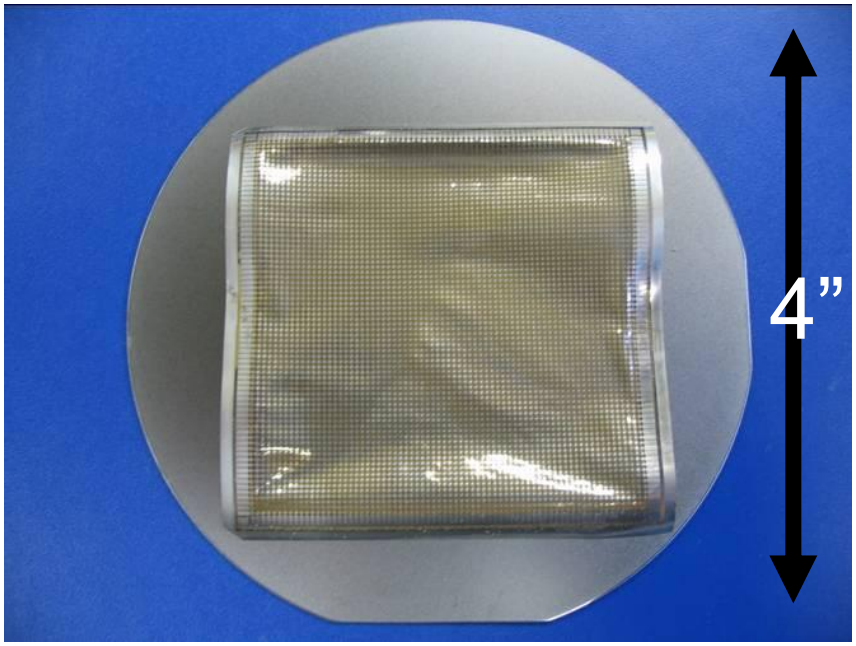
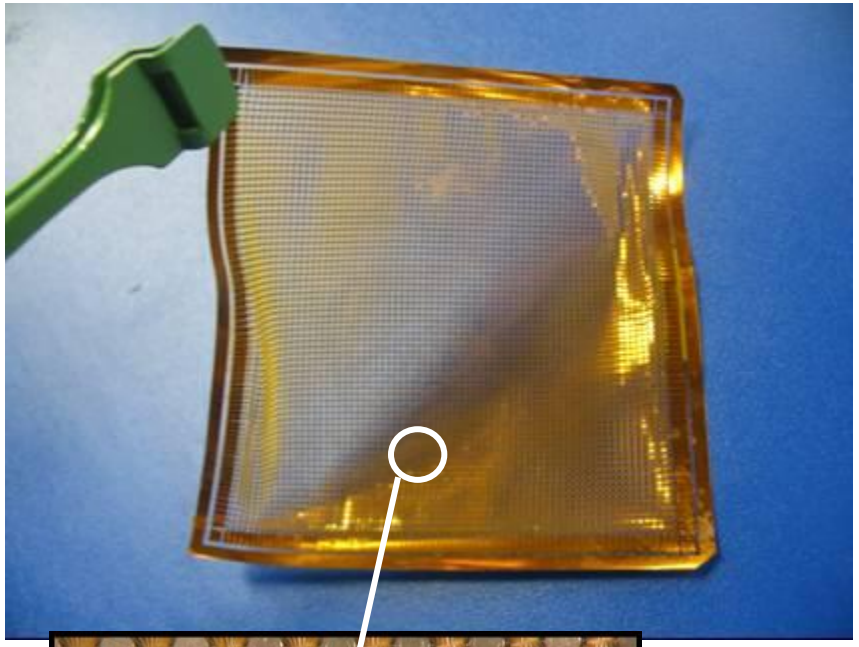
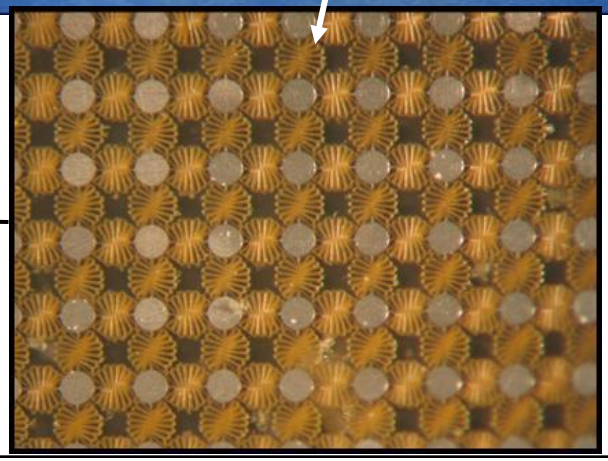
Flexible and transparent



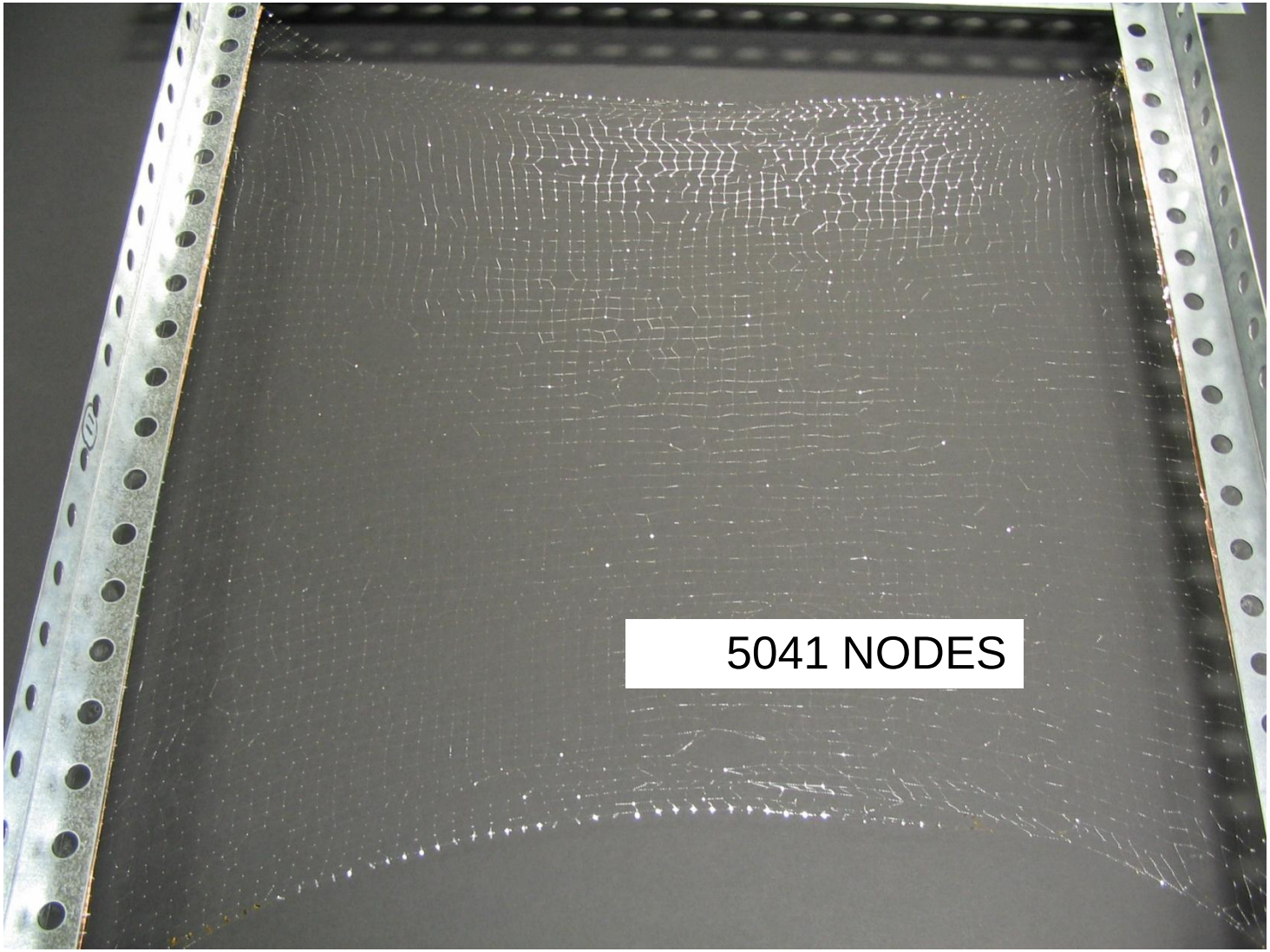


Microscope image of the network



5000 Nodes Network

SACL



A 71 Nodes Silicon-based Network

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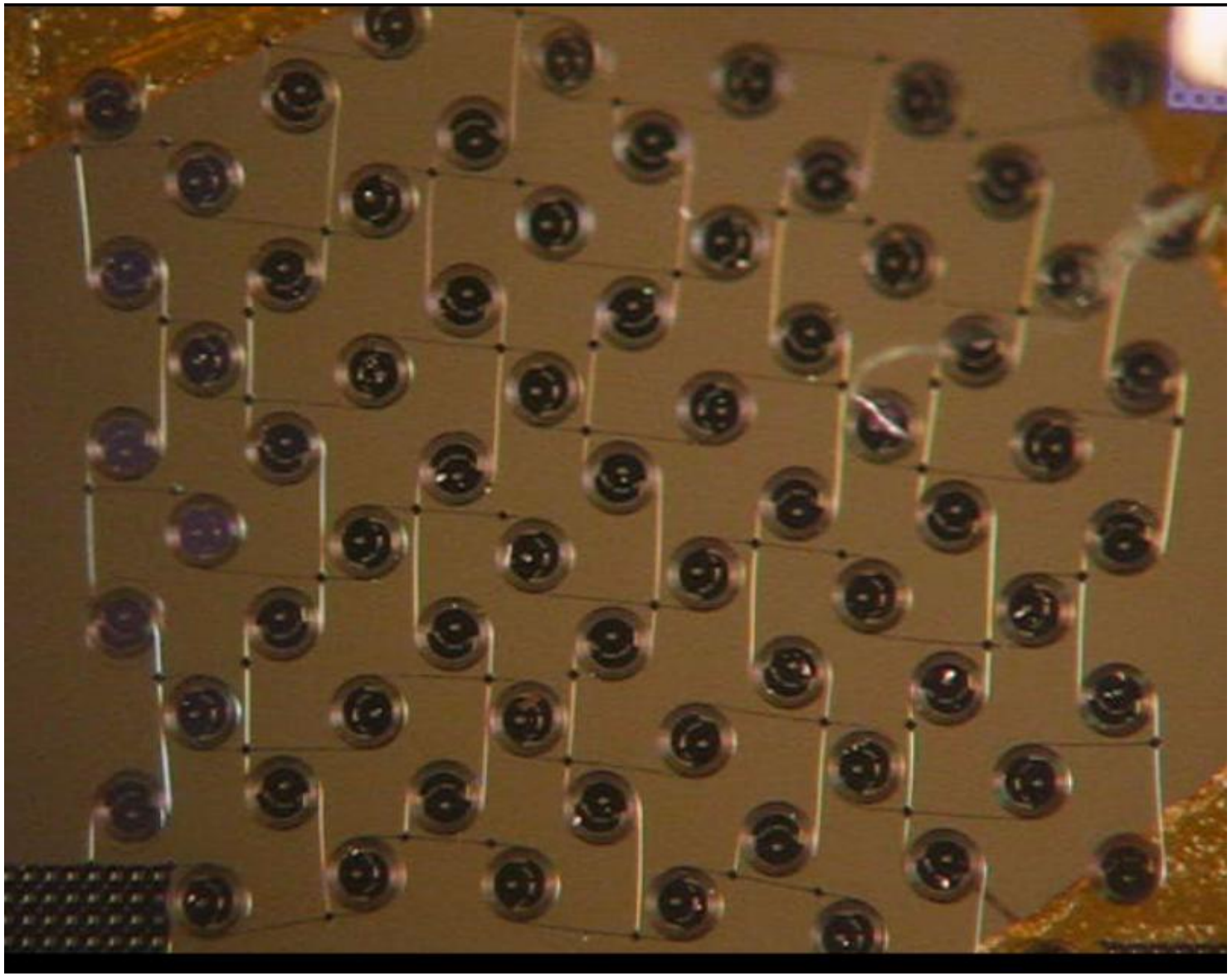

Individual Silicon-based Node

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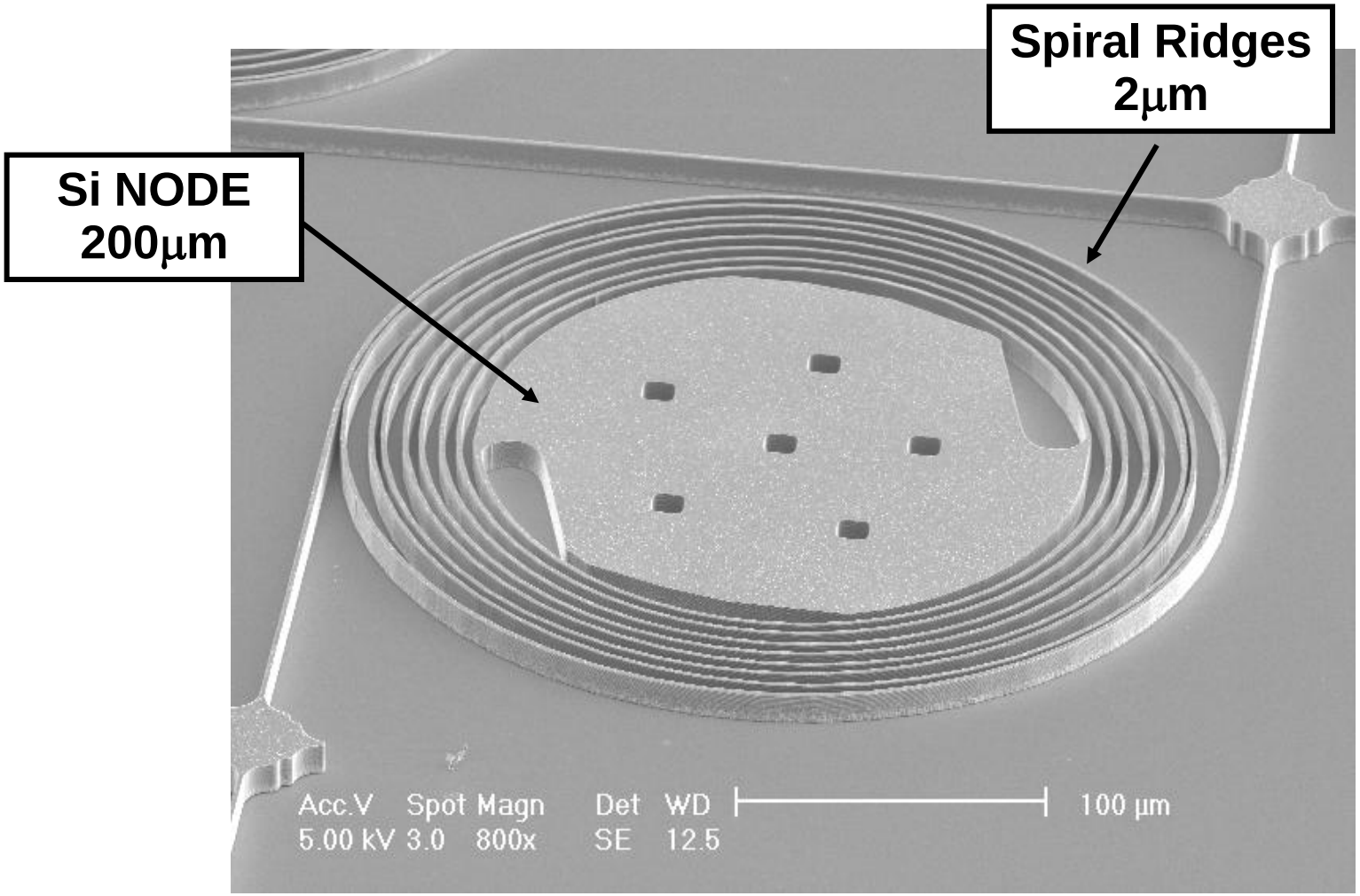

RTD Network

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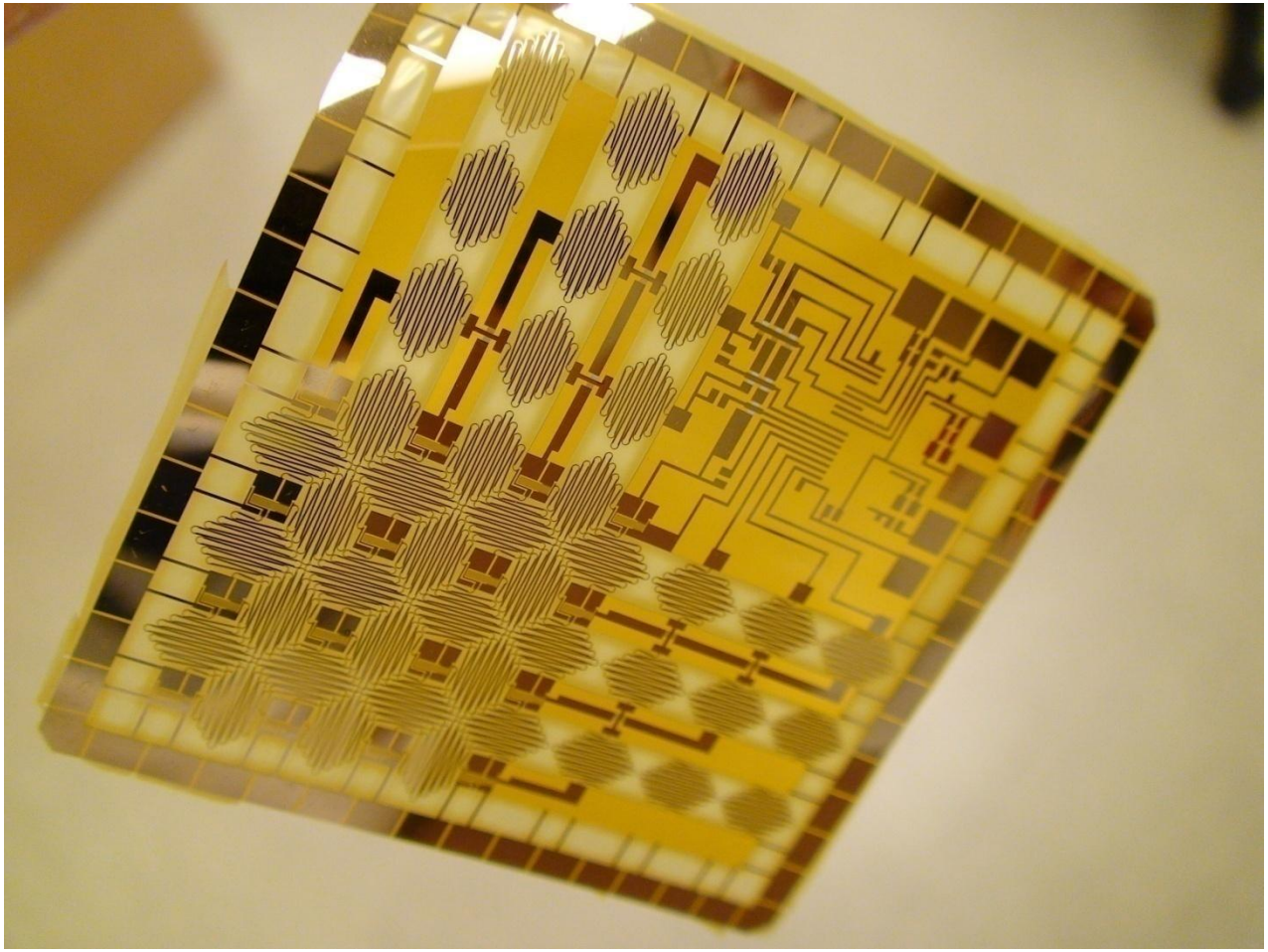

Temperature Gradient Display

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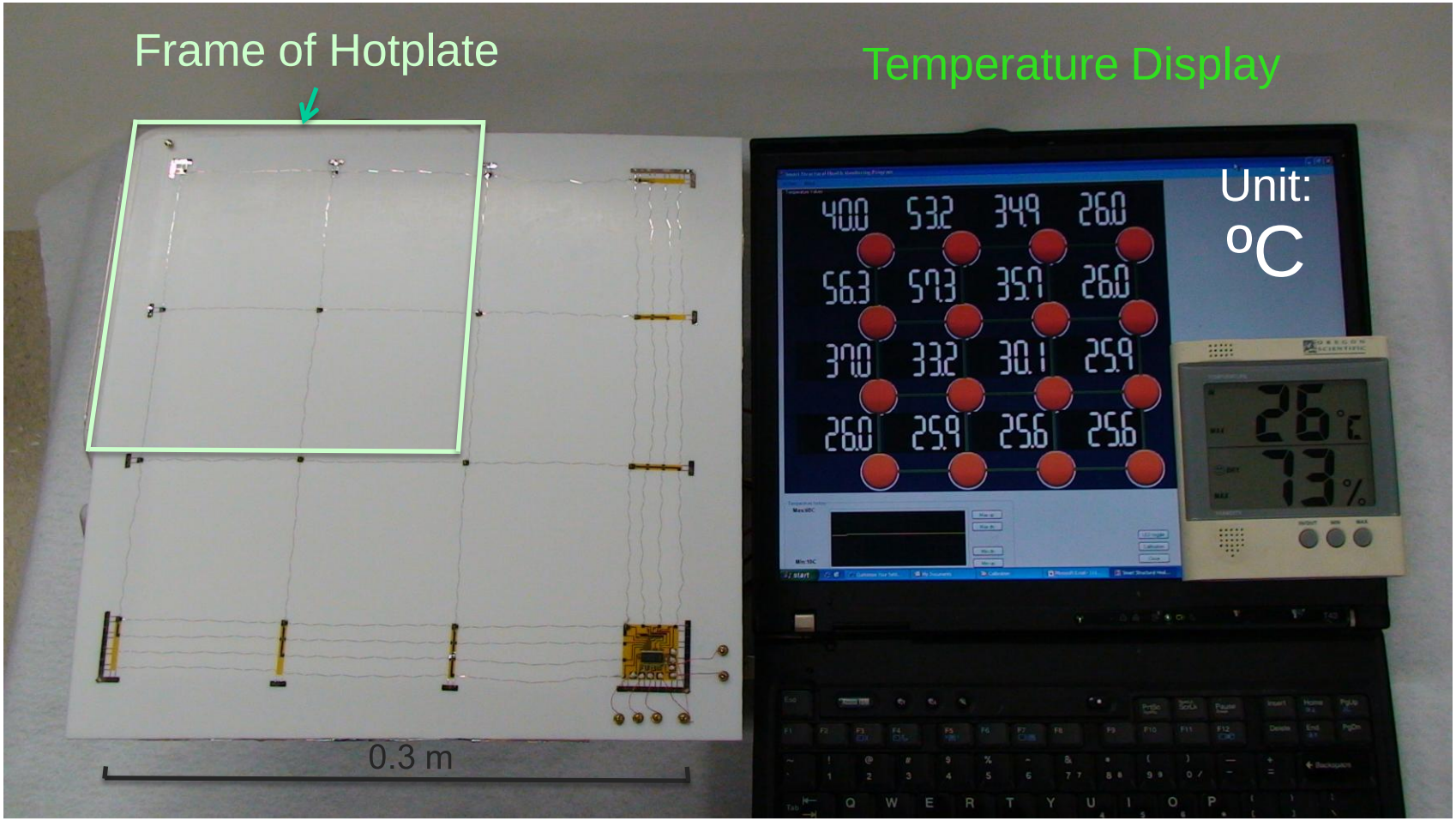

Square Region Heated by Hotplate from Bottom

Cooperated with Kyunglok Kim

2

SENSORS DEVELOPMENT

PZT Integration Problem

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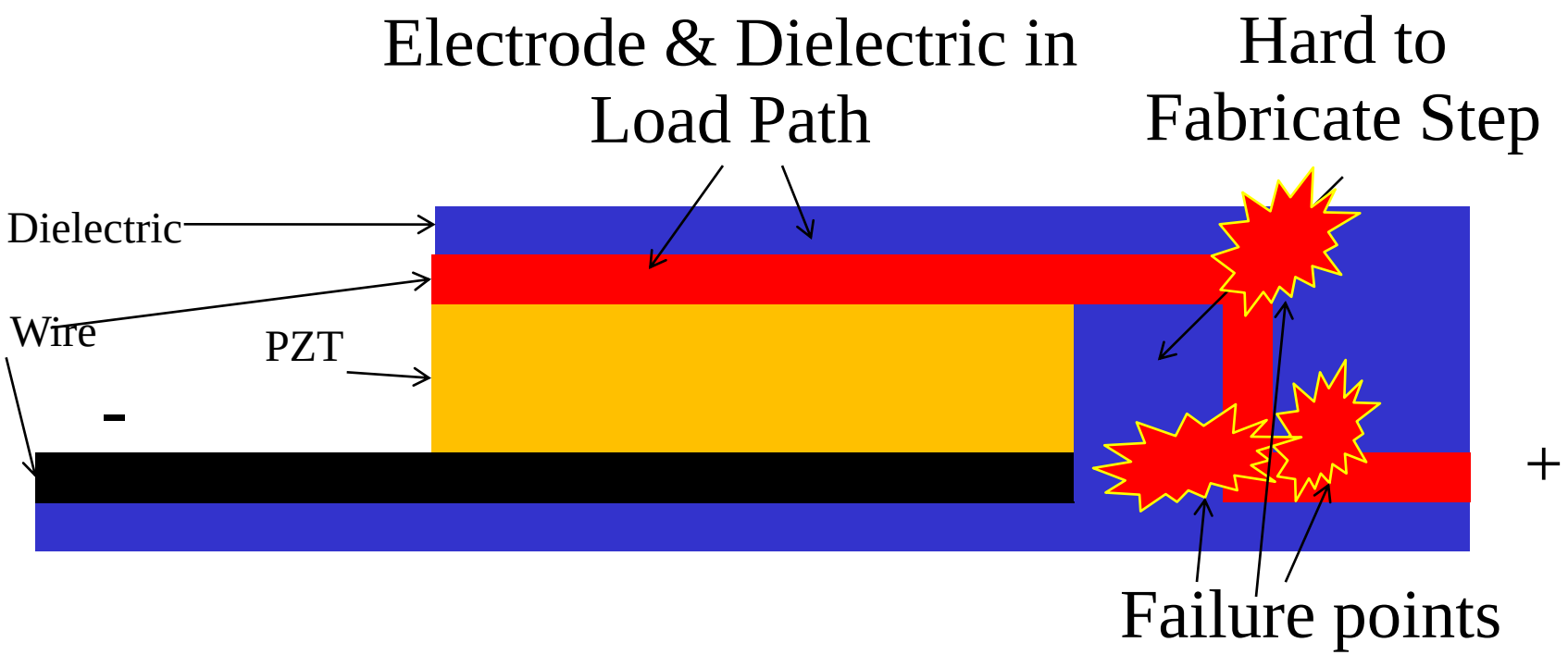

Many Layers

Image by Nathan Salowitz

Solution

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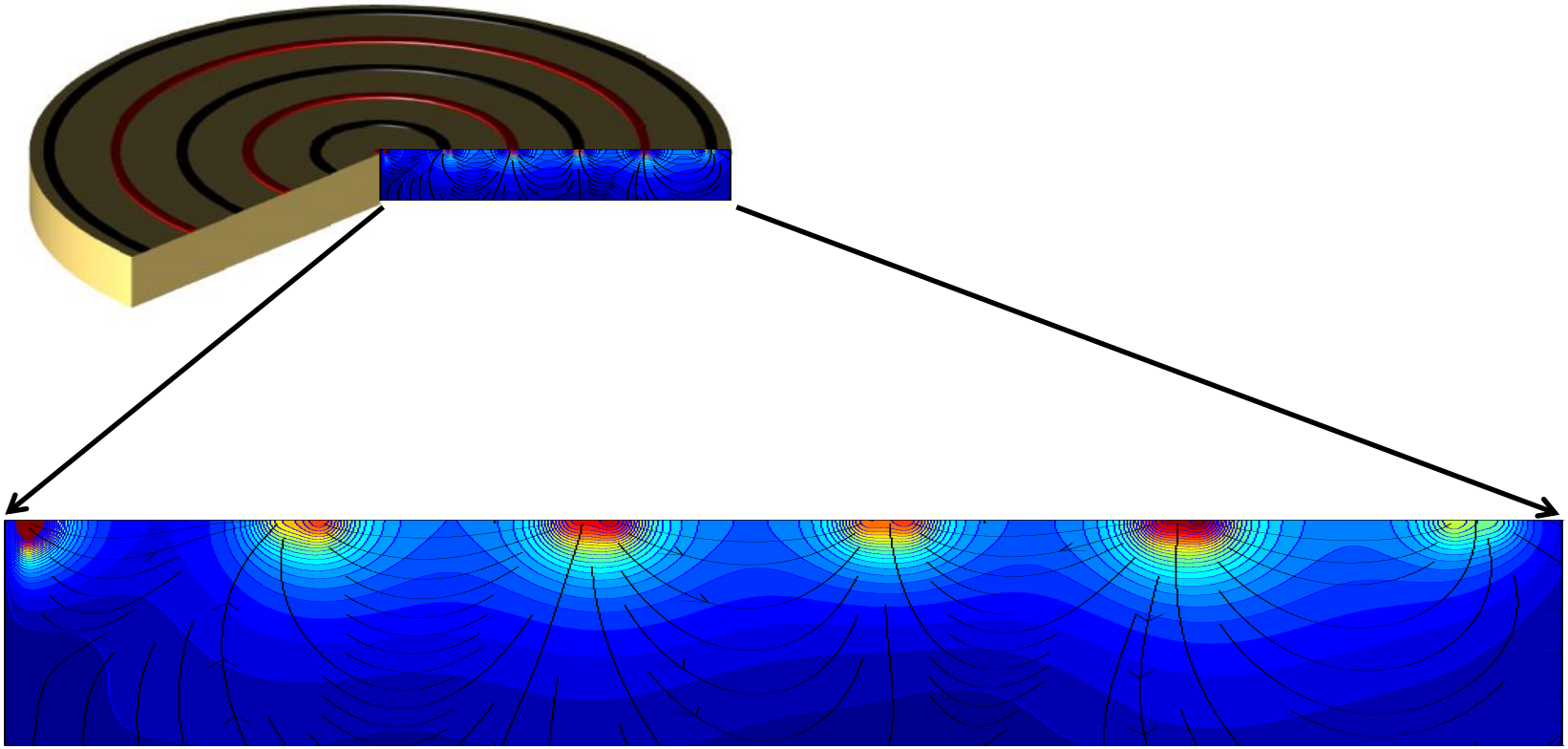

PZT New Design

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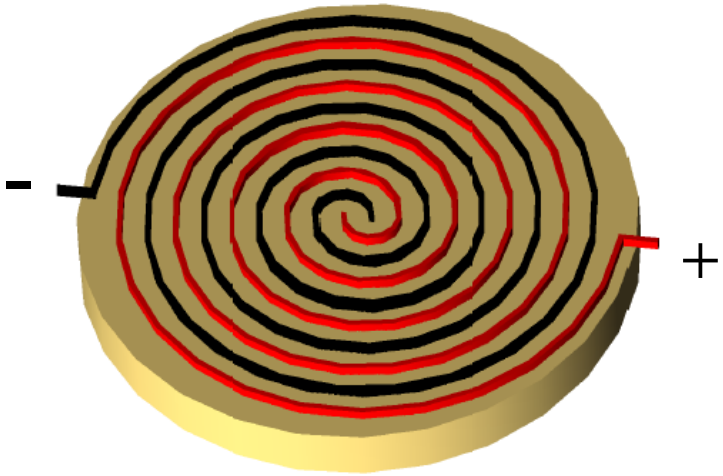
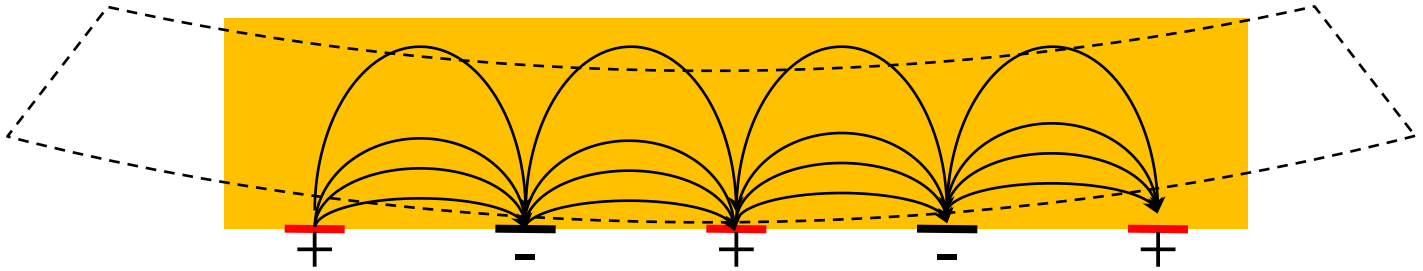


In Plane Polarization



PZT Preliminary Results

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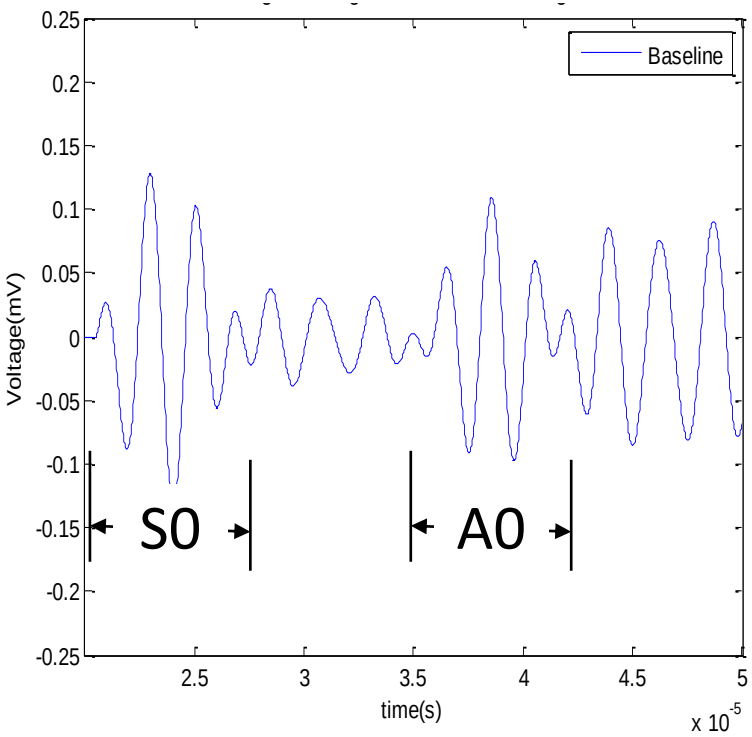
- Signals appropriate to SHM
- Interfaced with state of the art data acquisition system



PZT + RTD Design and Result

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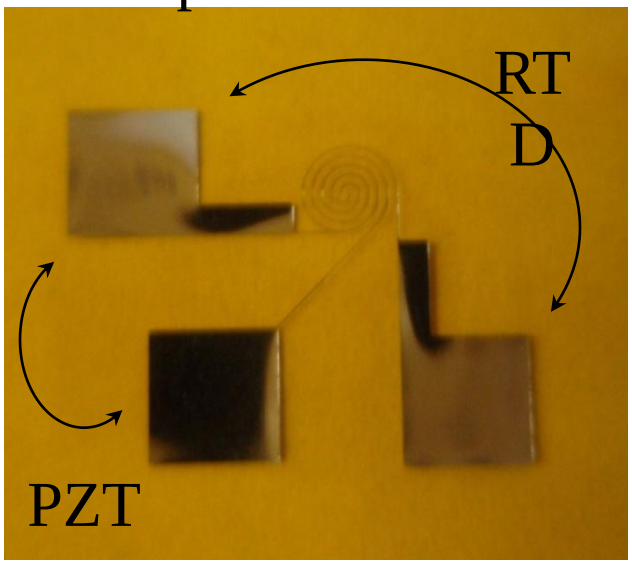
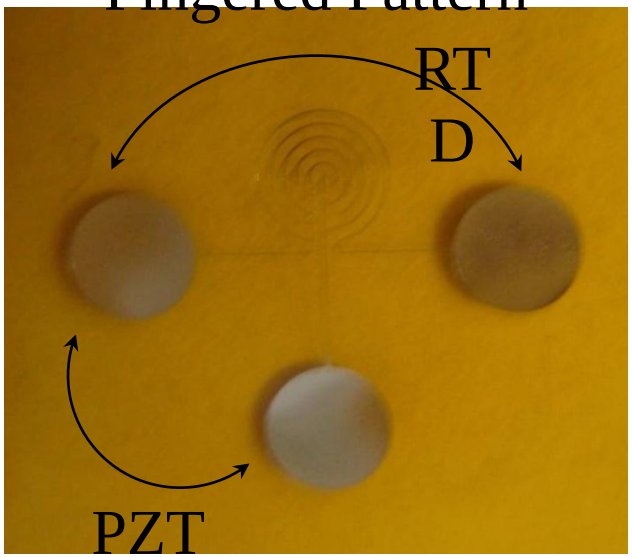
RTD into the electrode pattern

Assembly and testing are underway

Spiral Pattern



Fingered Pattern



3

INTEGRATION IN COMPOSITES

Integration in composites

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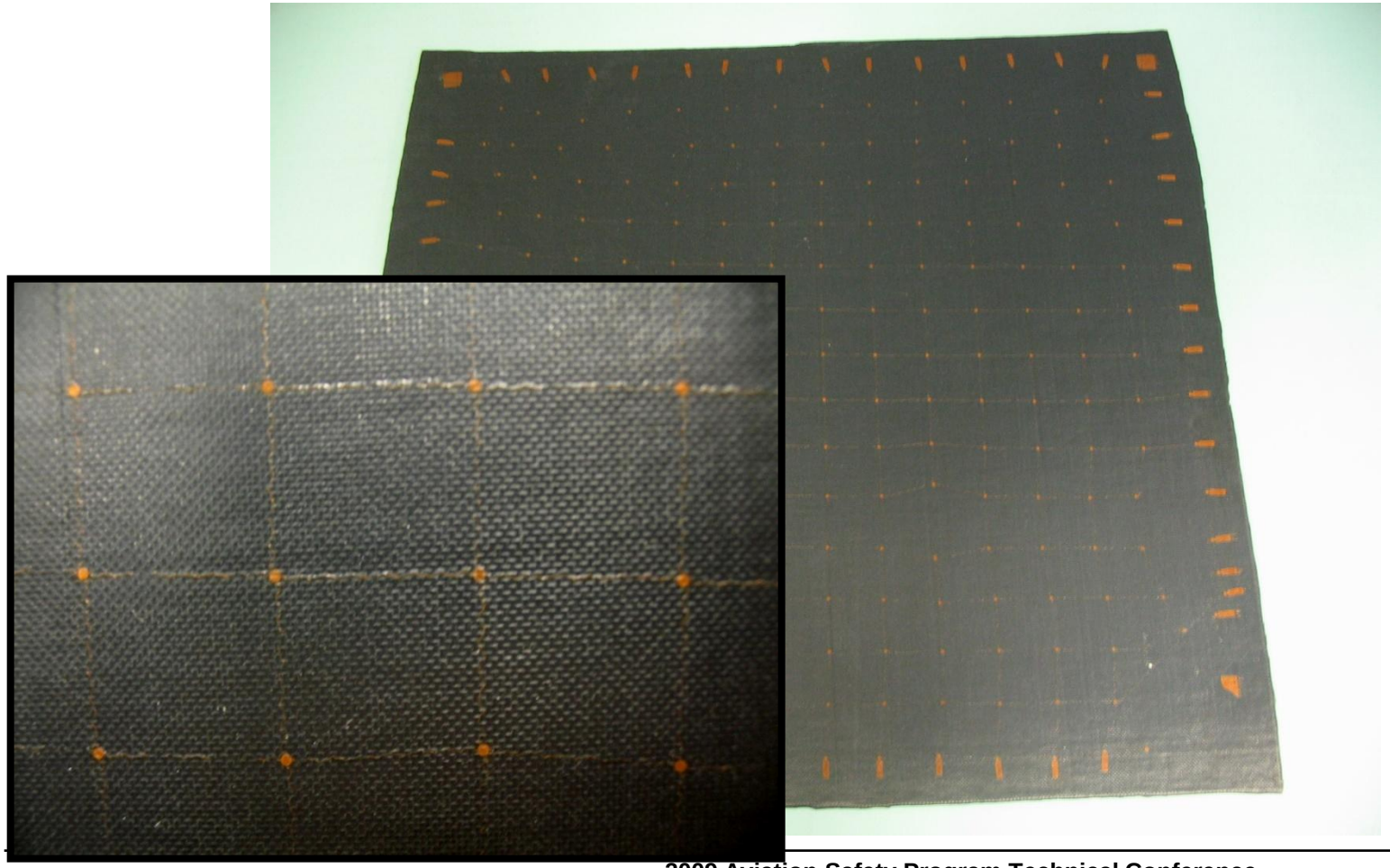
256 nodes network surface bonded to a composite and cured



Future Challenges

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FUNCTIONALIZATION

EMBEDDING
"INTO"
COMPOSITES

DURABILITY
AND RELIABILITY