



Passive Wireless SAW Sensors, Microsystems & Applications

October 9, 2019

Outline

- Industrial needs for Sensing Solutions
- Strain and Torque Sensing requirements
- First SAW Torque Implementation
- Expansion into new spaces
- Developments for larger systems and lower costs
- Future needs



Contemporary research ... GE's innovation legacy & scale

Discovery ... world's firsts



Foreground IP

Portfolio ... differentiated tech

- ✓ **Top 10 global patents ...**
63,000+
- ✓ **Broad applicability ...**
cross disciplinary
- ✓ **Market tested ...**
product deployed

Building background IP

Prosperity ... ecosystem impact



-  **Generating**
1/3 of world's electricity
-  **Powering**
Takeoff every 2 seconds
-  **Curing**
16,000+ scans every minute

GE Businesses "+"

IP+IQ is the key to unlock the world's most valuable problems

Contemporizing our Innovation Engine



Future of:

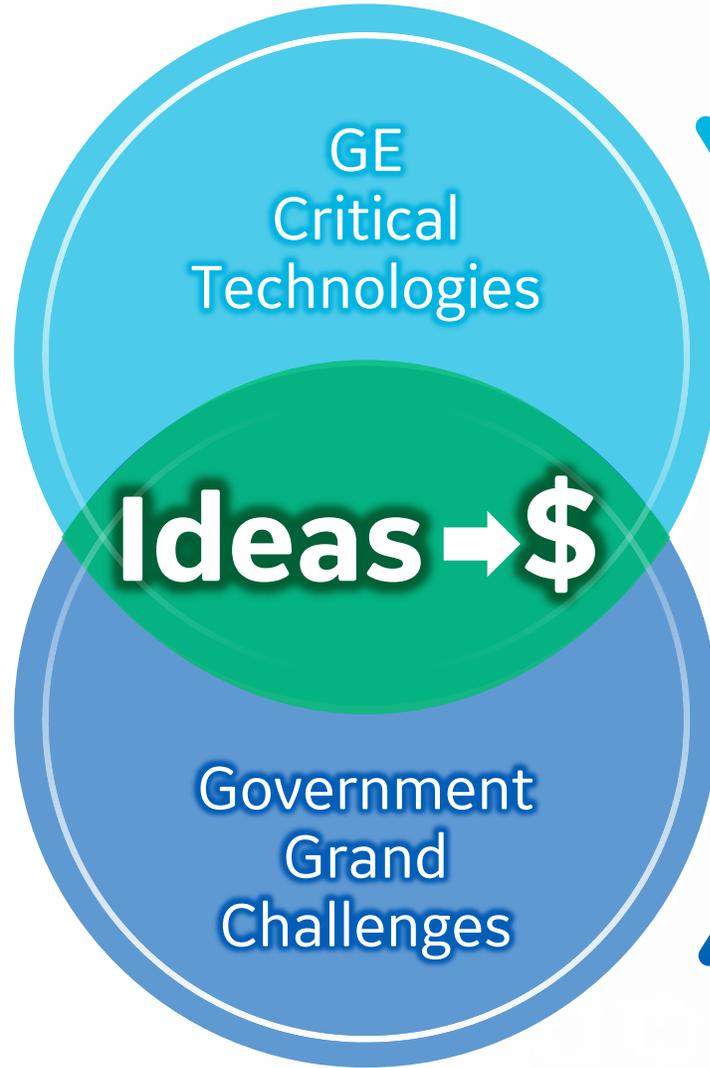
- Flight
- Energy
- Healthcare
- Manufacturing

.....

Gov't Agencies

Future of:

- Security
- Energy
- Healthcare
- Infrastructure

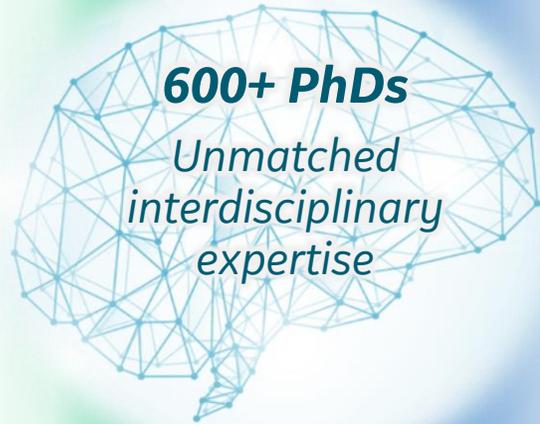


See
Move
Create
... the Future of GE

GE Research ... unique value proposition

Capabilities

- Artificial Intelligence
- Biology & Physics
- Controls & Optimization
- Edge Computing
- Electronics
- Electric Power
- Functional Materials
- Mechanics & Design
- Software & Analytics
- Structural Materials
- Thermosciences



Research to Reality

Breakouts

VERTICAL

2 Cent Wind	65% CC GT	Additive	Renewables Full Time
Castings	Plug & Play MR	Renewable Reservoir	Hybrid - Electric Flight

HORIZONTAL

Additive	Artificial Intelligence	CMC	Robotics
Controls/Edge	Digital Twin and Ghost	Specialized Materials	SiC

EXPONENTIAL

Autonomous Imaging	Bioelectronics	Blockchain
Microsystems	Mission Unbreakable	Trusted Autonomy

Scientific depth & breadth ... delivering real economics

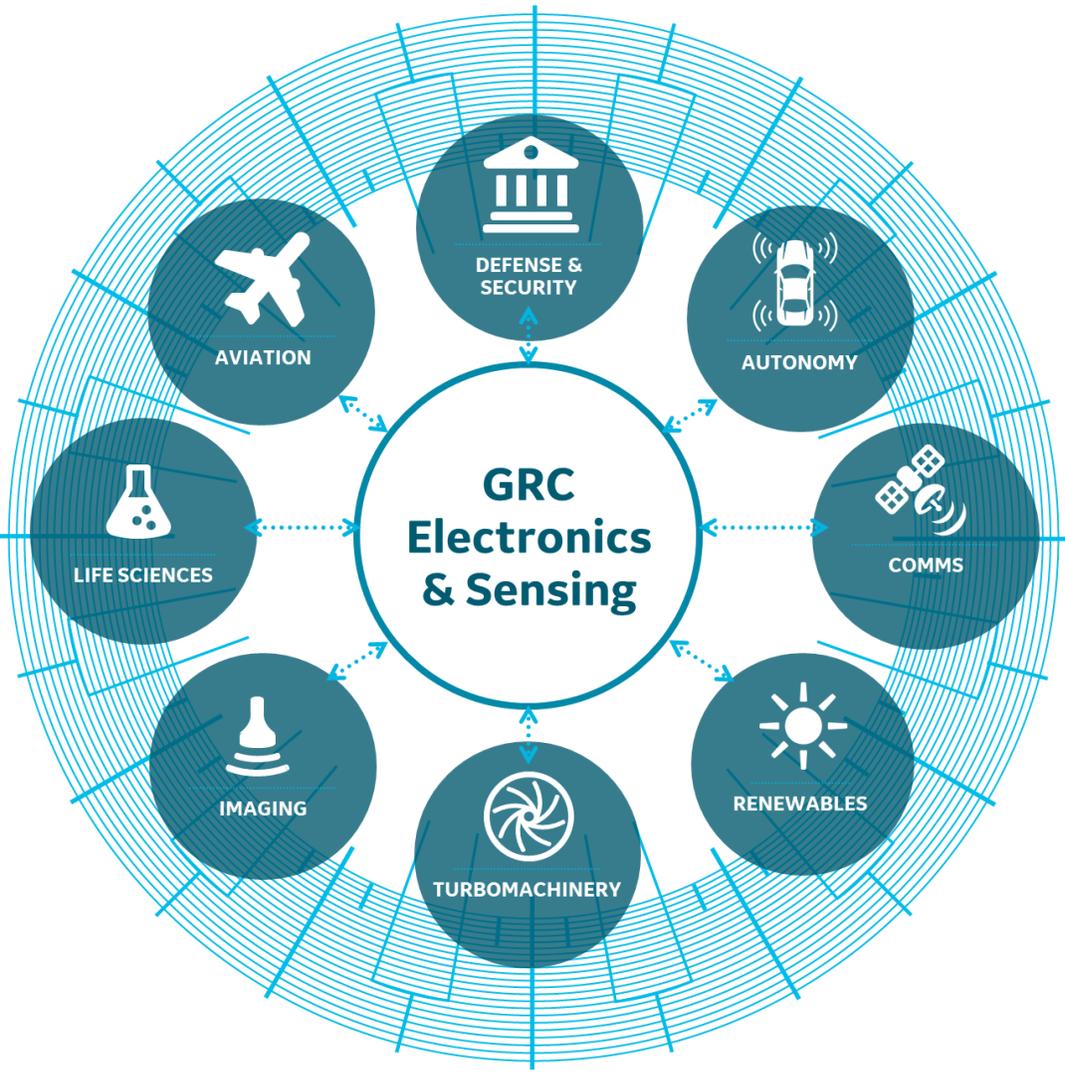
GRC inside ... an innovation engine for today's GE

- **Larger innovation network**
- **Knowledge sharing**
- **Technical depth & breadth**



Connecting to GE businesses, government agencies & strategic partners

Track record of innovation to production



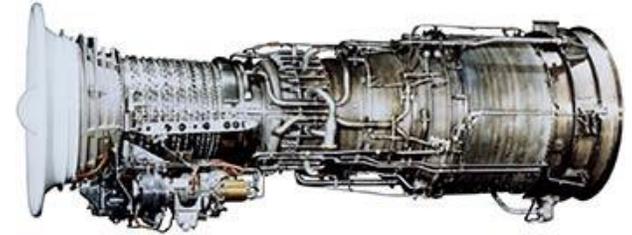
This section displays eight circular images of electronic components and systems, each accompanied by a year and a description of the achievement:

- 1995**: SILICON CARBIDE PHOTODIODE
- 1997**: WORLD'S FIRST FULL FIELD X-RAY
- 2005**: CT DETECTOR SYSTEM INTEGRATION
- 2006**: OPTO-ELECTRONIC PACKAGING
- 2013**: THIN FILM PV WORLD RECORD
- 2014**: RF MEMS SWITCH
- 2015**: SILICON CARBIDE MOSFET
- 2018**: IN-SITU TISSUE MULTIPLEXING PLATFORM

Ideas, Expertise, Speed, Scale ... Our unique competitive advantage

Torque Sensing Needs

- Engine torque measurement
 - Increased controllability provided by direct torque output monitoring
 - $\pm 2\%$ accuracy for improved output capacity and operation efficiency
 - Reliability testing at 150C for 20,000 hours
 - Shaft assembly testing up to 40,000g's
 - Axial length of <1" for dual redundant system

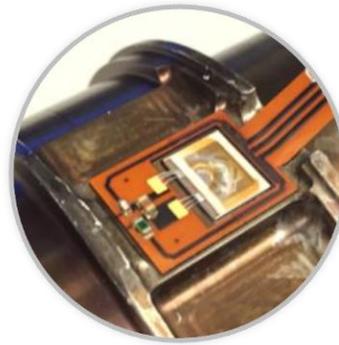


First GE Implementation (SAW)

Integrated Surface Acoustic Wave (SAW) torque measurements



Die



Shaft Assembly



System

SAW technology provides

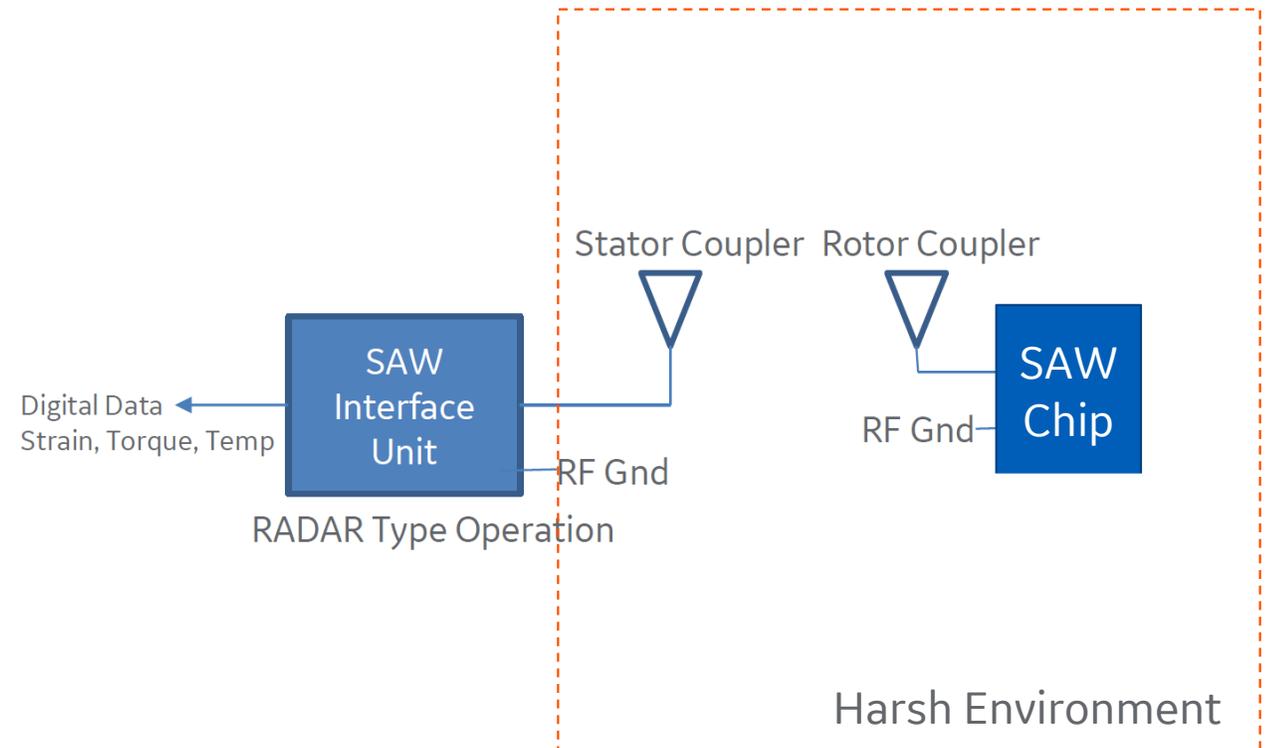
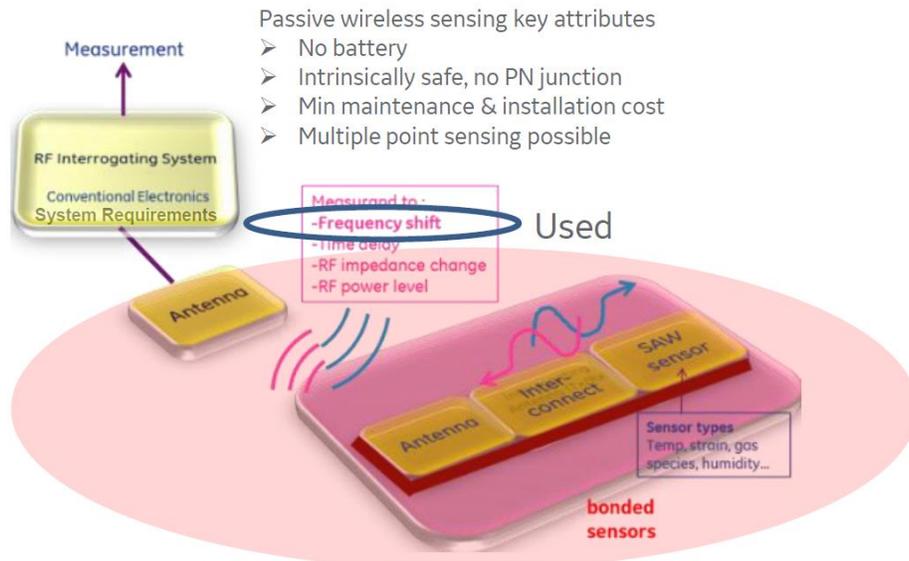
- Excellent direct strain measurements without creep impacts over time for torque and linear applications
- Passive measurement, non P-N junction technique with simultaneous temperature readings (higher reliability and accuracy)

GE Research works with the GE Businesses and Transense Technologies Plc to develop SAW solutions for GE systems and applications.

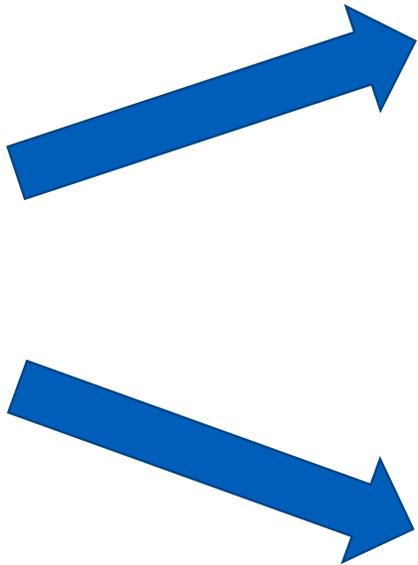


SAW Operation

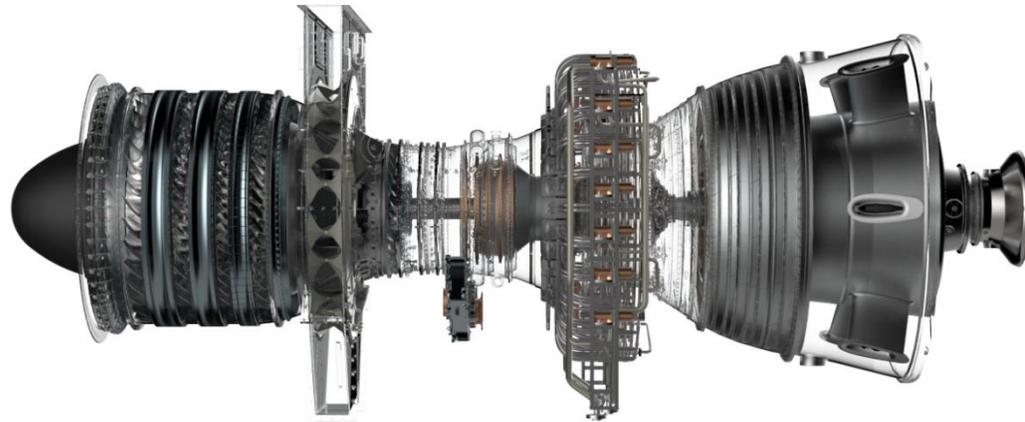
All Passive components in Harsh Zone



Continued Evaluations in new spaces



Strain: Wired

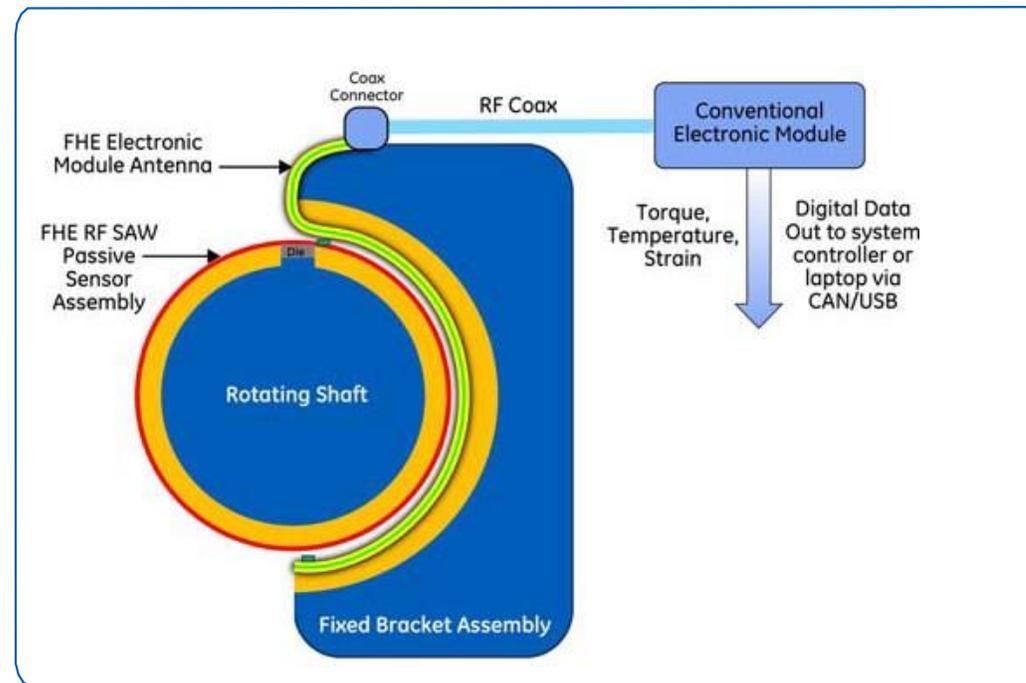


Large diameter: Wireless



Need for scalable solutions with low complexity

Need solution from 3 inch to 3 foot diameter shaft



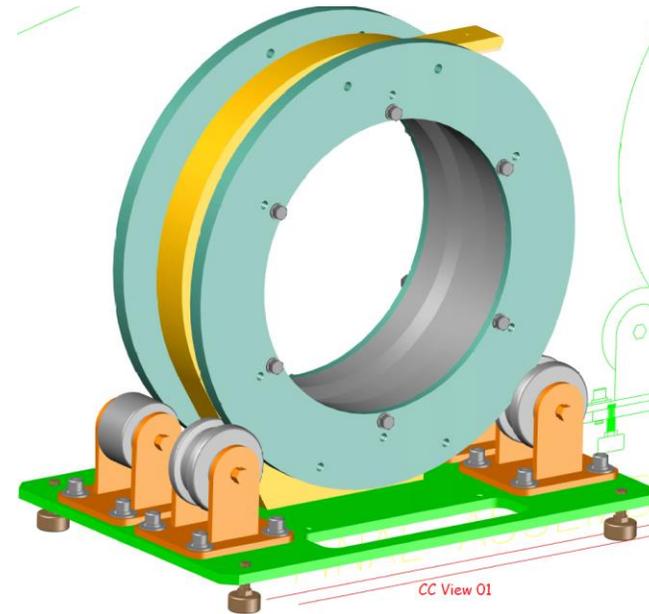
Generalized problem

- Large format Flexible Electronics with high reliability and low cost with pre-assembly capability



Developments

- ✓ Printed Conductors
- ✓ Wirebond free attachment
- Reliability testing
 - ✓ Adhesion
 - ✓ High G
 - ✓ Bend testing
 - ✓ Tensile testing
 - ✓ Humidity
 - ✓ Thermal Stability
 - ✓ RF and breakdown



TMS Platform

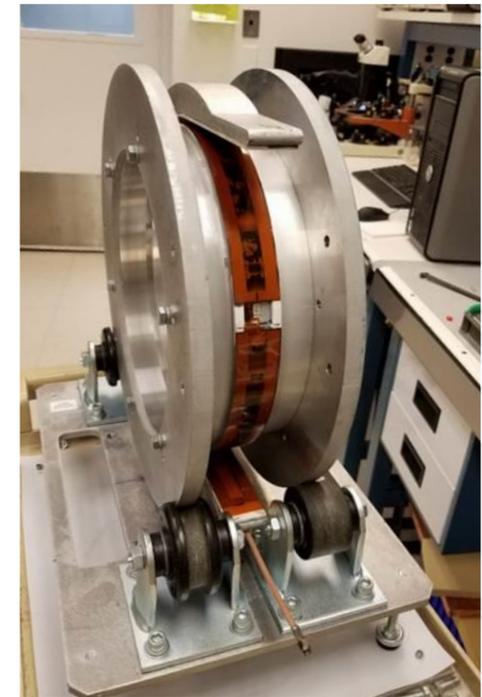
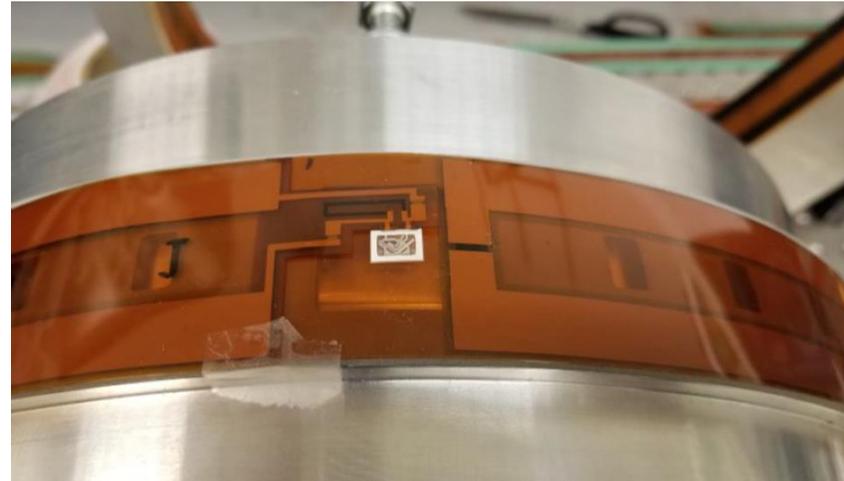
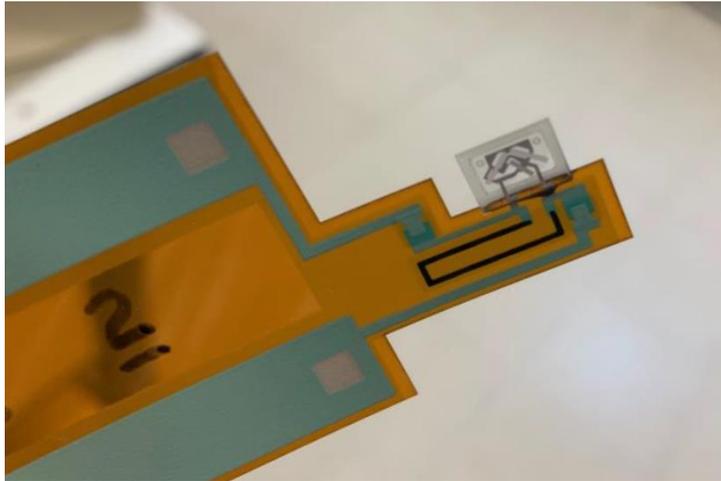


Printed Conductors & Integral passives



Fully Integrated solution

- Sub-Assemblies
- Low temp die attach



Future needs

- Higher Temperature capability (Sensor, Package & System)
- Identify further high value applications
- EMI/EMC
- Security



- **Acknowledgement:**

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