HUMANIZING THE DIGITAL EXPERIENCE

TDK Developers Conference 2018

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HUMANIZING THE DIGITAL EXPERIENCE

Miniaturized Solutions for IoT by Integrating Sensors and Wireless Communication with Flexible Circuitry

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Principal Engineer, Precision Components Development
TDK – Hutchinson Technology

See our demonstration videos at:
www.htch.com/demos/

TDK Developers Conference
September 17-18, 2018
Santa Clara Marriott

Introduction

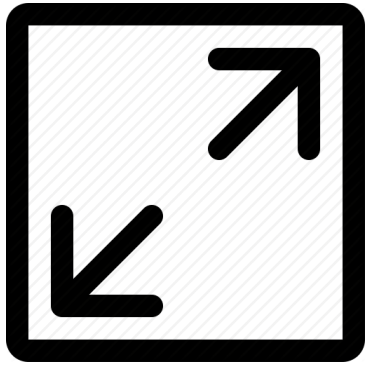
- Section 1
  - ¬ IoT Challenges
    - Introduce you to a manufacturing ‘toolkit’
  - ¬ Practical examples of how this technology can be utilized for IoT
    - Integrated Analog Sensors
    - Wireless Power & Communication
    - Integrated Actuators
    - Advanced Chip Packaging

- Section 2
  - ¬ Overview of the Semi-Additive ‘toolkit’
    - Processing steps and the versatility of semi-additive technology

Section 1:
IoT Challenges & Practical Examples

Enabling IoT

- Practical concerns with typical manufacturing methods
  - ¬ Existing ‘toolkits’
    Imagination Killers
    - TIME: Need to produce prototypes in weeks, not months
    - COST: Sensors and actuators are expensive
    - SIZE: Limitations in packaging options



- Process Innovations are Needed: *More ‘Toolkits’*

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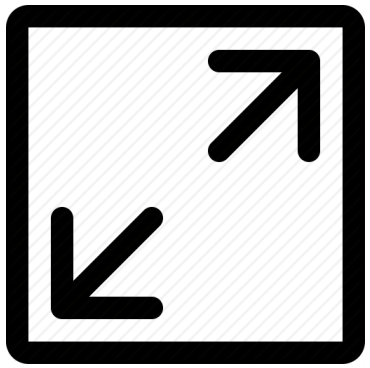
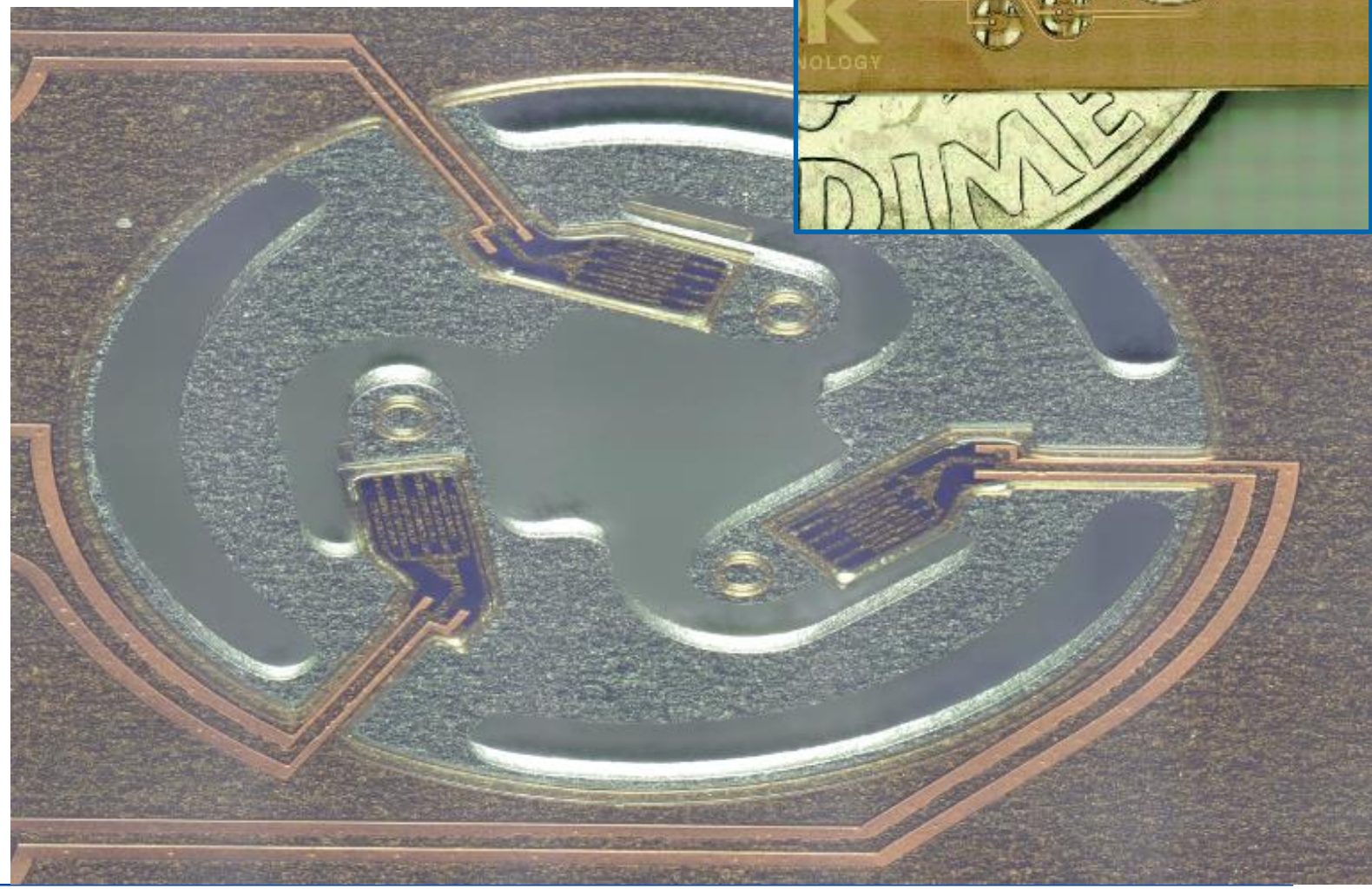


- Process Innovations are Needed: *More ‘Toolkits’*
  - ¬ *One Answer: Roll to Roll Semi-Additive Process Technology*

Better Process Toolkit → Better Solutions

- HTI's Semi-Additive Processing Allows:
  - ¬ Integrated Sensors
  - ¬ Precision Electromechanical Components
  - ¬ Fast Time to Market
  - ¬ Miniaturization
  - ¬ Advanced Chip Packaging
  - ¬ Facilitation for Automated Assembly



IoT Applications

Source:
Yole Development

Component Fabrication Methods

- PCB/Flex Fabrication
  - Use
    - Packaging/Connect
  - Attributes
    - Flexible
    - Large Size
    - Short Lead Time
    - Low Cost

- Silicon Fabrication
  - Use
    - Sensors
    - Actuators
    - Data Processing/Storage
  - Attributes
    - Rigid
    - Small Size
    - Longer Lead Times
    - Higher Cost

What if there was a 'Tool Kit' that could integrate both the component and the package?

Component Fabrication Methods

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Roll to Roll Semi-Additive Manufacturing Processes can provide some of the best of both!

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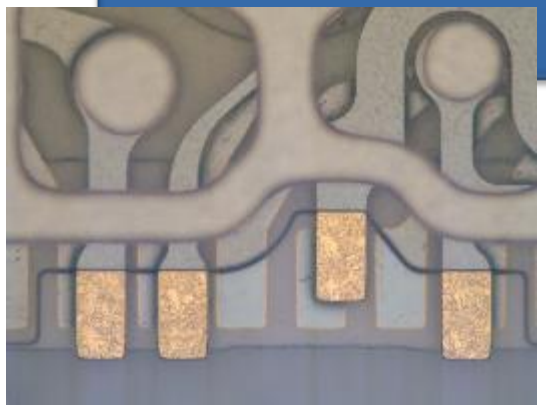

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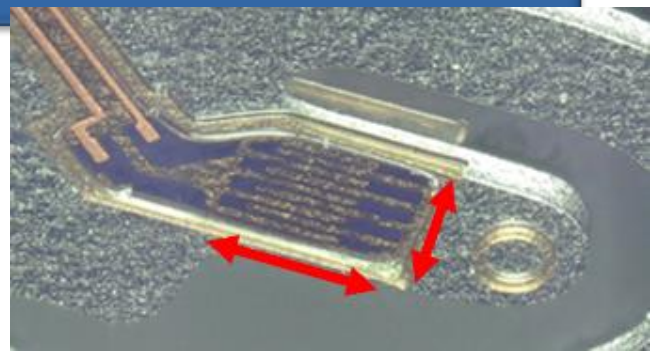
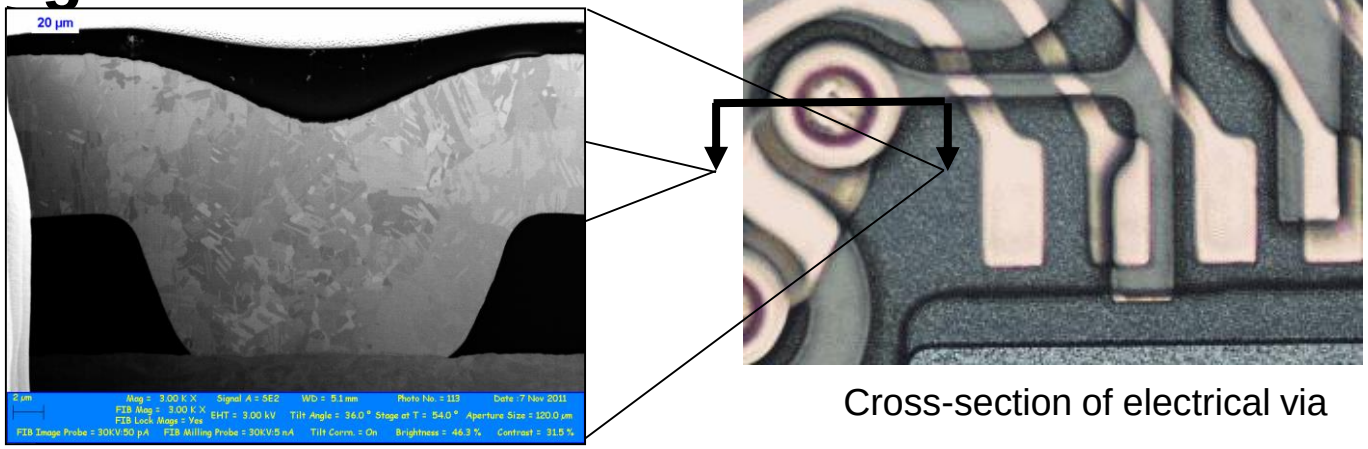


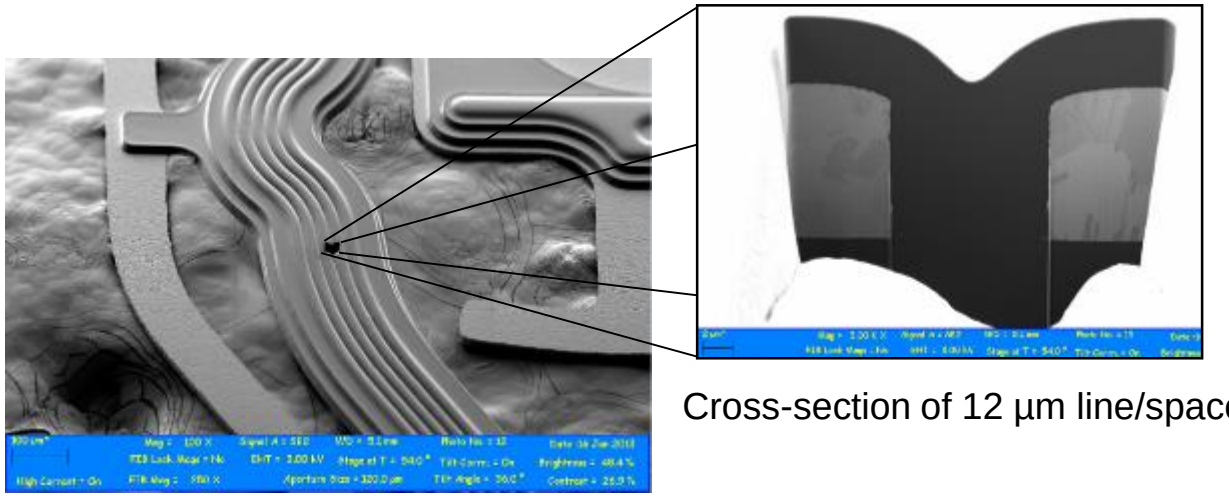
Hutchinson Technology Advantages

- Design Flexibility
  - ¬ Multiple circuit layers
  - ¬ Interlayer connections (vias)
  - ¬ Fabricate circuitry on just about any rigid or flexible, flat substrate:
    - Metal
    - Plastic/Polymer
    - Ceramic / Glass
    - Semiconductor
  - ¬ Connections to outside world
    - Solder
    - Adhesive
    - Crimp
    - Ultrasonic fusion
    - Laser/Resistance weld

Si Fab-Like Processing In Roll to Roll Format on Flexible Substrates



Cross-section of electrical via



Cross-section of 12 µm line/space product

Hutchinson Technology's Core Processes

Semi-Additive

- Metal Etching (Photo-Chemical Milling)
- Polymer Coating / Etching
  - Dielectric
  - Solder Mask
  - Dry Etching
  - Wet Etching
- Additive Metal Deposition
  - Physical Vapor Deposition: Sputtering
  - Plating: Electrolytic & Electroless
- Fine Line & Space Circuitry
  - Multilayer
  - 10 um line / 10 um space for new products
- Precision Layer to Layer Registration
  - 10 um registration @ 1.33 CpK

Other Processes

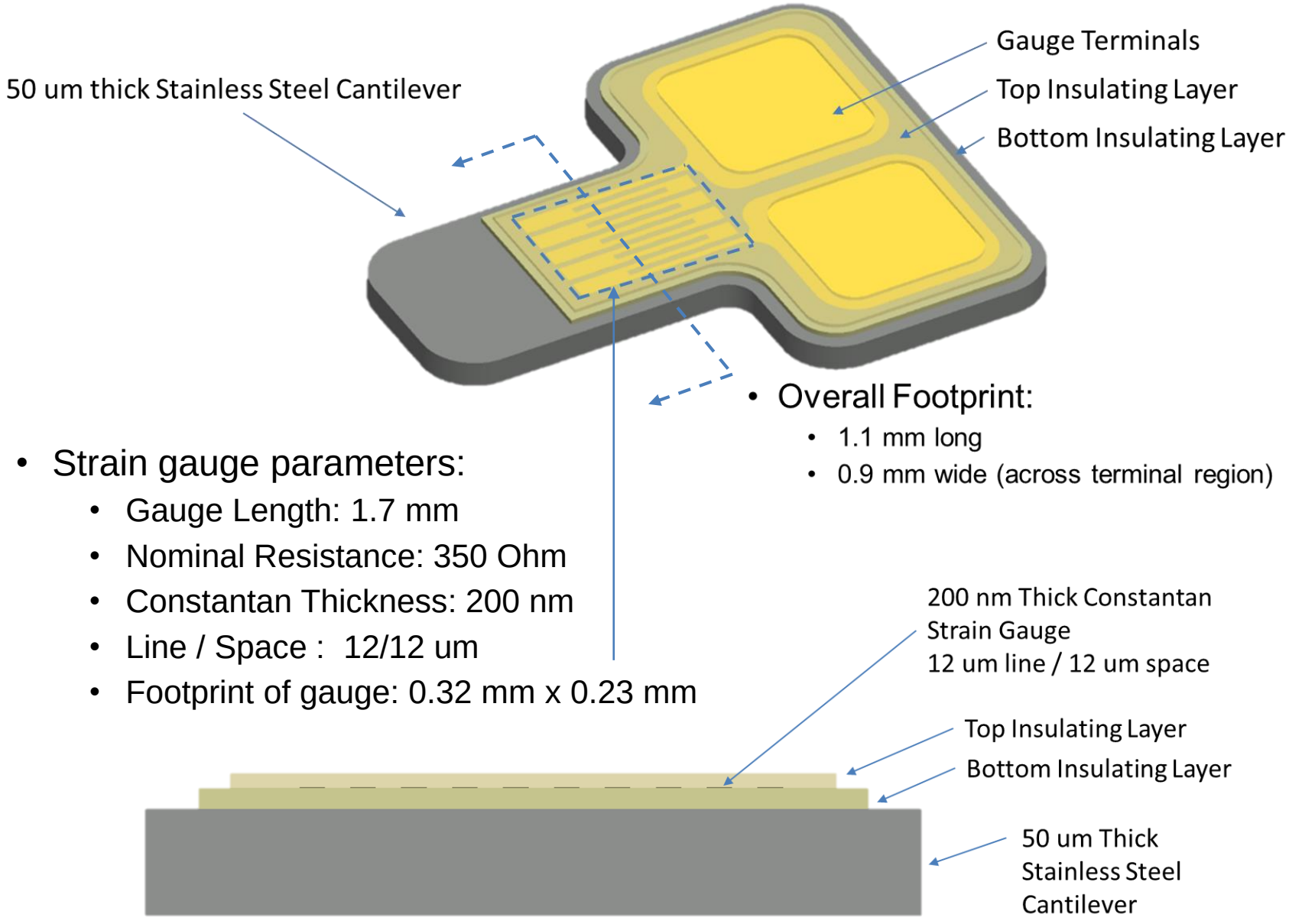
- Die/Component Placement & Bonding
- Laser Technologies:
  - Ablation / Welding / Polishing / Adjusting
- Forming & Shearing
- Precision Stamping
- Precision Tooling
- Automated Assembly

Section 1: Practical Examples for IoT

- 1.1: Integrated Analog Sensors
  - ¬ **Strain Based Sensors**
  - ¬ RTDs
  - ¬ Capacitance Based Sensors

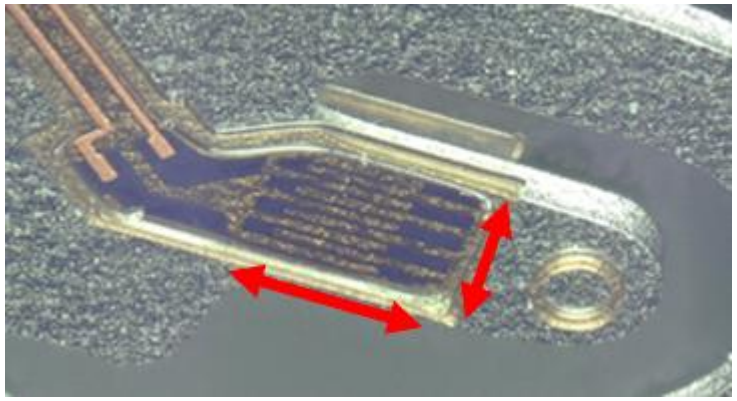
Strain Gauge

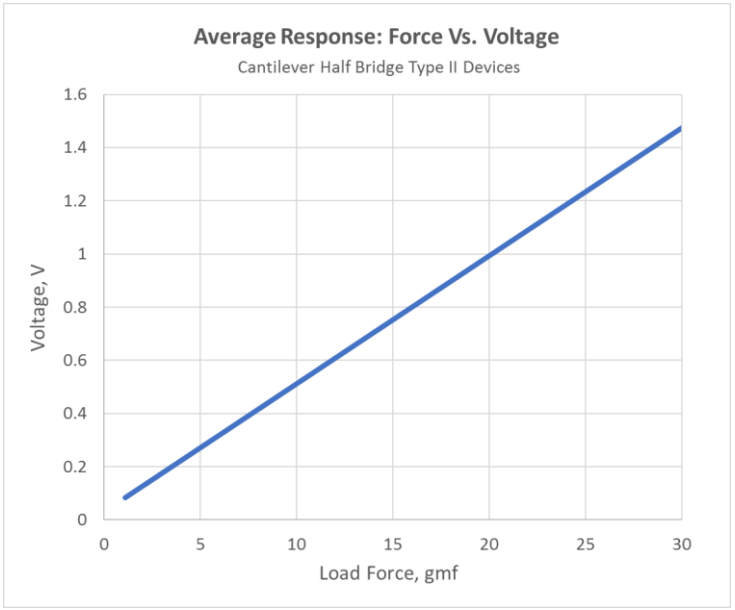
- Thin film Constantan strain gauge
- Precision aligned to spring cantilever
- Single sided, quarter bridge gauge shown here

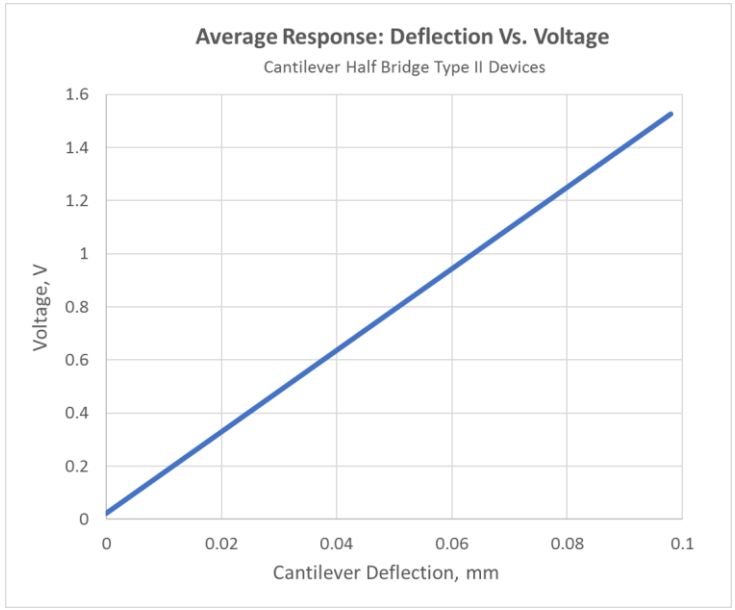


Strain Gauge IoT Example

- Performance of Hutchinson Technology Prototype
  - ¬ 0.32 mm x 0.23 mm Type II device (dual sided gauge)
  - ¬ 350 Ohm nominal







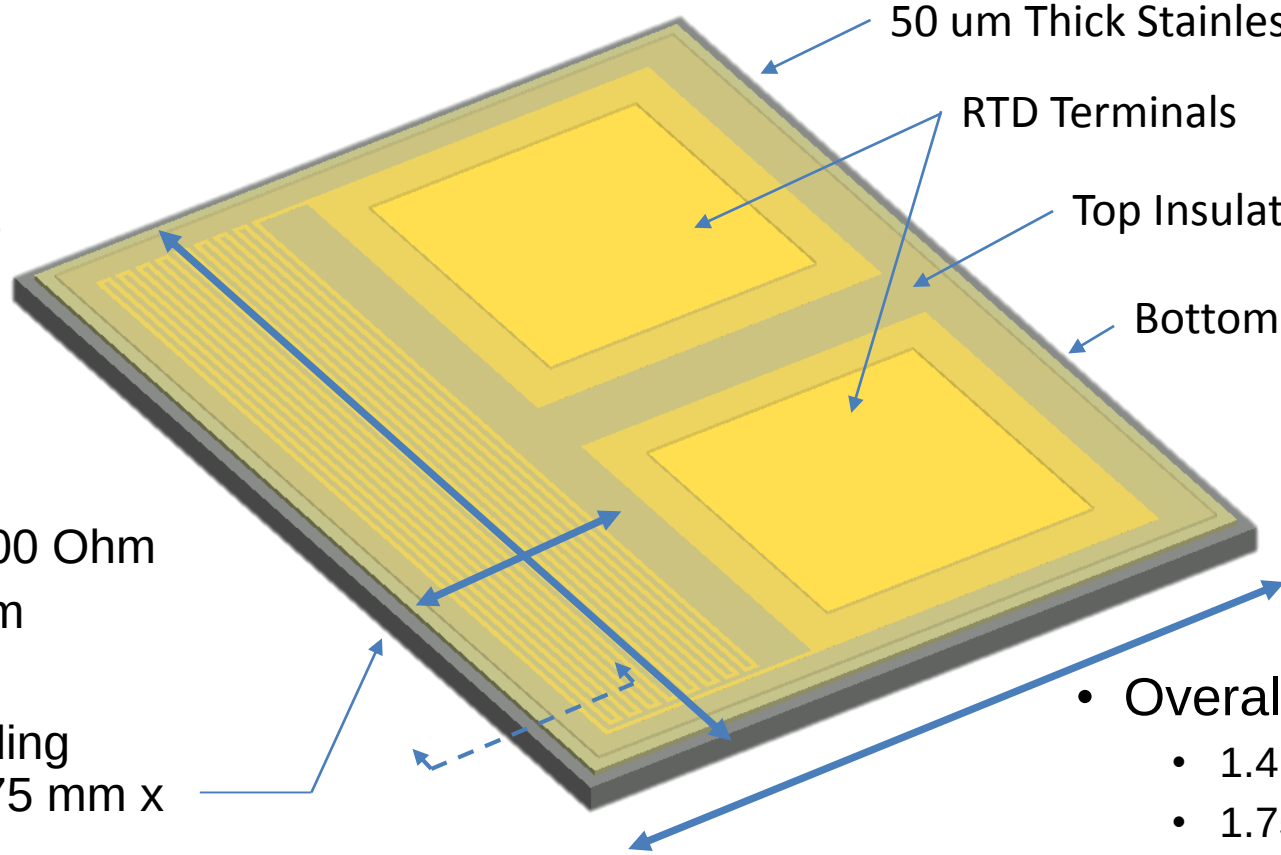
Triple beam strain gauge array for diagnostic catheter application

Section 1: Practical Examples for IoT

- 1.1: Integrated Analog Sensors
  - ¬ Strain Based Sensors
  - ¬ **RTDs**
  - ¬ Capacitance Based Sensors

RTDs

- Thin film Nickel RTD
  - ¬ *Resistance Temperature Detector*
    - RTD parameters:
      - Gauge Length: 26 mm
      - Nominal Resistance: 1000 Ohm
      - Nickel Thickness: 200 nm
      - Line / Space : 10/10 um
      - Package Size (not including terminals): 0.5 mm x 1.75 mm x 0.075 mm



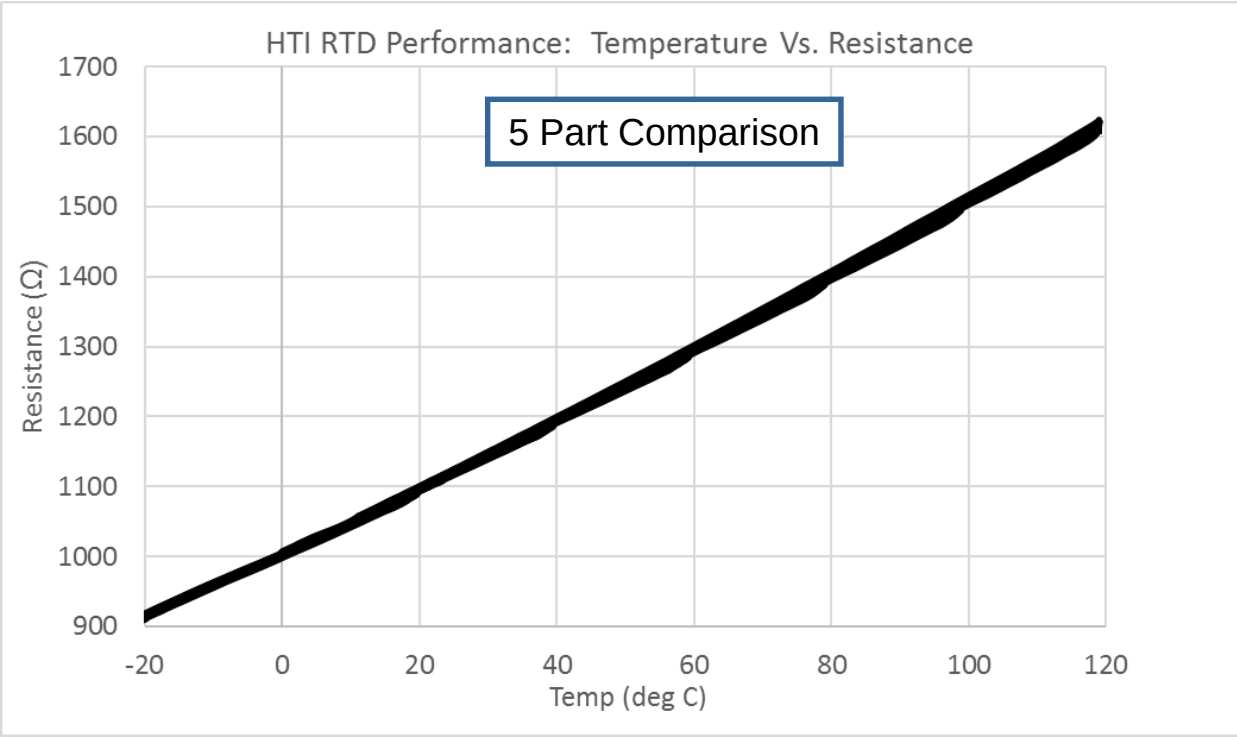
- Overall Footprint:
  - 1.4 mm long
  - 1.75 mm wide

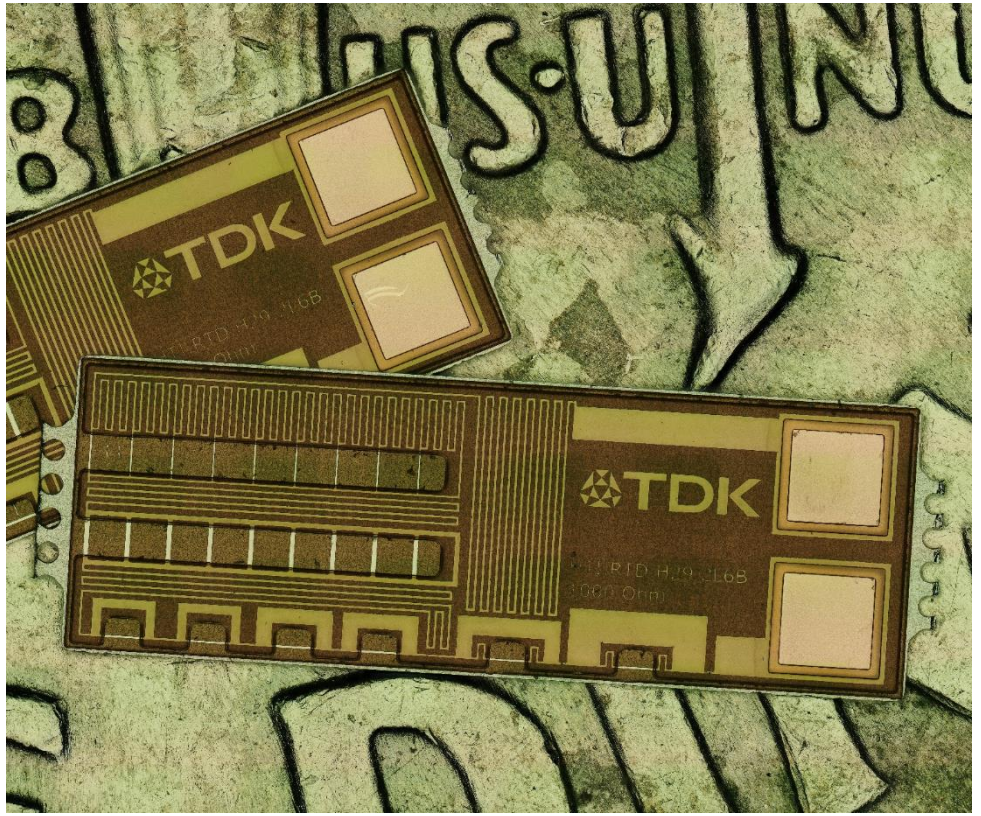
RTDs

- Performance of Hutchinson Technology Prototype

RTD: 1.75 mm x 4.95 mm footprint

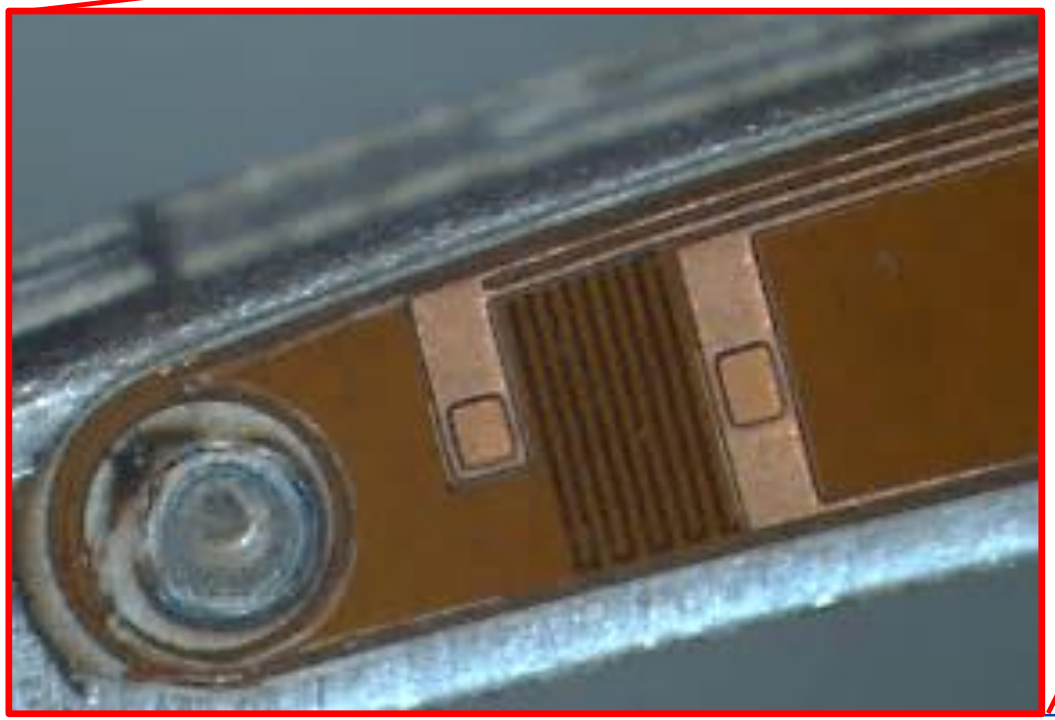
Devices trimmed to precise resistance target (1000 Ohms at 0 C)

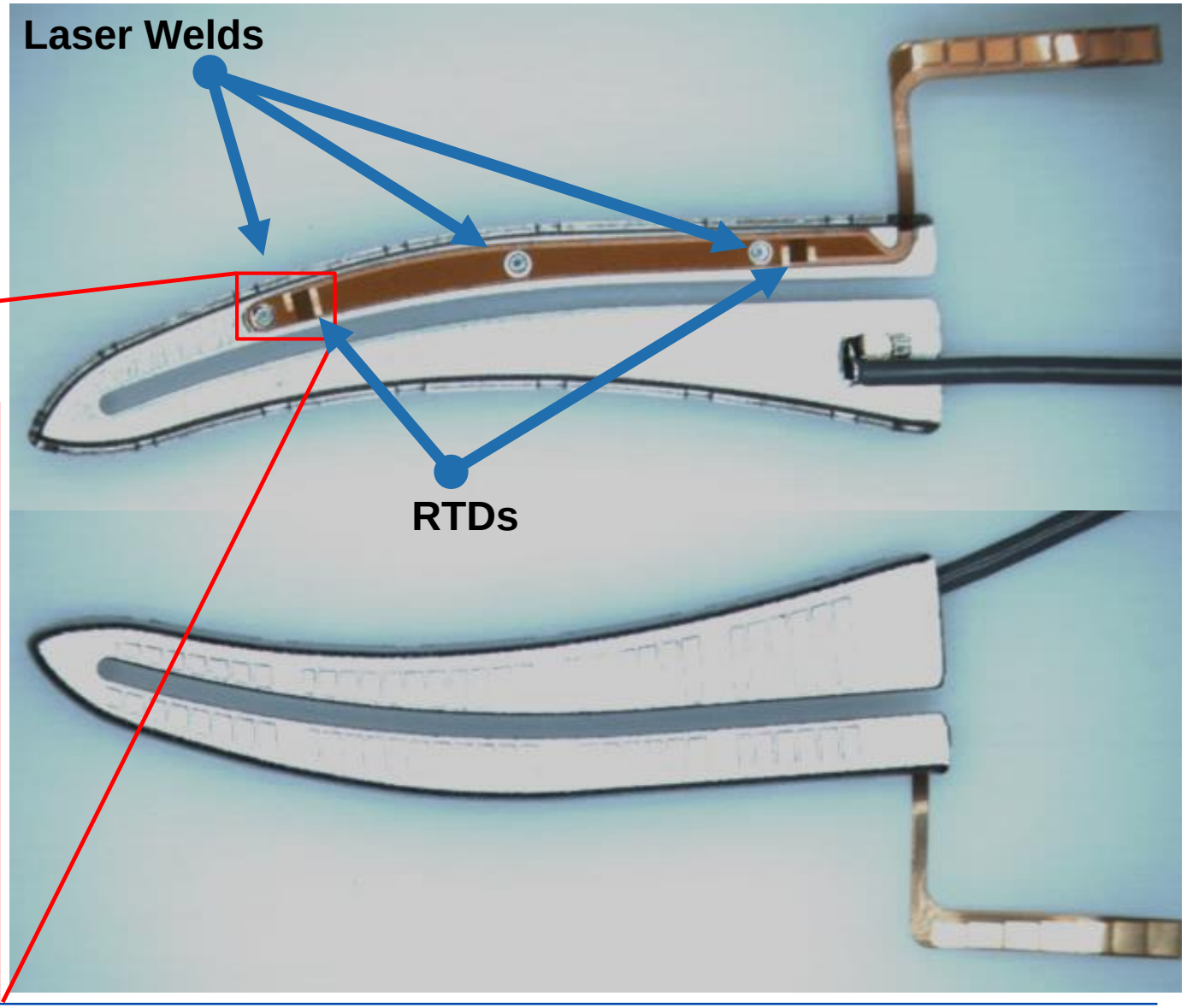




IoT Example: RTDs

- Custom integrated 7 lead flexible circuit with 2 RTDs precision placed at critical locations
- Laser welded to the underside of a metallic medical grasping device that utilizes a heat therapy cycle
- RTDs used for automated endpoint detection and diagnostics





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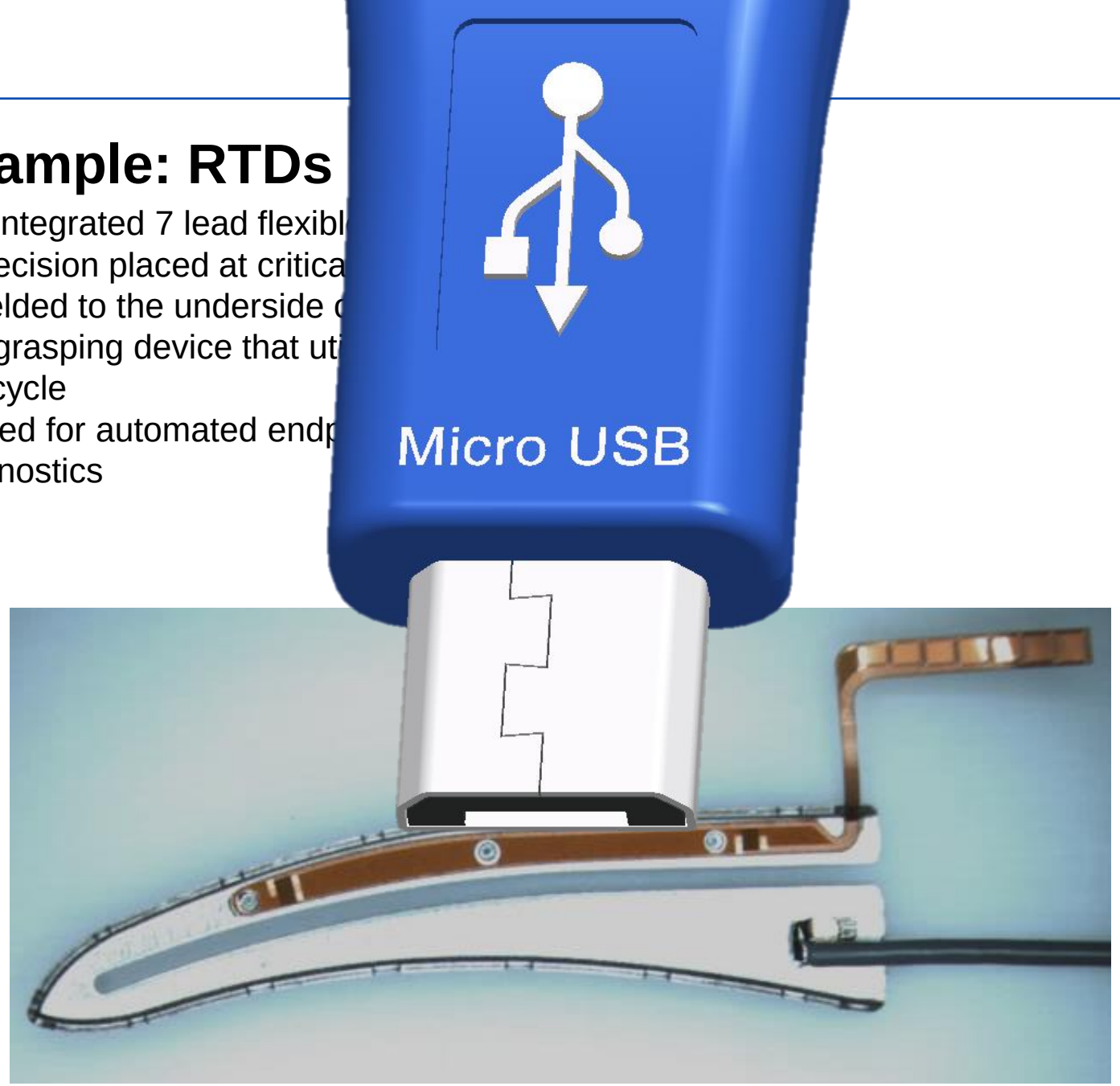
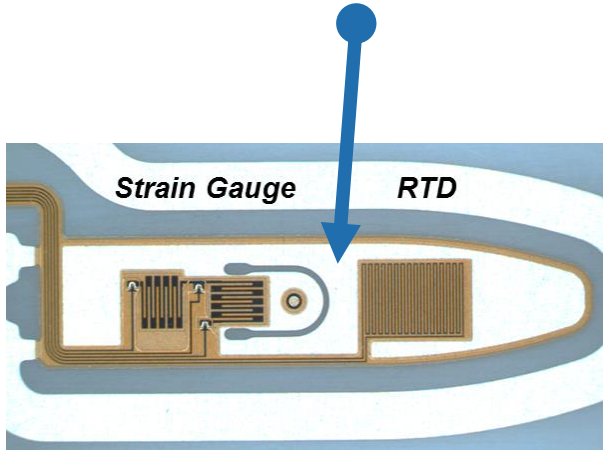
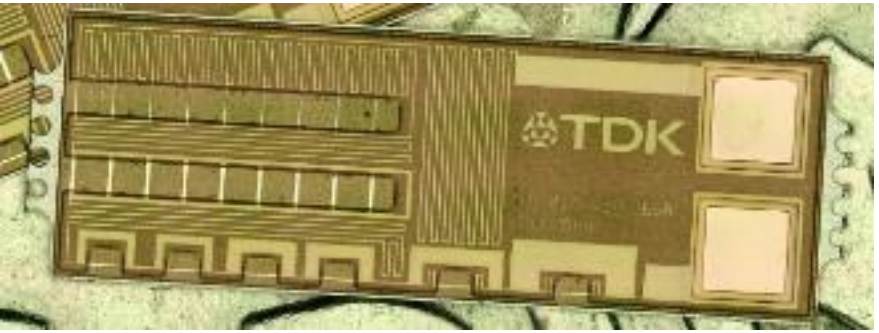


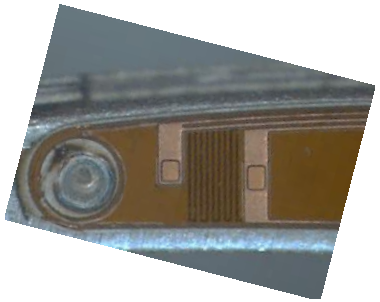
In this demonstration example, both an RTD (Nickel) and a Strain Gauges (Constantan) showing how multiple sensors can be integrated with HTI's Semi-Additive Process

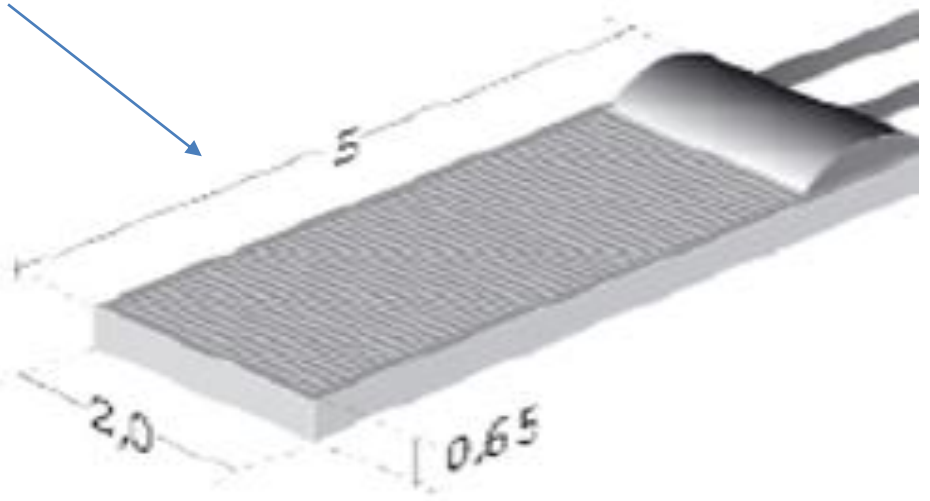


RTDs

- Relative Size Comparisons to Smallest Commercially Available Device







- Hutchinson Technology RTD Prototype Example
- 5.0 mm x 1.75 mm x 0.10 mm package
- 1000 Ohm (Trimmable)

- Hutchinson Technology Customized Integrated RTD
- 0.4 mm x 0.65 mm x 0.075 mm RTD package
- 100 Ohm (Non-Trimmable)

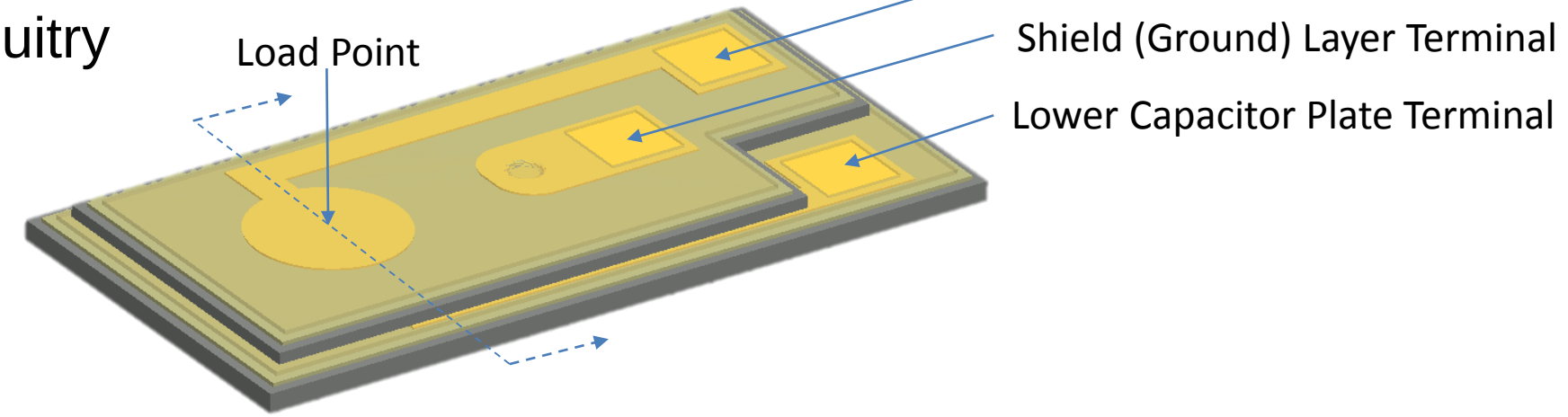
- Smallest Commercial Nickel RTD
- 5.0 mm x 2.0 mm x 1.3 mm package
- 1000 Ohm (Trimmable)

Section 1: Practical Examples for IoT

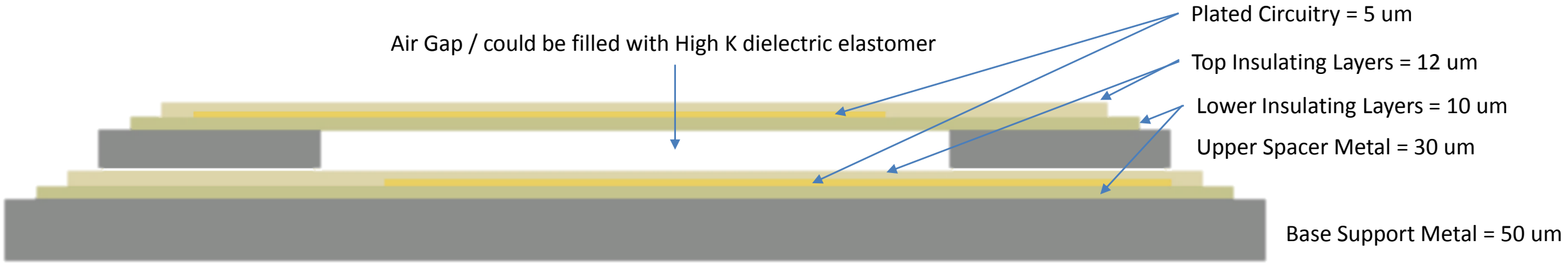
- 1.1: Integrated Analog Sensors
  - ¬ Strain Based Sensors
  - ¬ RTDs
  - ¬ **Capacitance Based Sensors**

Capacitance Pressure / Force Sensor

- Sensor fabricated from two layers of stacked circuitry

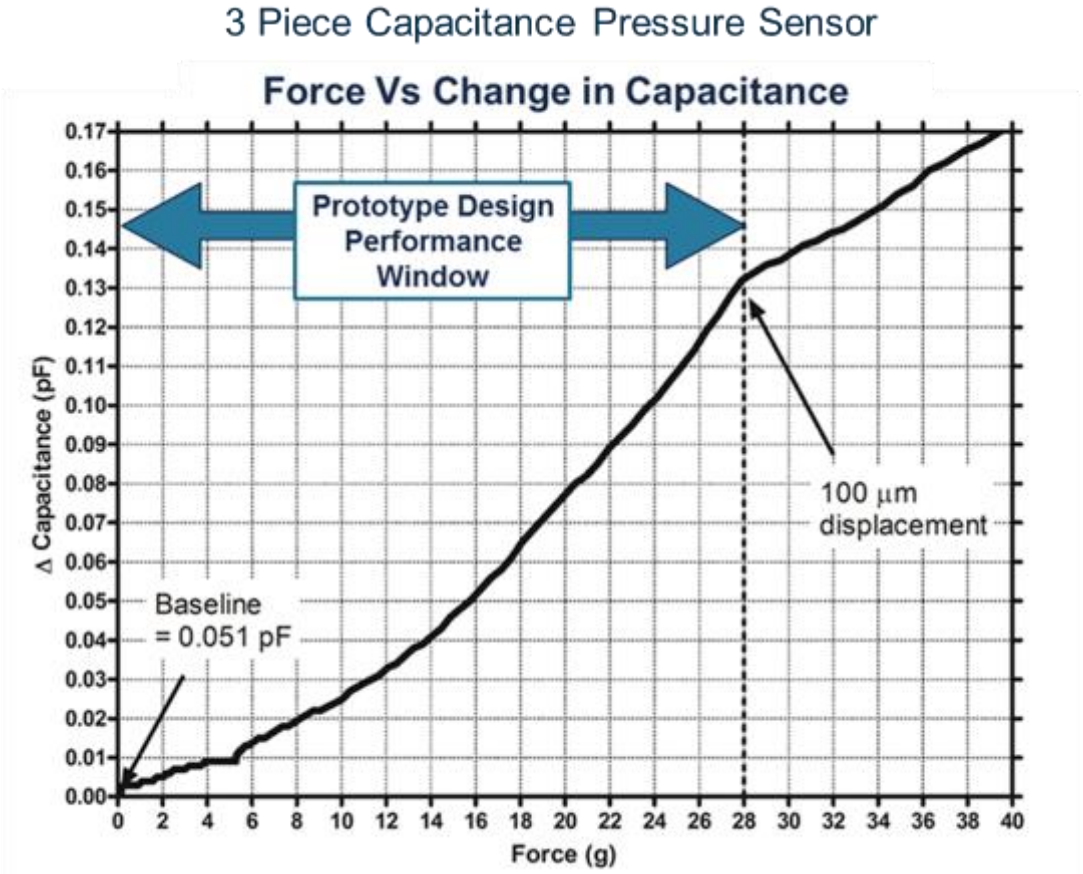


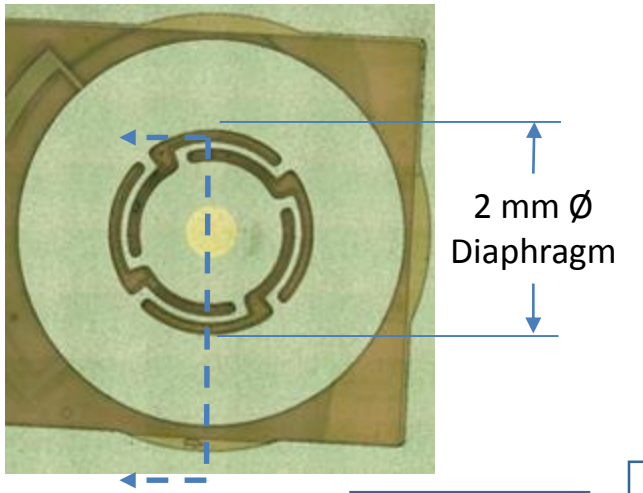
- Package size of example shown:
  - Length = 2 mm
  - Width = 1 mm
  - Height = 0.150 mm

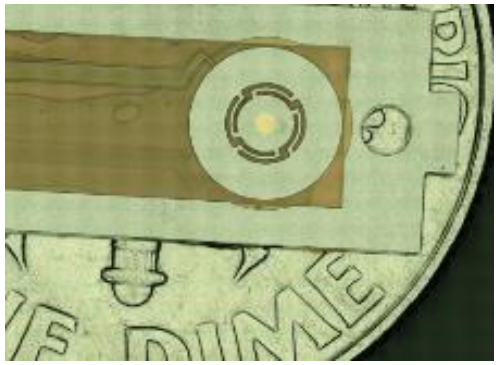


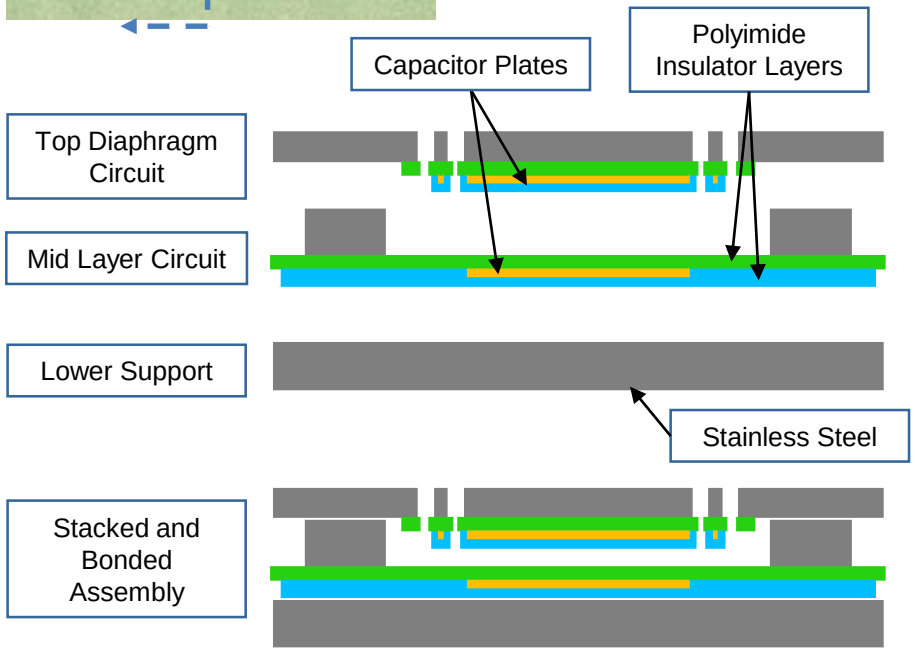
Capacitance Pressure / Force Sensor

- Prototype Example



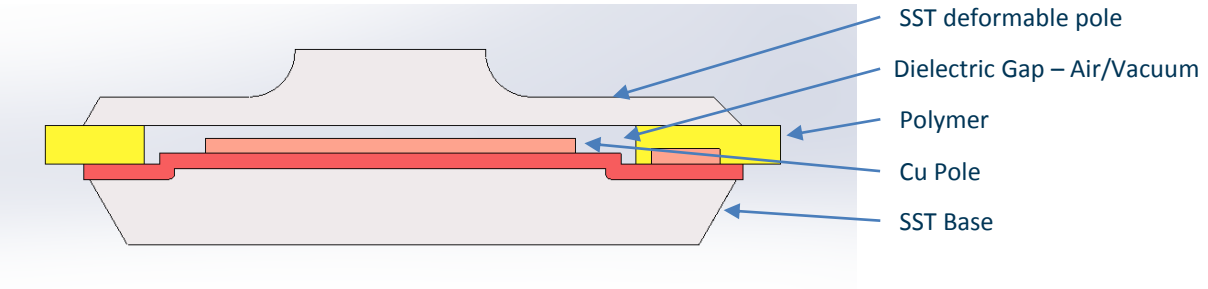




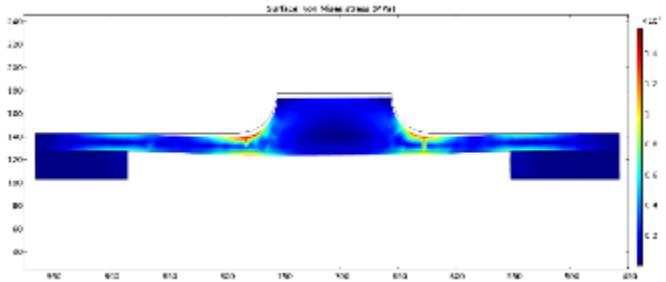


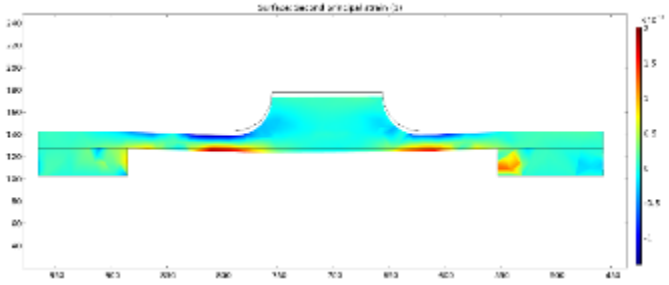
Capacitance Pressure / Force Sensor

- Example of alternative sensor and construction

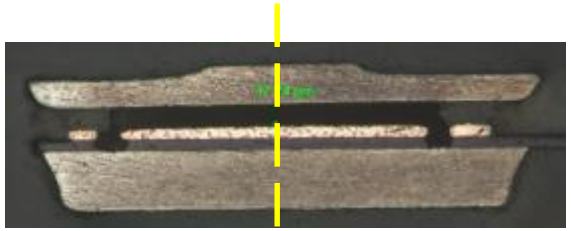


- FEA modeling the deflection of the diaphragm





- Model to prototype in 5 weeks



Section 1: Practical Examples for IoT

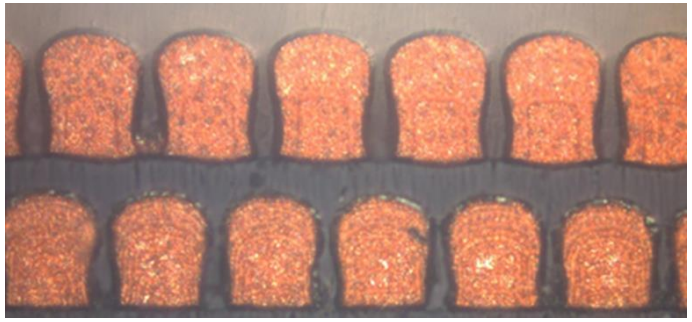
- 1.2: Wireless Solutions

  - ¬ **Wireless Power Transmission**

  - ¬ NFC

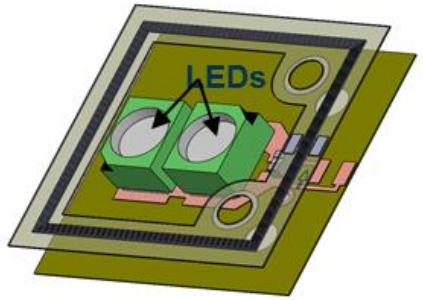
Wireless Power Transmission

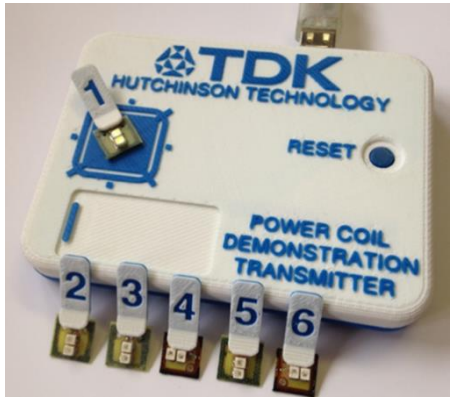
- Advantages of High Density Copper Traces for Power Transmission
  - ¬ Separate or 'in-package' within a larger circuit
  - ¬ High density copper trace optimizes inductance relative to resistance
  - ¬ More current is generated per unit of coil area



Cross Section of a Two Layer Coil

Industry Leading Copper Cross Section Density!





Single Layer Technology Comparison for Given Package Dimensions

	HTI Additive Coils	Traditional Flex - 1/3oz	Traditional Flex – 1oz
Modeled Thickness	60 um	12 um	36 um
Modeled Width	43 um	30 um	90 um
Modeled Spacing	7 um	30 um	90 um
Turns (Baseline of 10 turn HTI Coils)	10	8	3
Inductance	2.9 uH	1.9 uH	0.27 uH
Resistance	2.8 Ohm	15.9 Ohm	0.66 Ohm
X/R Ratio (Q Factor)	87.9	10.1	34.7
Tuning Capacitor (pF)	47 pF	72 pF	550 pF
Peak diode current with tuned circuit	16mA	4mA	5mA

Section 1: Practical Examples for IoT

- 1.2: Wireless Solutions
  - ¬ Wireless Power Transmission
  - ¬ **NFC**

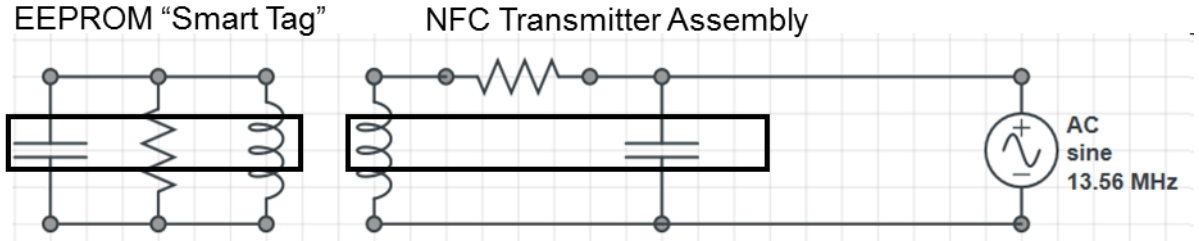
Small NFC Example

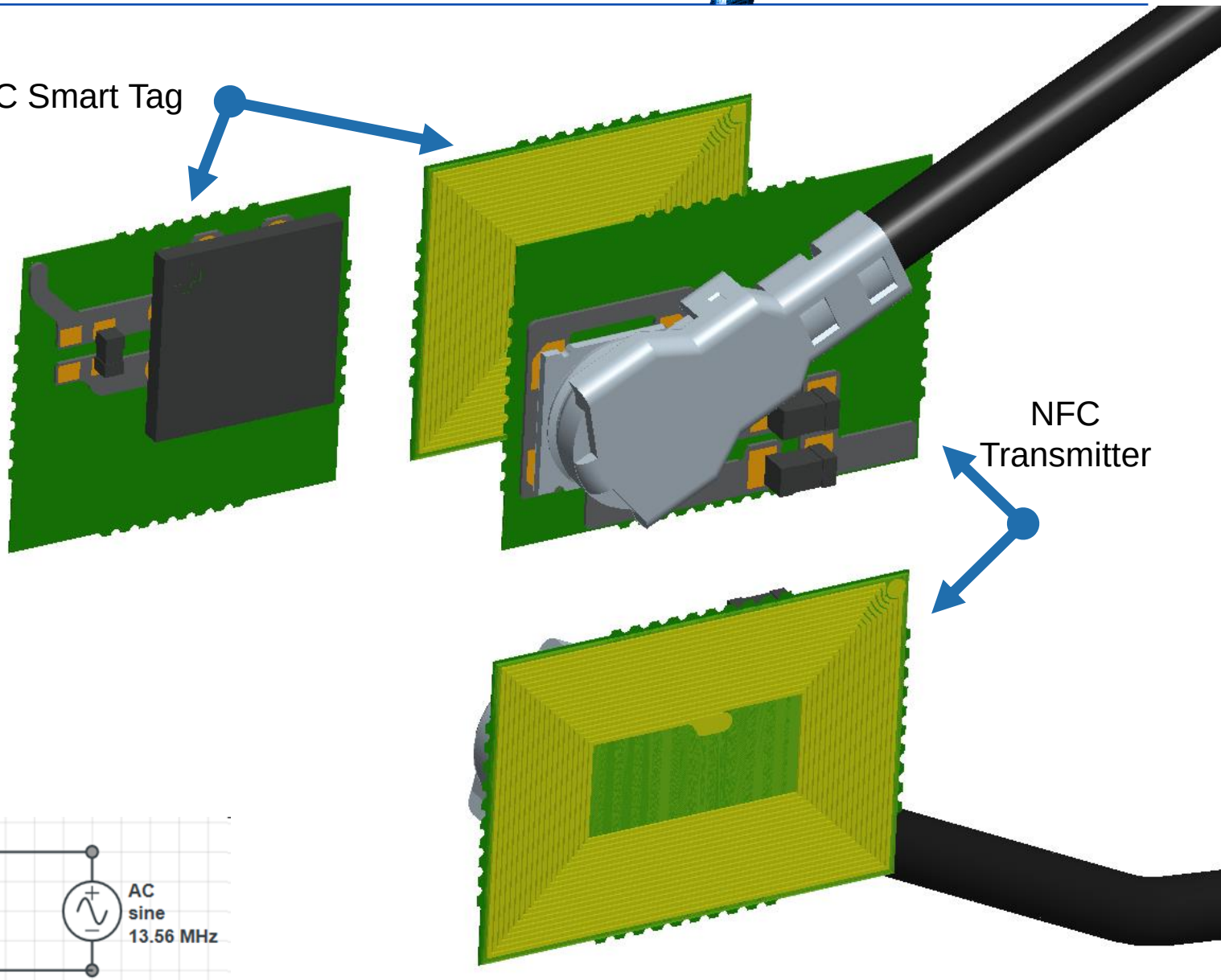
- NFC Smart Tag
  - 3.1 x 3.5 mm
  - 0.33 mm thick
  - NFC EEPROM
    - SHA-256
  - ISO 15693

- Designed for working read distances up to 3 mm

- Designed to resonate at 13.56 MHz

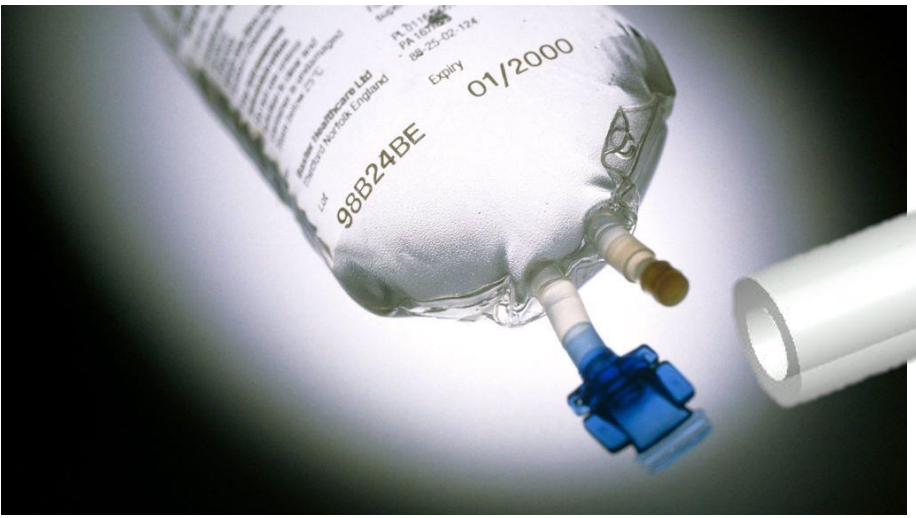
$$f = \frac{1}{2\pi\sqrt{LC}}$$

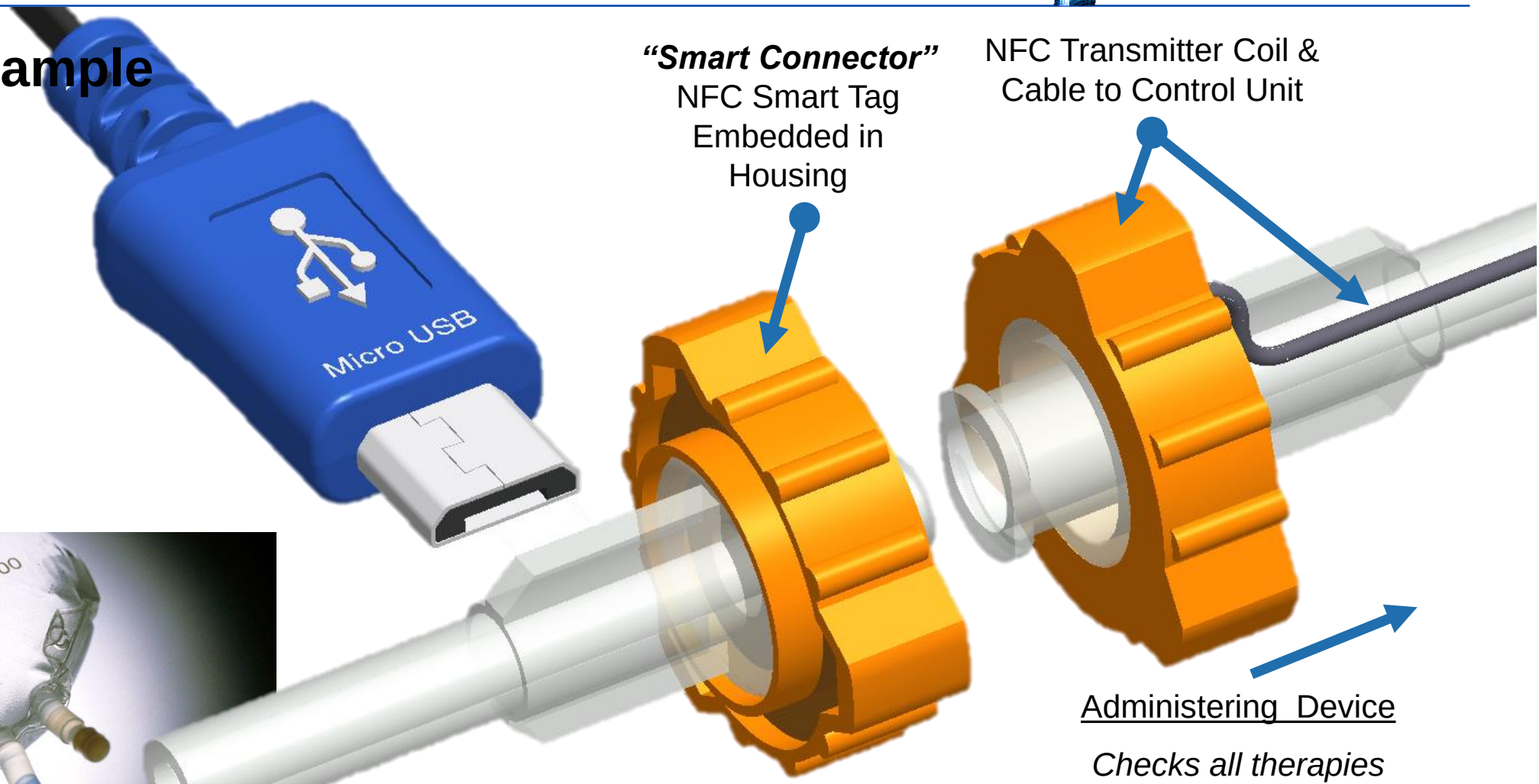




Large NFC Example

- NFC Smart Tag for "Smart Connector"**
  ***Patent Pending**
- NFC security used to verify:
  - ¬ Compatibility
  - ¬ Dosage Rate
  - ¬ Dosage Limit
  - ¬ Expiration
  - ¬ Data Logging





"Smart Connector"
NFC Smart Tag
Embedded in
Housing

NFC Transmitter Coil &
Cable to Control Unit

Therapy Delivery Stream

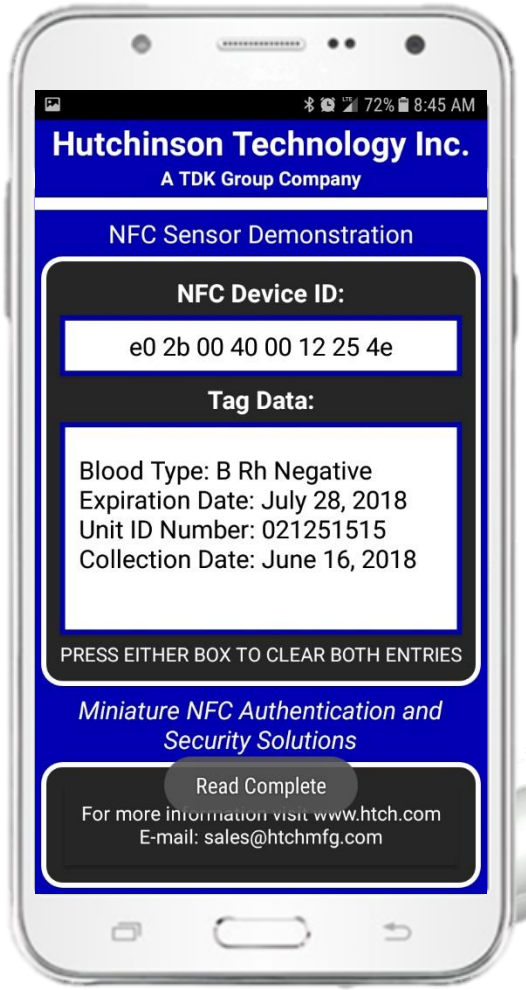
Fluids, Blood, Rx

Administering Device

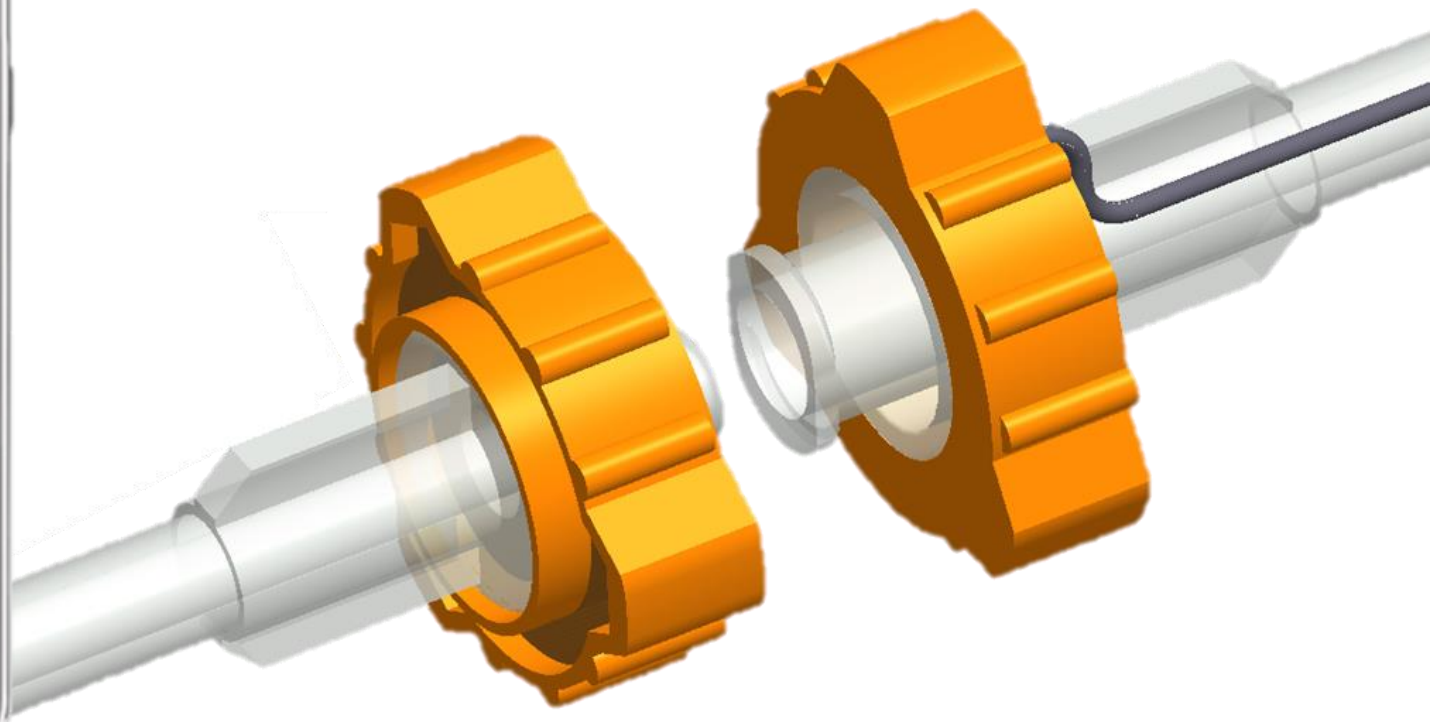
Checks all therapies against patient parameters & physician settings

NFC Demonstration

- "Smart Connector" Demonstration

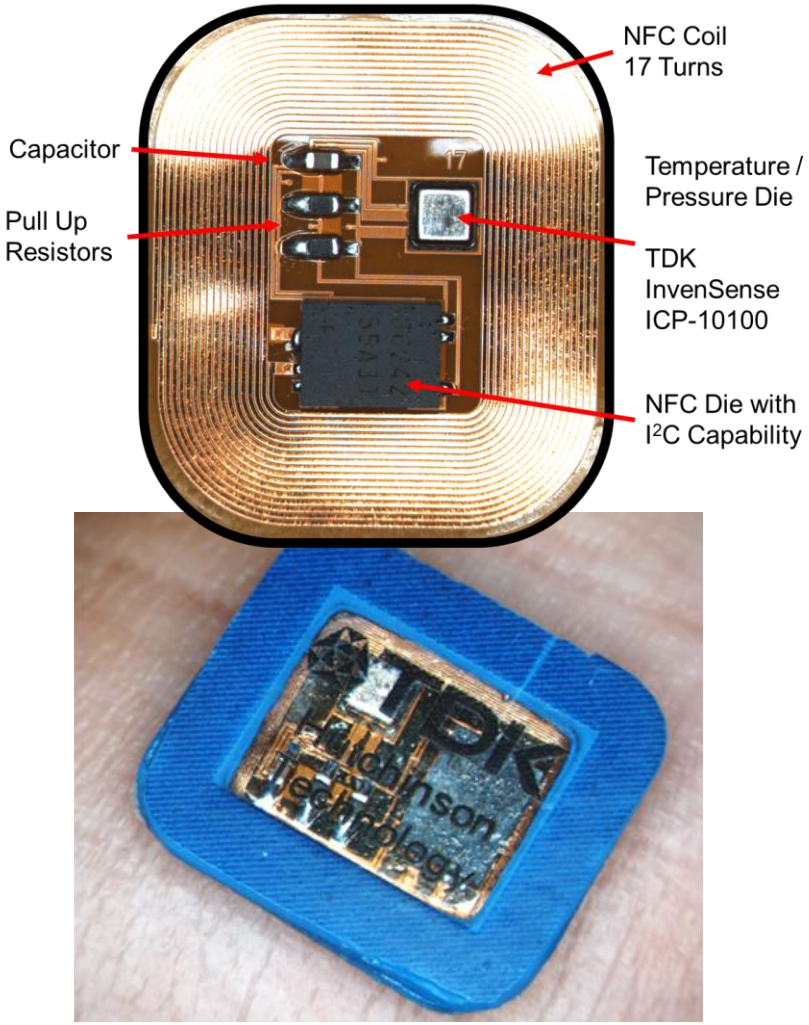


- *What other applications could this be applied to...?*
  - ¬ *Fiber optic network security*
  - ¬ *Hydraulic / Pneumatic 'smart connectors'*
- *Think of HTI's Semi-Additive technology as an additional 'toolkit' to add to your options for unleashing your creativity and vision without compromise.*



NFC / I²C Demonstration

- Temperature / Pressure Wearable



- *What other applications could this be applied to?*

Add battery & bluetooth for sports safety wearable

Chiropractic, posture, physical therapy wearables

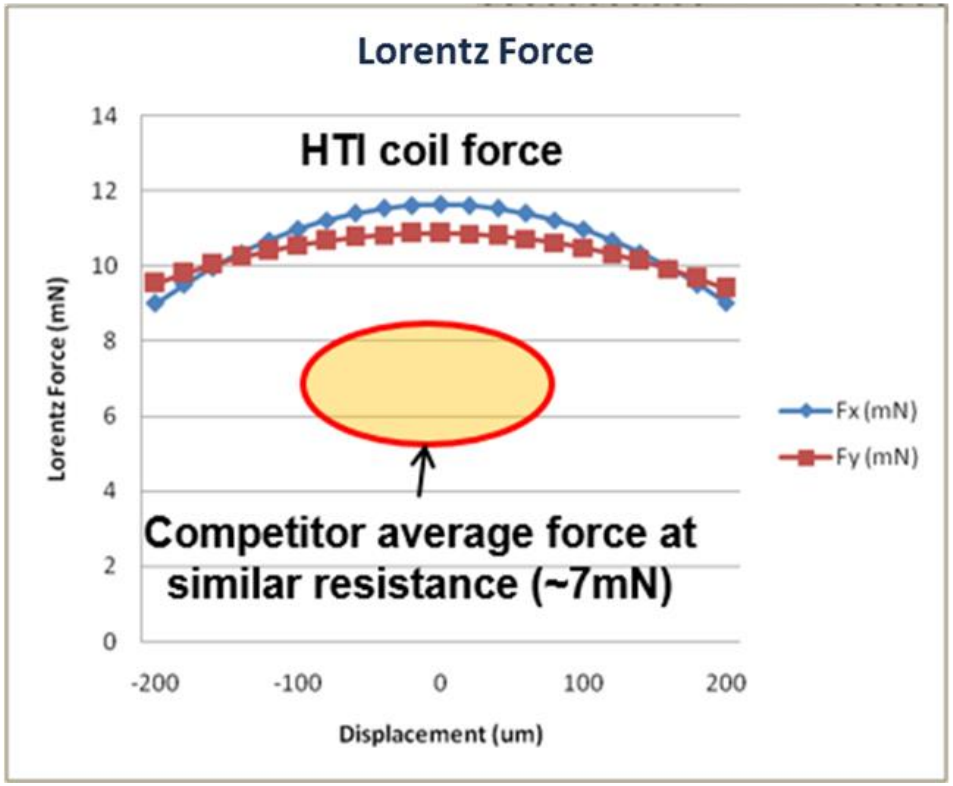
Automotive connectors, OEM component authenticators, remote sensors

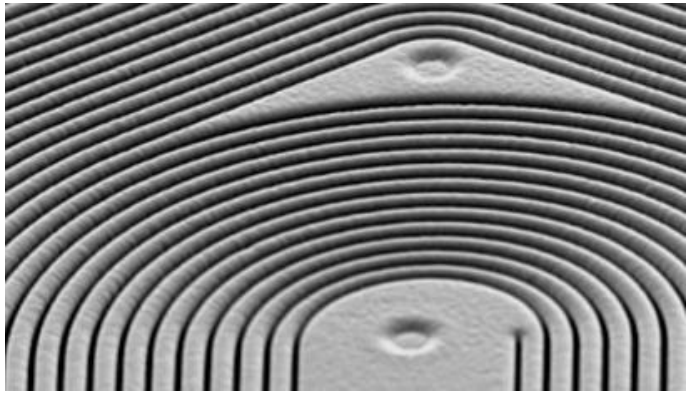
Section 1: Practical Examples for IoT

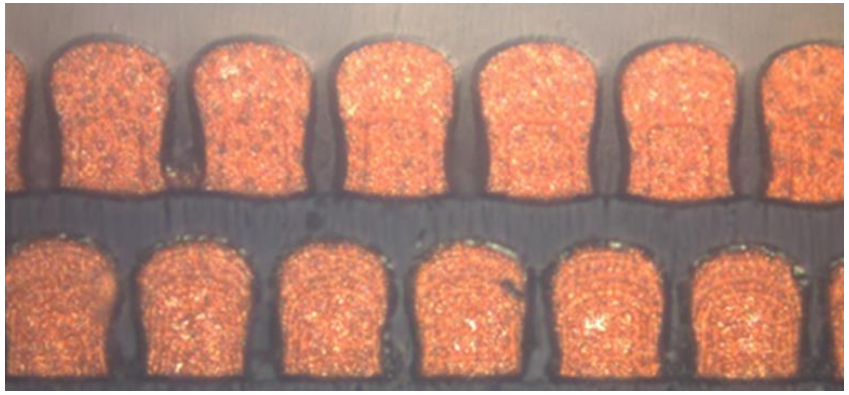
- 1.3: Actuators
  - ¬ **VCM Coils**
  - ¬ Piezoelectric Actuators
  - ¬ Shape Memory Alloy Actuators

Actuators: VCM Coils

- Advantages of High Density Copper Traces for VCM Coils
  - ¬ Higher force and lower power consumption than competition
  - ¬ High aspect ratio copper coil process increase coil turns while reducing coil resistance







Cross Section of a Two Layer Coil

Industry Leading Copper Cross Section Density!

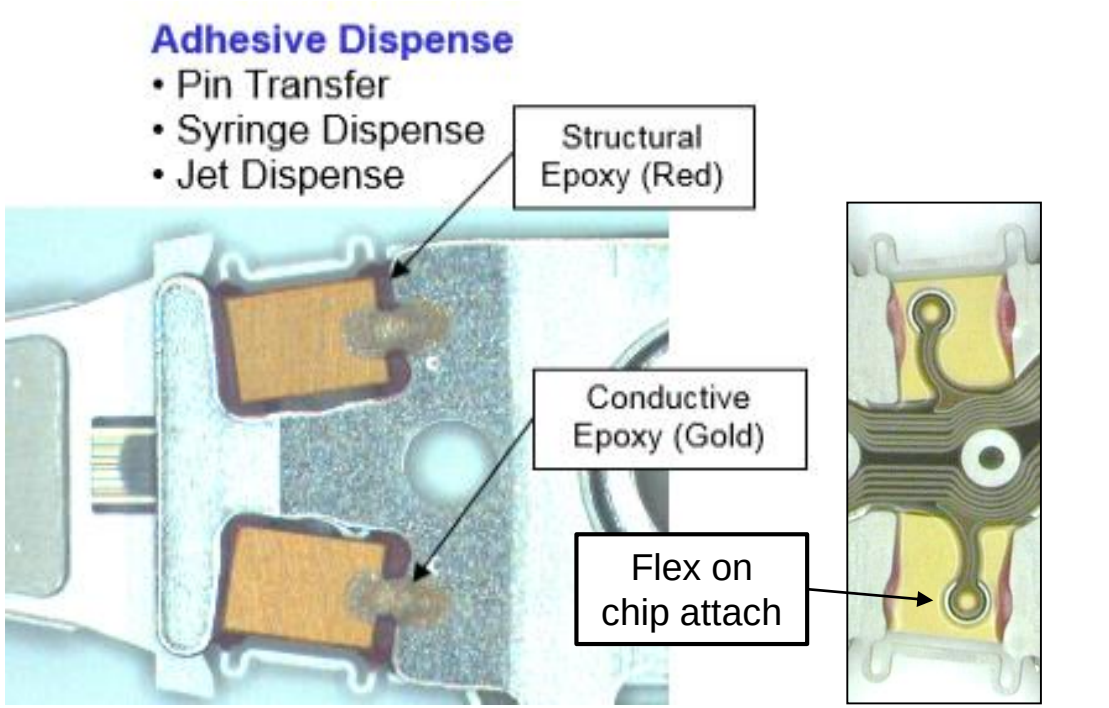
Section 1: Practical Examples for IoT

- 1.3: Actuators
  - ¬ VCM Coils
  - ¬ **Piezoelectric Actuators**
  - ¬ Shape Memory Alloy Actuators

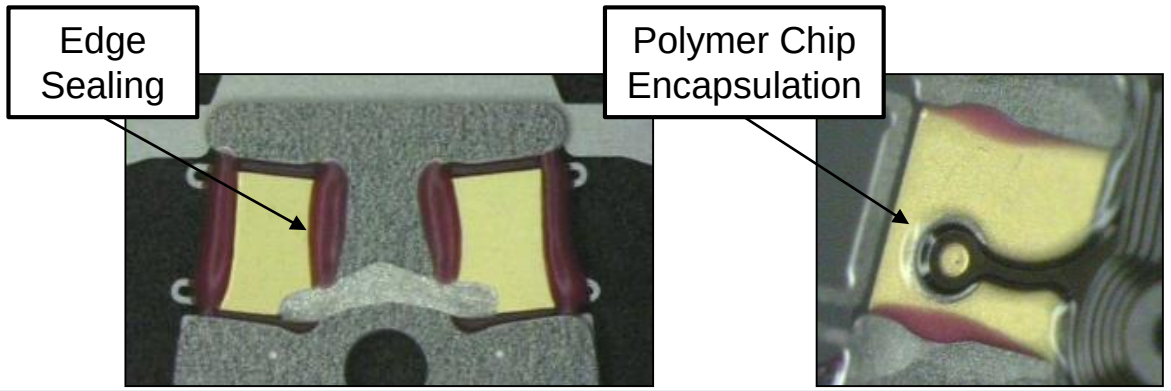
Actuators: Piezoelectric IoT Example

Addition of PZT turns the sensor package into a microactuator

- HDD suspension assembly
  - ¬ PZT motors provide fine positioning control for track following
  - ¬ Semi-additive process capability for die / SMT attach



Top View **Underside View**



Section 1: Practical Examples for IoT

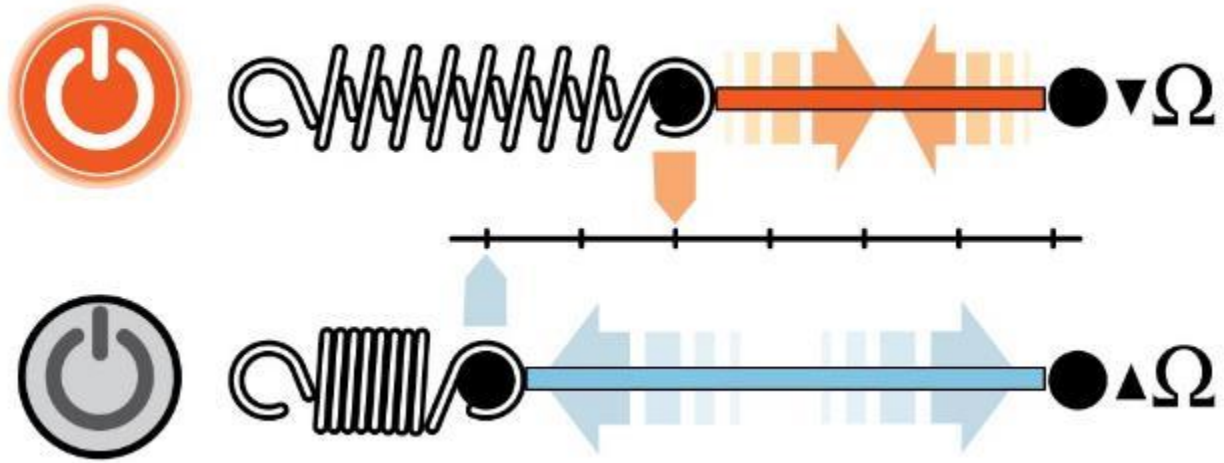
- 1.3: Actuators
  - ¬ VCM Coils
  - ¬ Piezoelectric Actuators
  - ¬ **Shape Memory Alloy Actuators**

SMA Actuators

- SMA Wire: "how it works"

SMA Actuation: SMA shrinks when heated and relaxes when cooled => Applying current heats wire inducing material structural change and creating movement.

SMA Position Detection: Shape change reduces electrical resistance. Measuring resistance (Ω) gives precision position feedback (wire length) to enable CLOSED LOOP control without position sensors.

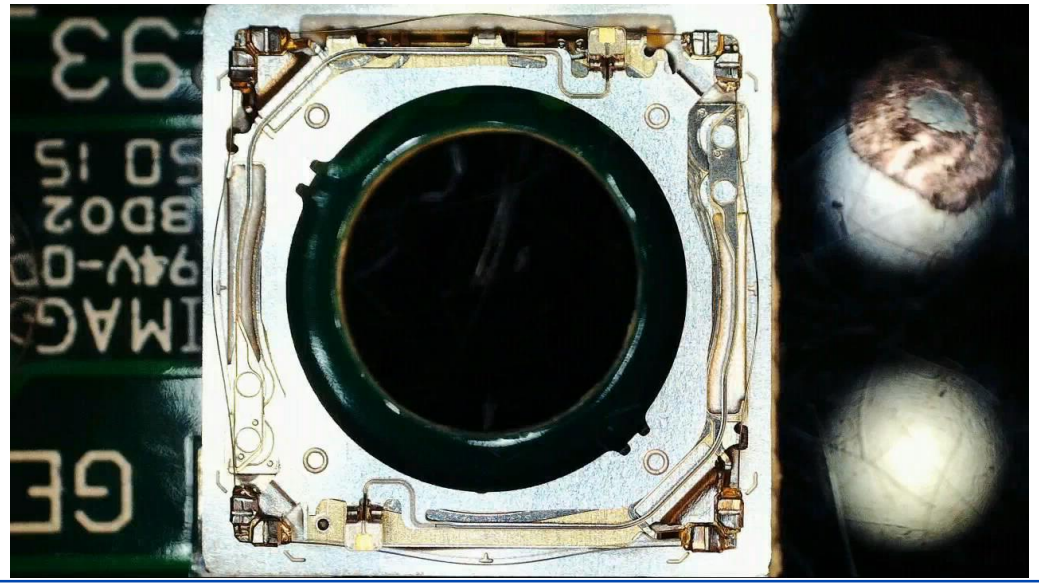


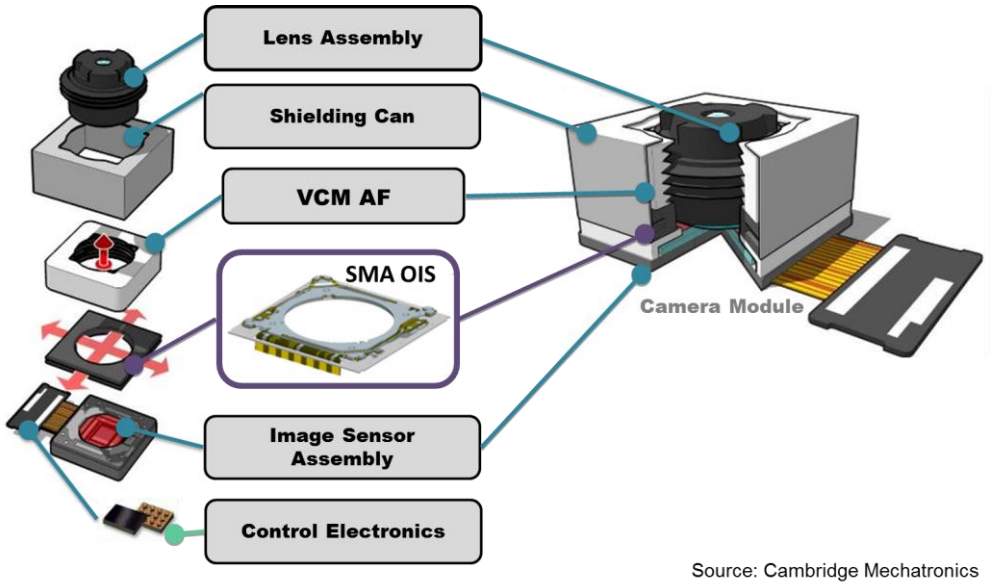
SMA Actuators

- SMA OIS (Shape Memory Alloy Optical Image Stabilization)

SMA Actuator Advantages:

- Resistance feedback for position detection
- Analog response (not binary on/off)
- Small footprint / minimal components
- Low power / higher force capability than VCM
- Potential for large mechanical advantage
- No magnets / coils – no magnetic interference

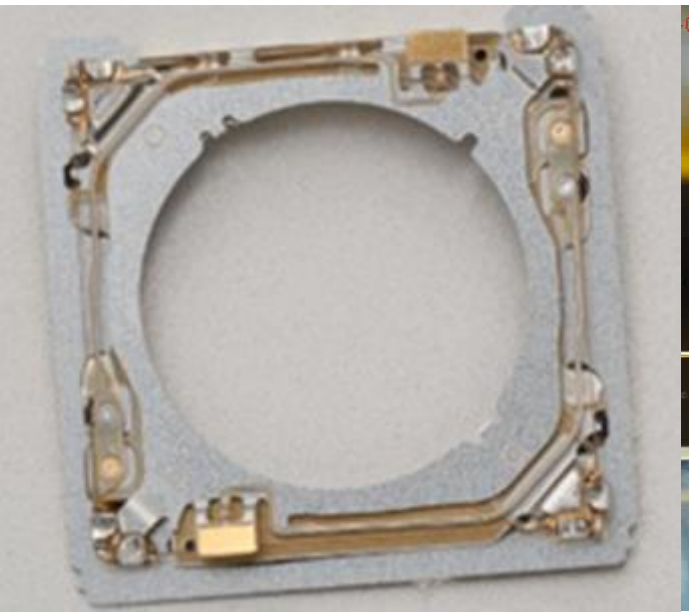


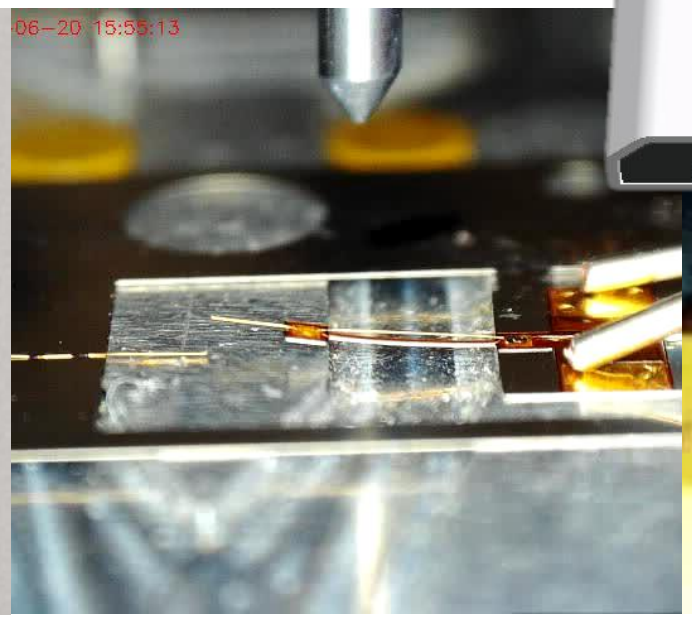


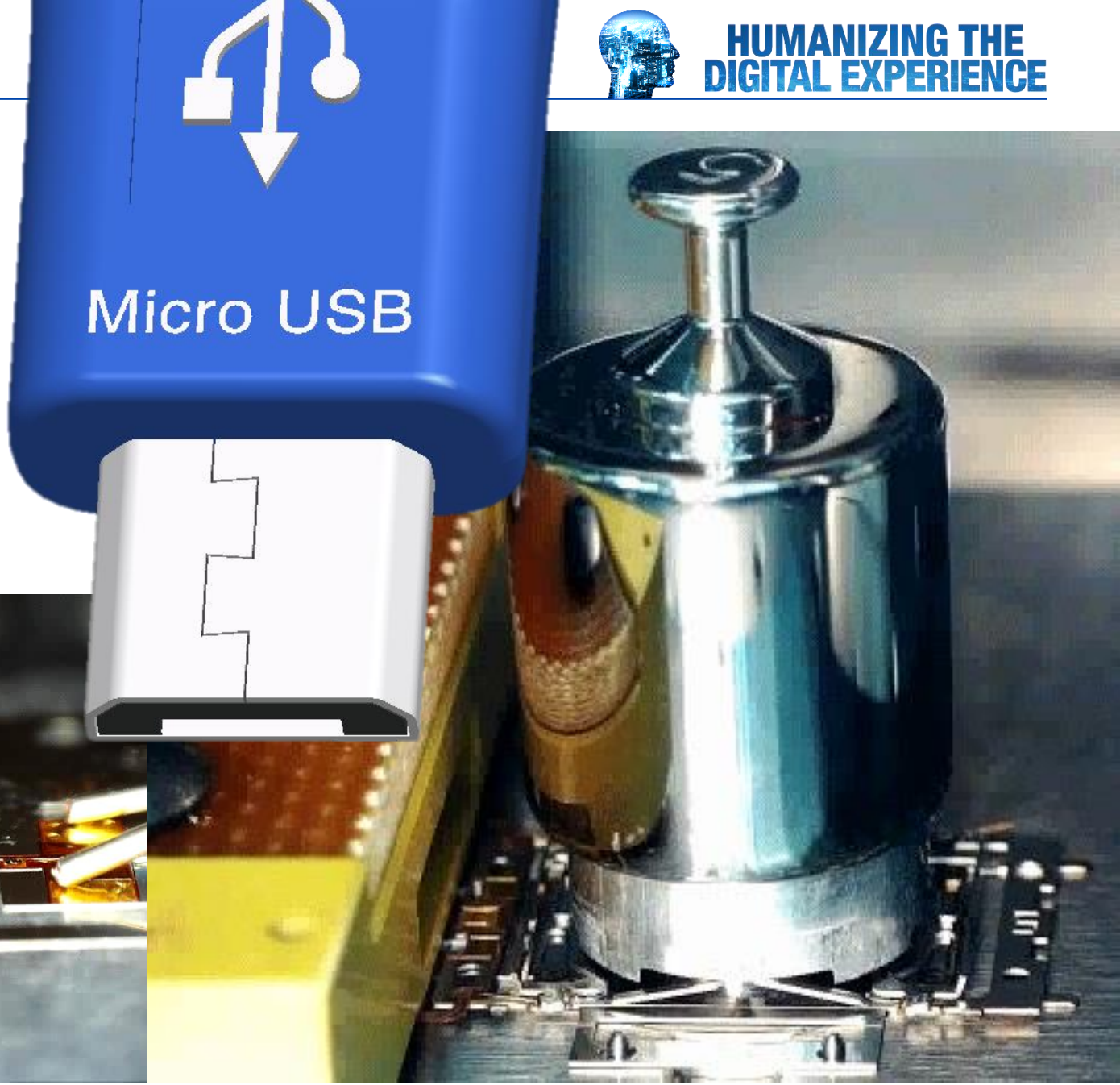
Source: Cambridge Mechatronics

SMA Actuators

- Actuator Configurations:
  - ¬ In-line Single Axis X or Dual Axis X-Y Actuation
    - Wire orientation in same direction as travel
  - ¬ 90 Degree Actuation
    - X wire orientation converted to Z actuation
    - Linkage design can amplify either force or stroke
  - ¬ Bimorph Actuation
    - Wire constriction results in flexing actuation

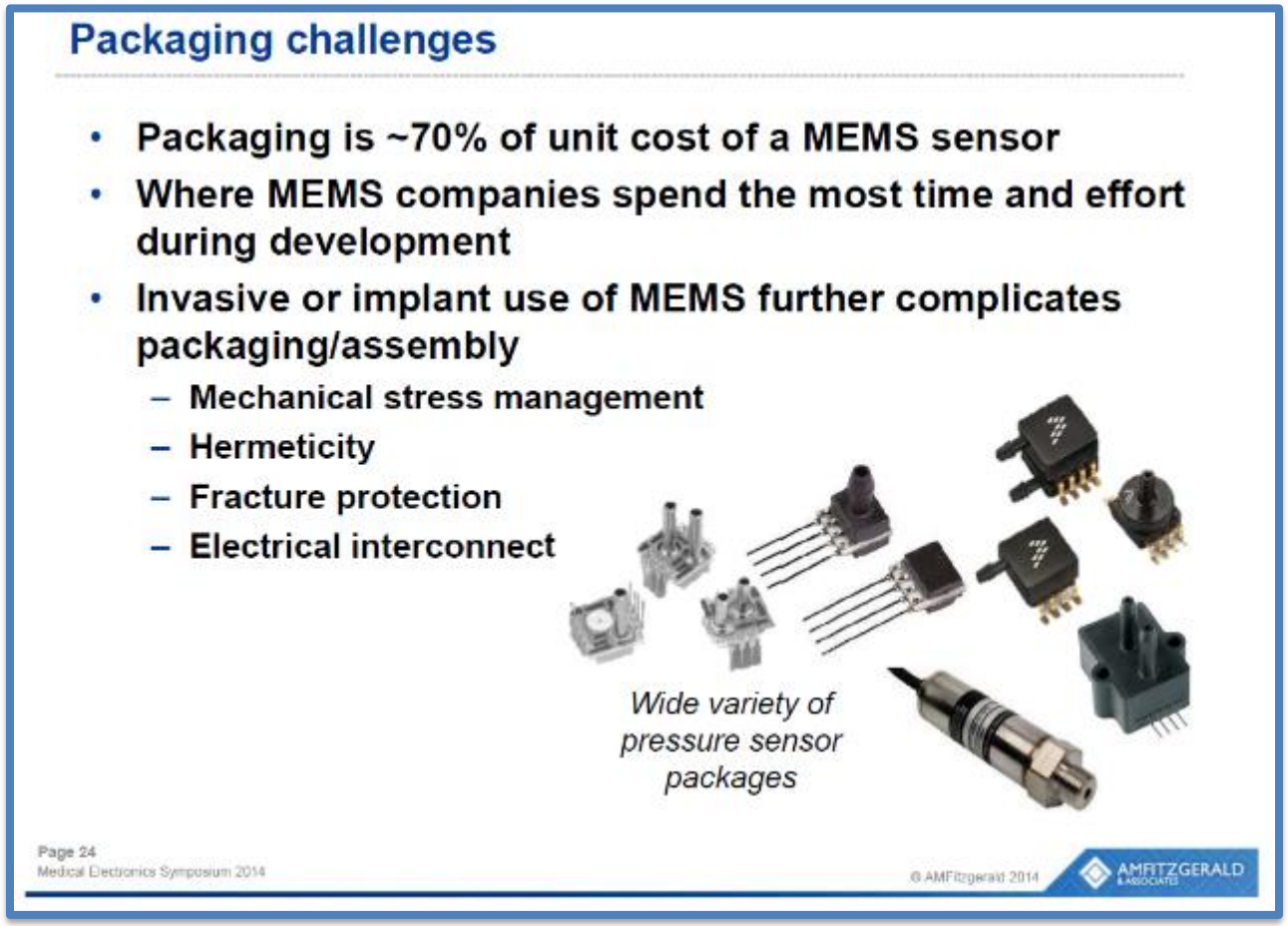






Section 1: Practical Examples for IoT

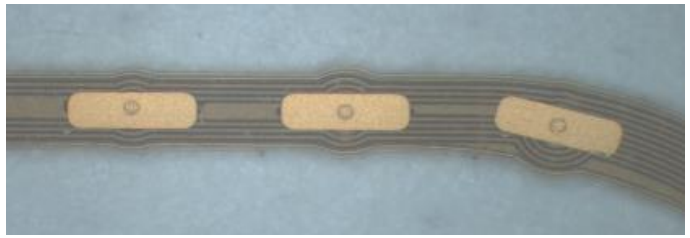
- 1.4: Advanced Packaging



Source: AMFITZGERALD

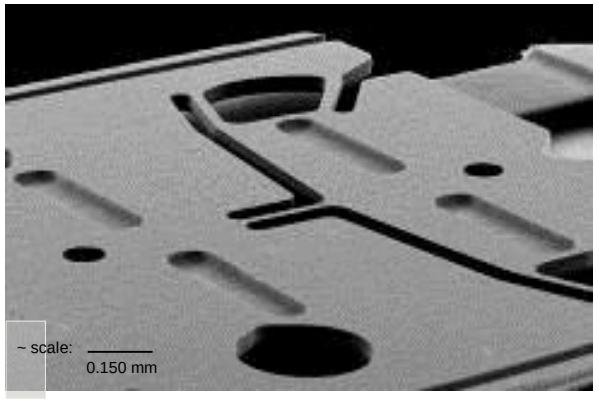
- ***Package can be more than environmental shielding and electrical connection***
- ***Integrated sensors and actuators can be included into the package***
- ***Incorporate cantilevers, wells, struts, springs and other mechanical features into the package***

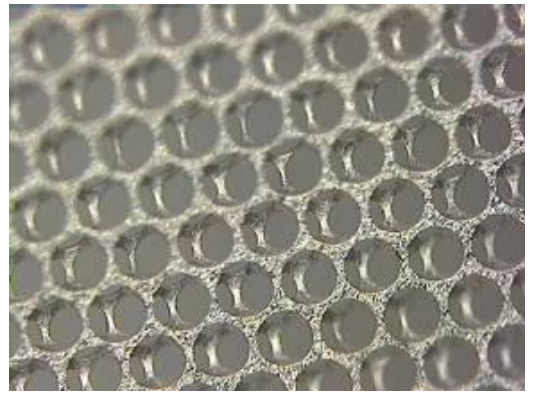
Advanced Packaging Examples

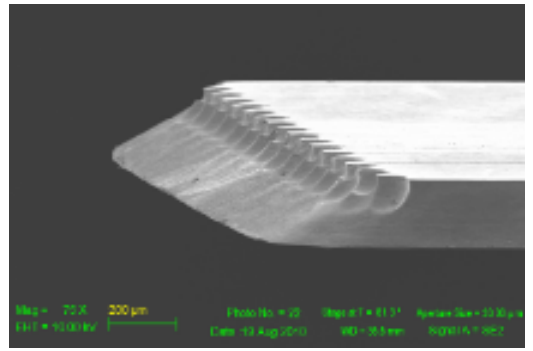


Circuitry on Superelastic Nitinol

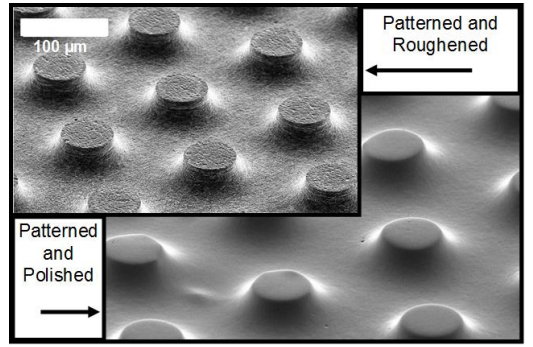
- ***Multi-layer Circuitry***

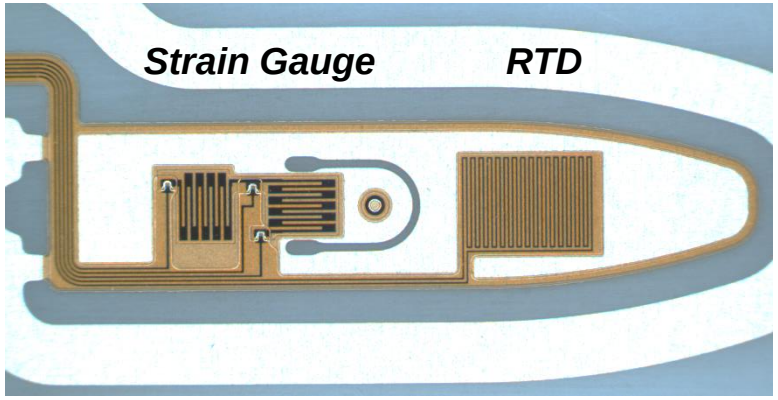


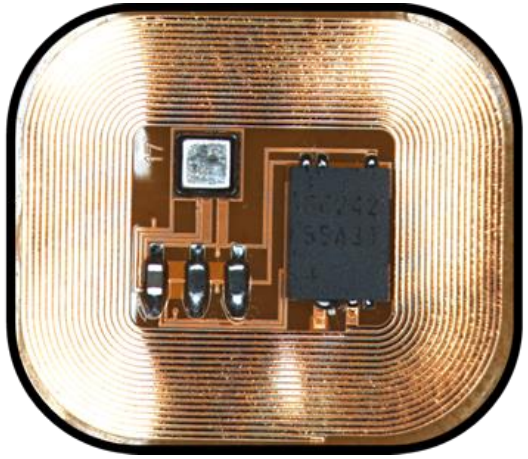




- ***Precision Etched Structures***







- ***Integrated Analog Sensors & SMT Assembly***

Section 2:
Overview of the Semi-Additive ‘toolkit’

What is Semi-Additive Processing?

Subtractive

Start with a laminate of a thin layer of circuit material and etch each layer

- ✗ Circuit material choices
- ✗ Interlayer connections
- ✗ Multiple circuit layers
- ✗ Substrate material choices

Semi- Additive

Photoimage insulator, **sputter deposit seedlayer**

Electroplate circuit and remove seedlayer

- ✓ Number of features
- ✓ Circuit material choices
- ✓ Adhesion
- ✓ Fine line/space
- ✓ Interlayer connections
- ✓ Multiple circuit layers
- ✓ Substrate material choices

Additive

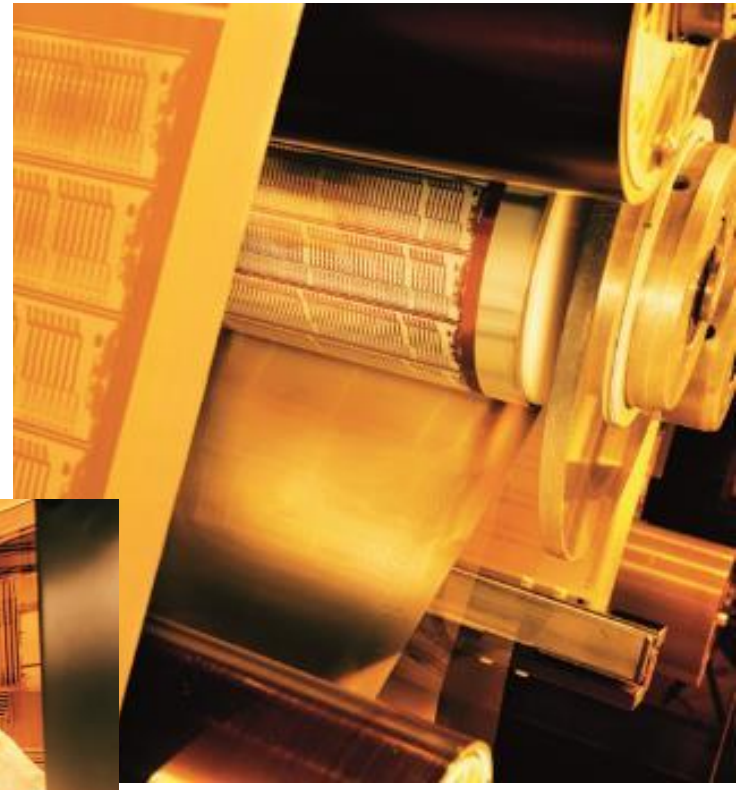
Ink-jet, screen print, etc. and cure

- ✗ Number of features
- ✗ Circuit material choices
- ✗ Adhesion
- ✗ Fine line/space

Advantages of Roll to Roll Semi-Additive Processing

- Low Cost Enabler
  - ¬ Parts per roll can exceed 1 million
  - ¬ Continuous flow processes
    - ○ Very few batch or step and repeat steps

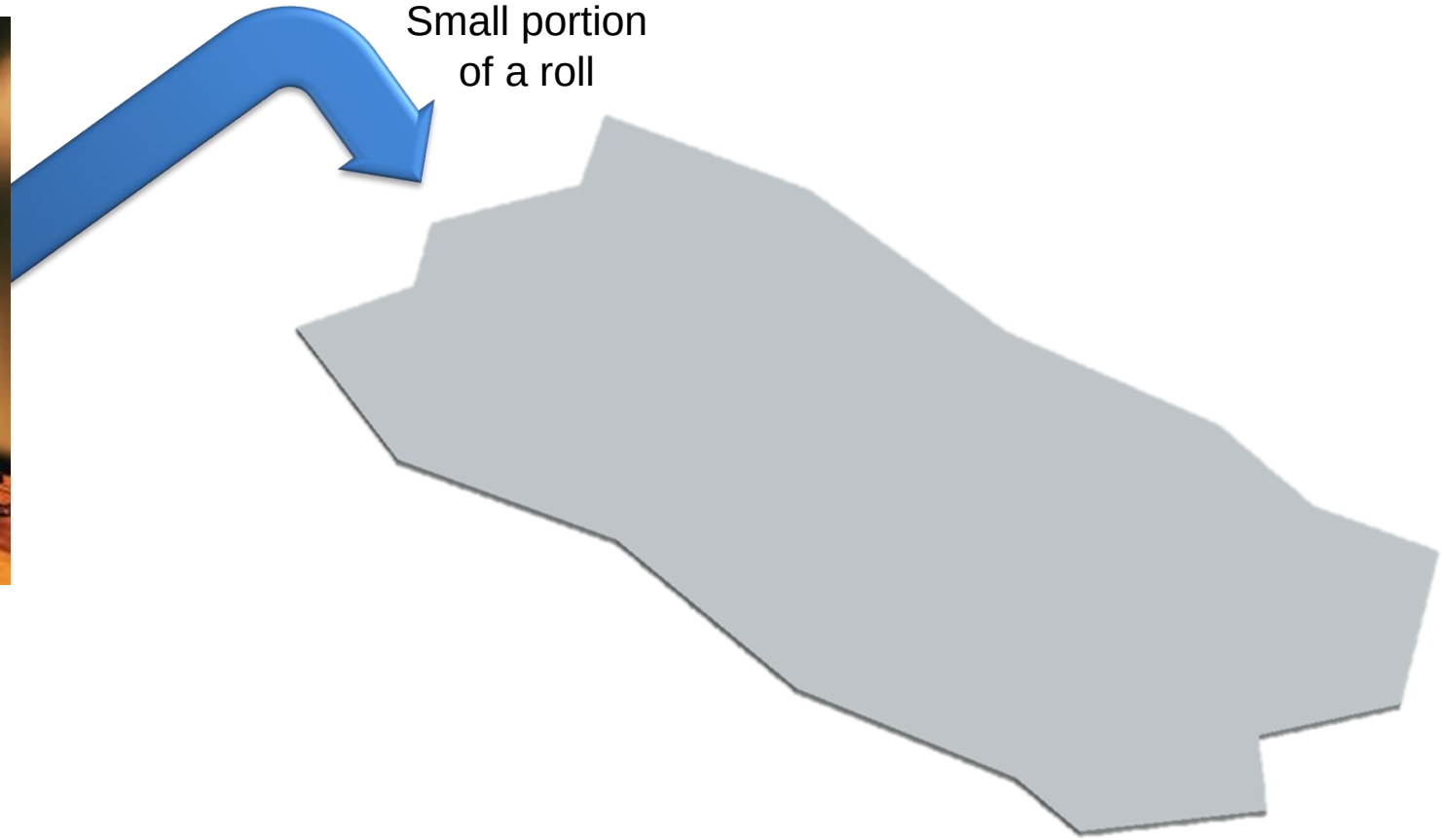
- Versatile / Customizable
  - ¬ Accommodates a wide variety of polymer or metal substrates
  - ¬ Metallizing steps can be tailored to specific needs



- ✓ Number of features
- ✓ Circuit material choices
- ✓ Substrate material choices
- ✓ Thin film material choices
- ✓ Adhesion
- ✓ Fine line/space
- ✓ Interlayer connections
- ✓ Multiple circuit layers

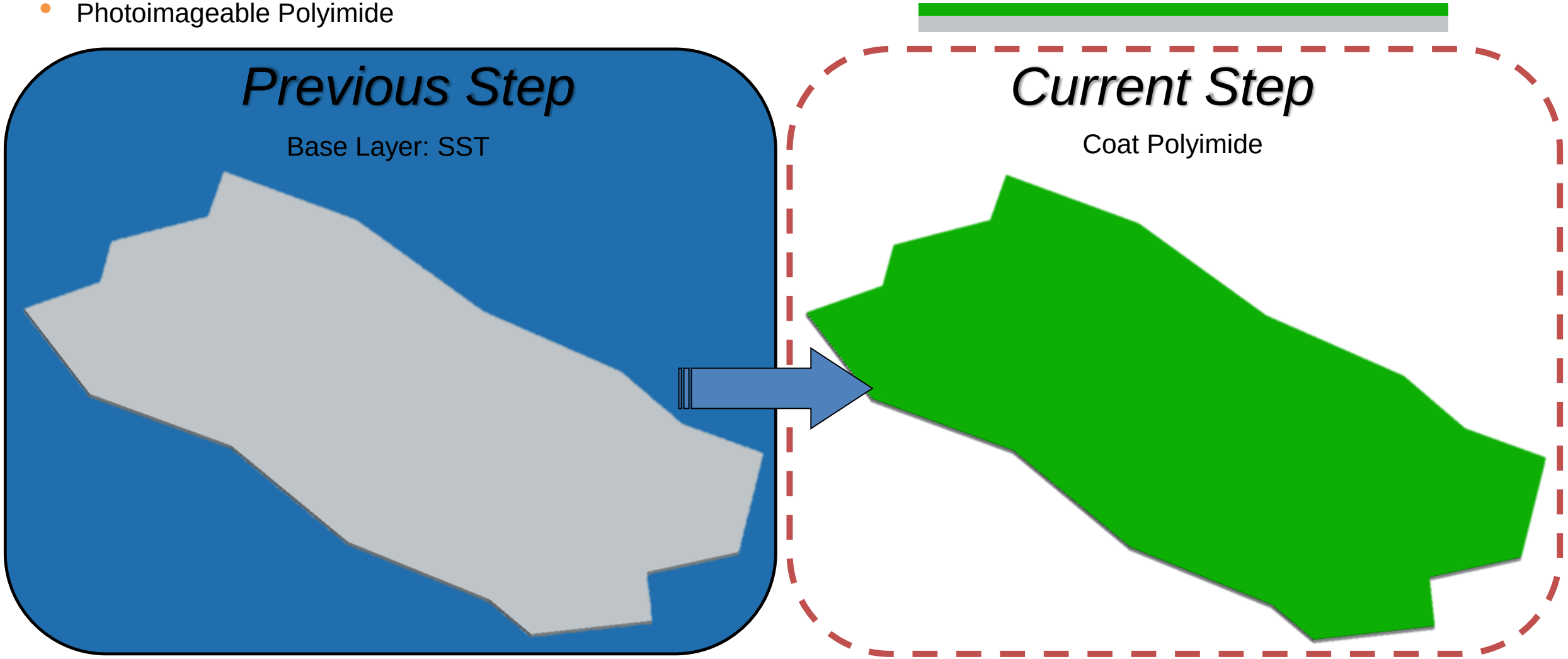
Semi-Additive Process Flow Example

- Base Layer: 50um Thick Stainless Steel



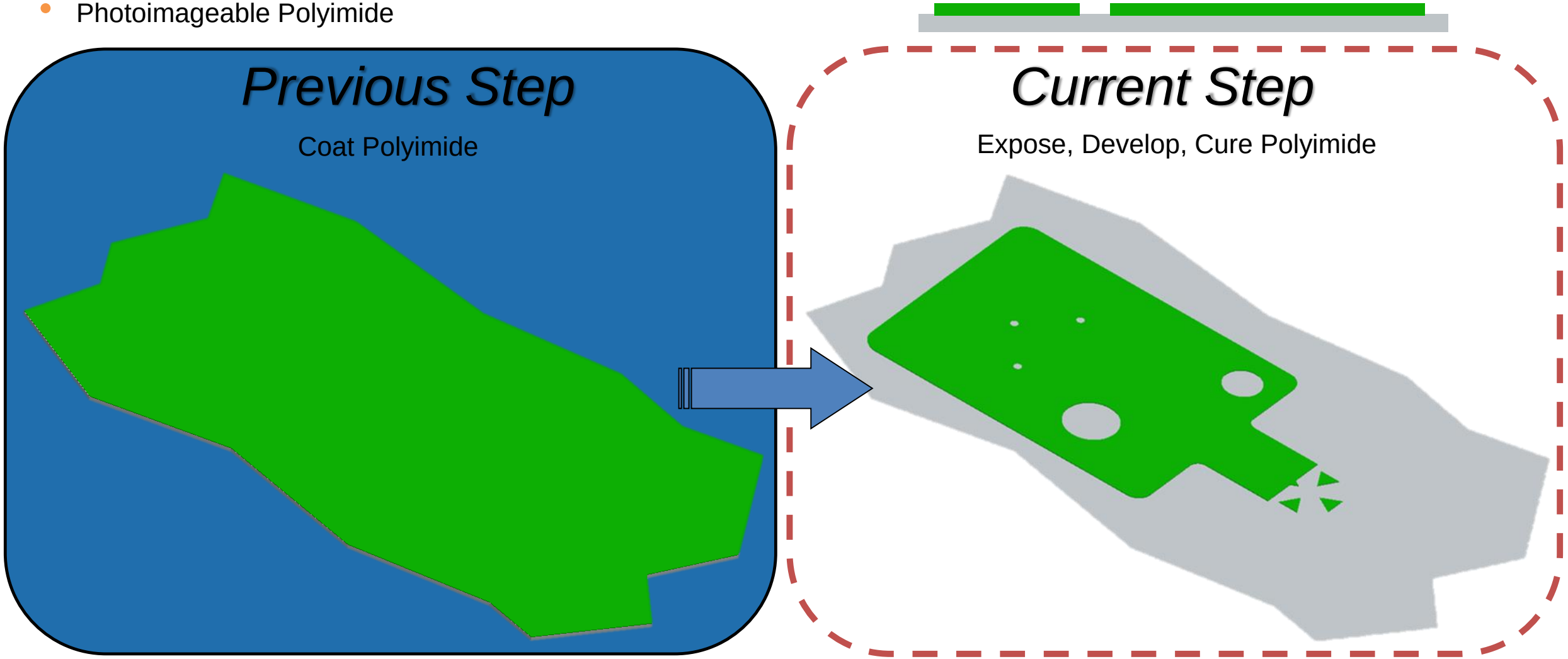
Semi-Additive Process Flow Example

- Photoimageable Polyimide



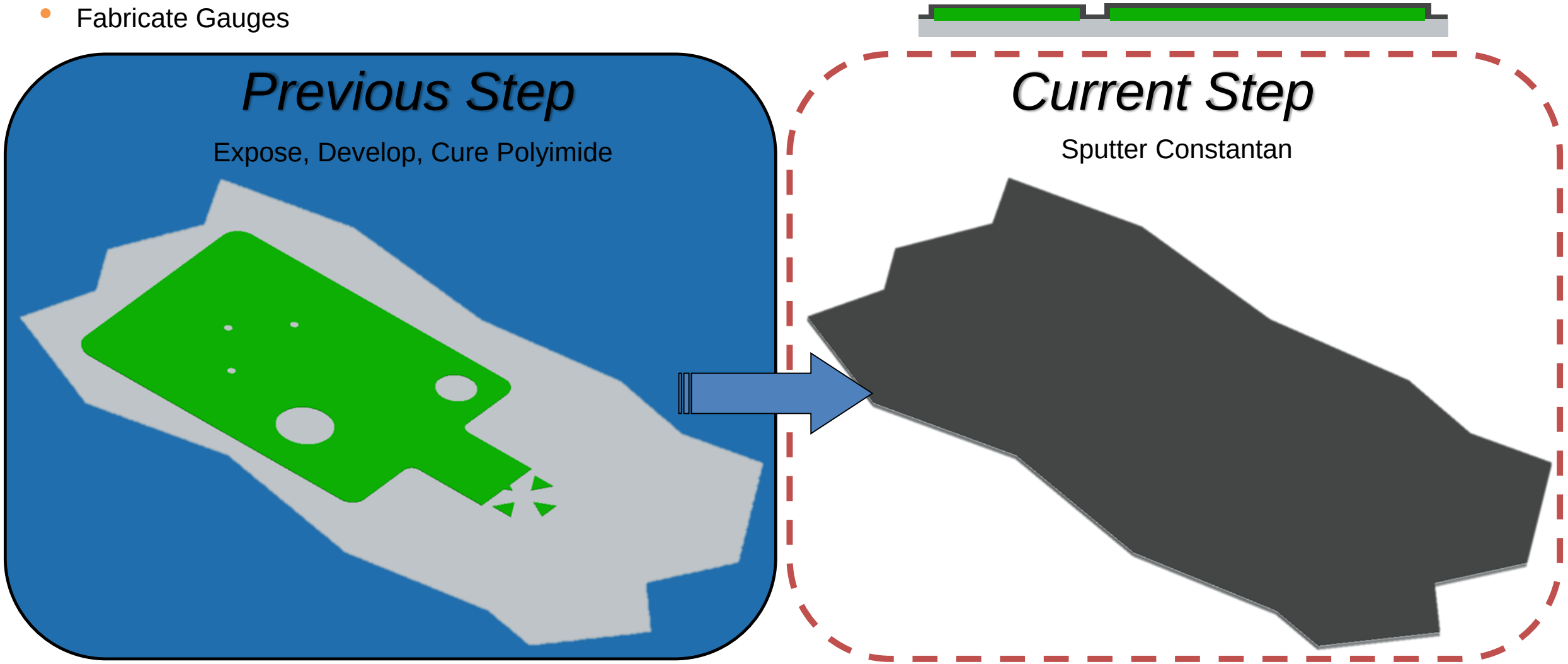
Semi-Additive Process Flow Example

- Photoimageable Polyimide



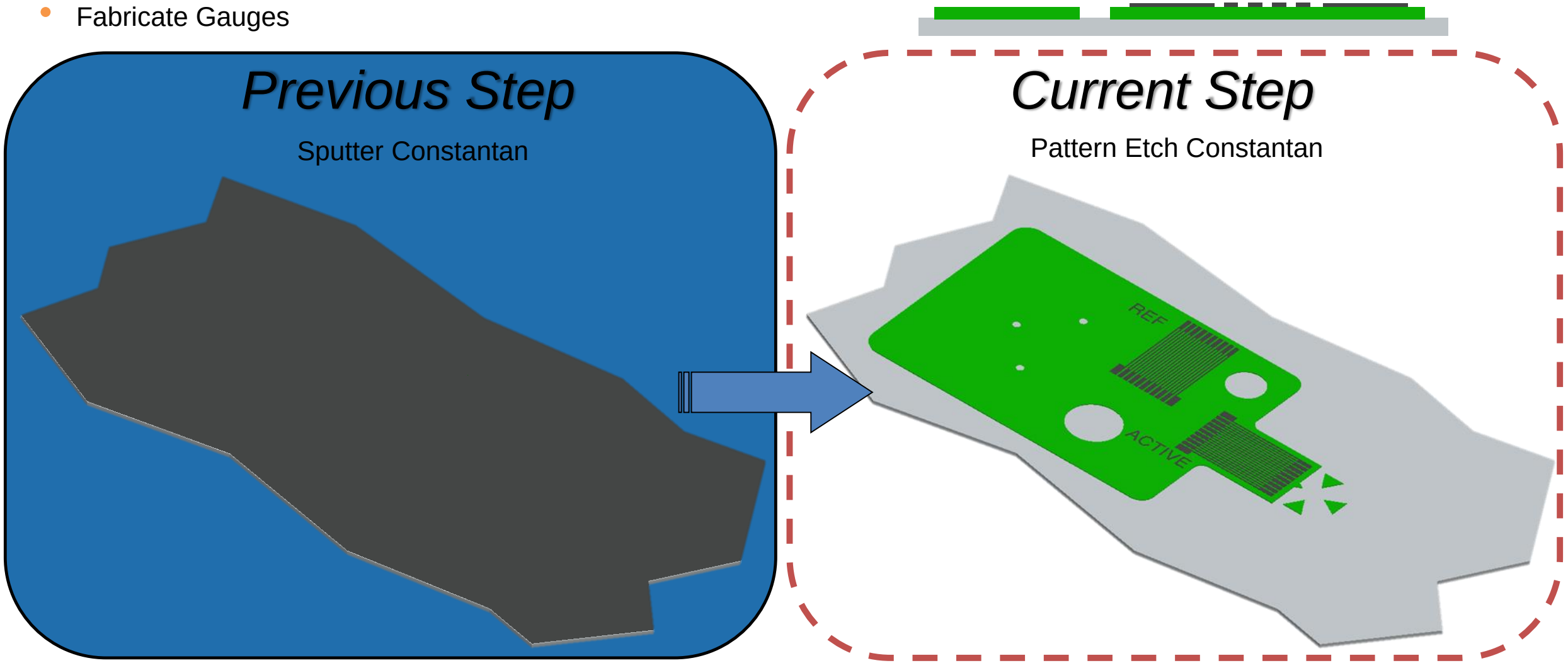
Semi-Additive Process Flow Example

- Fabricate Gauges



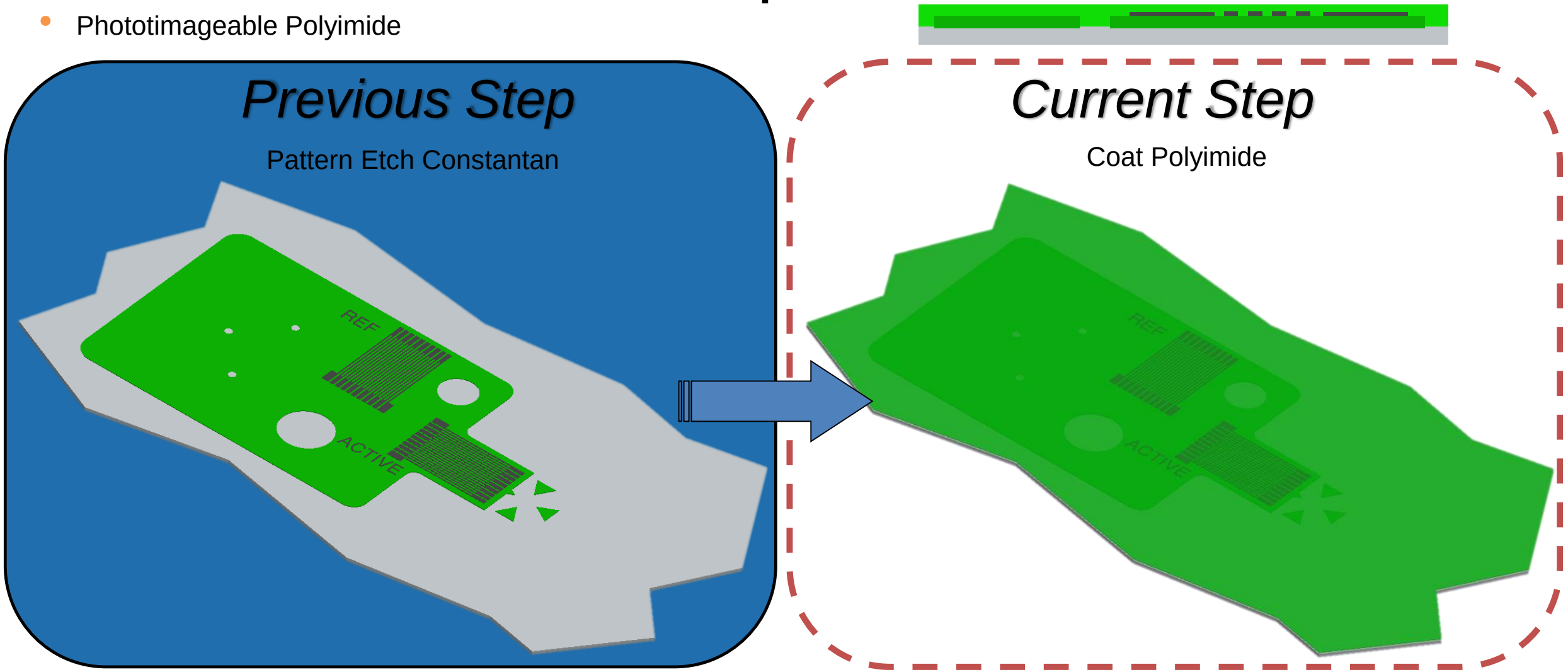
Semi-Additive Process Flow Example

- Fabricate Gauges



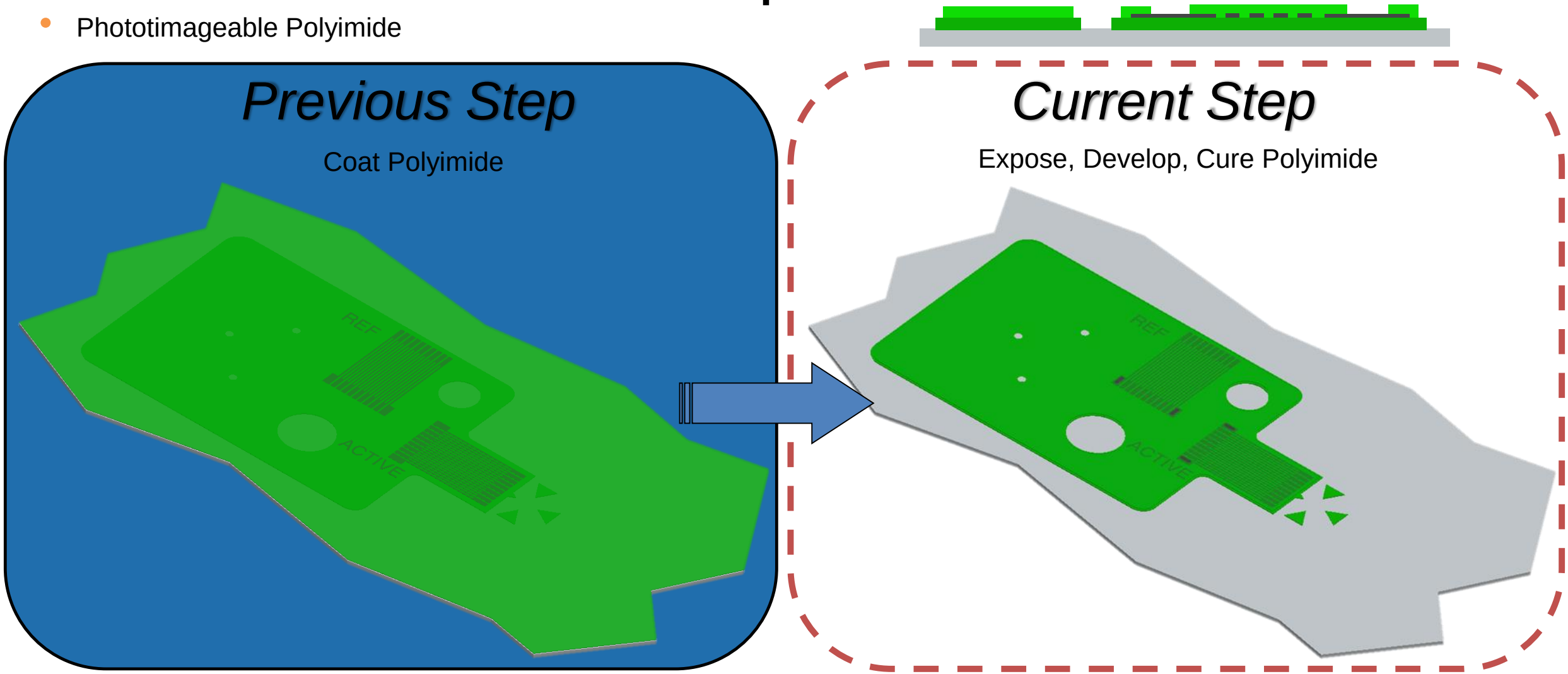
Semi-Additive Process Flow Example

- Phototimageable Polyimide



Semi-Additive Process Flow Example

- Phototimageable Polyimide

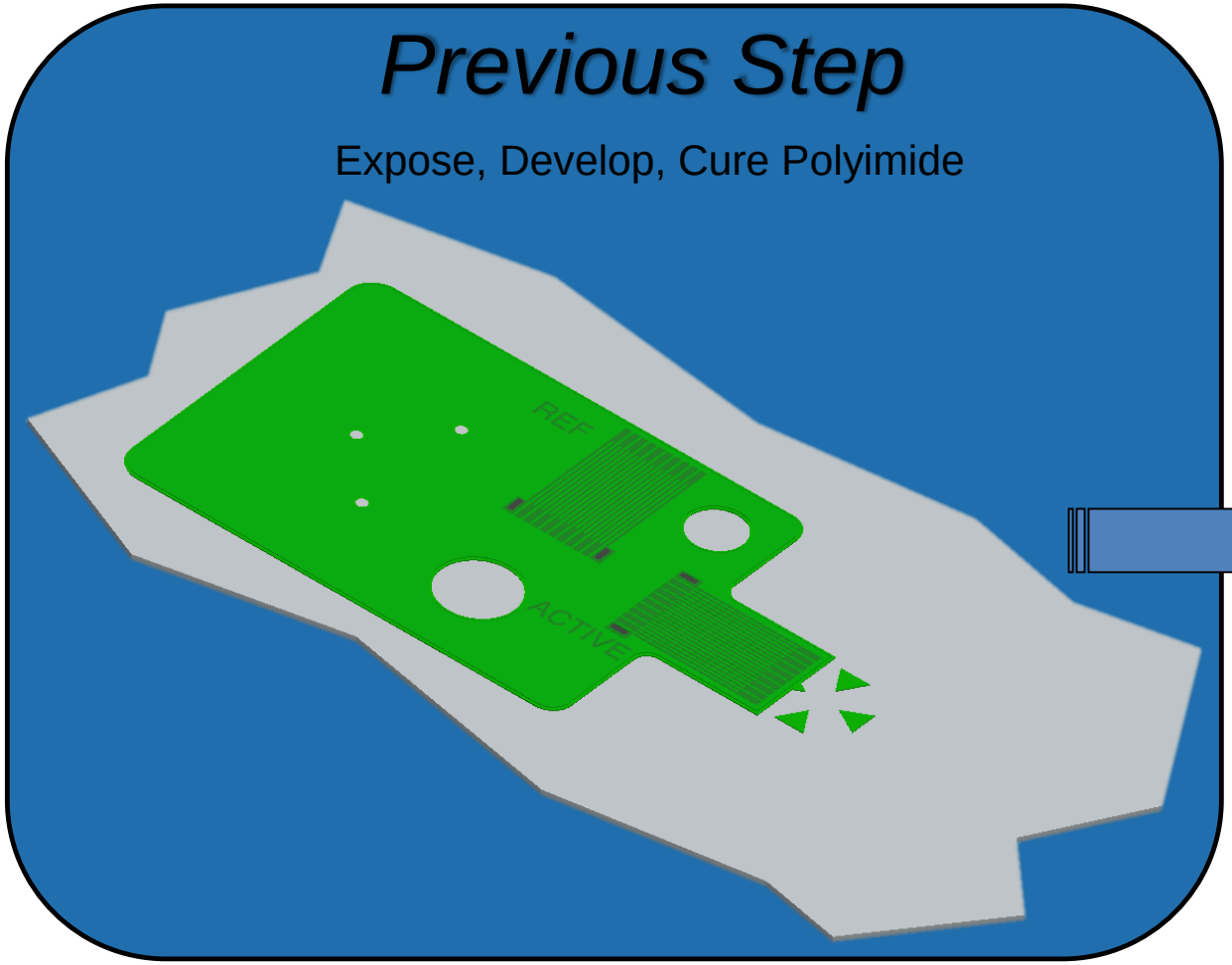


Semi-Additive Process Flow Example

- Fabricate Circuitry

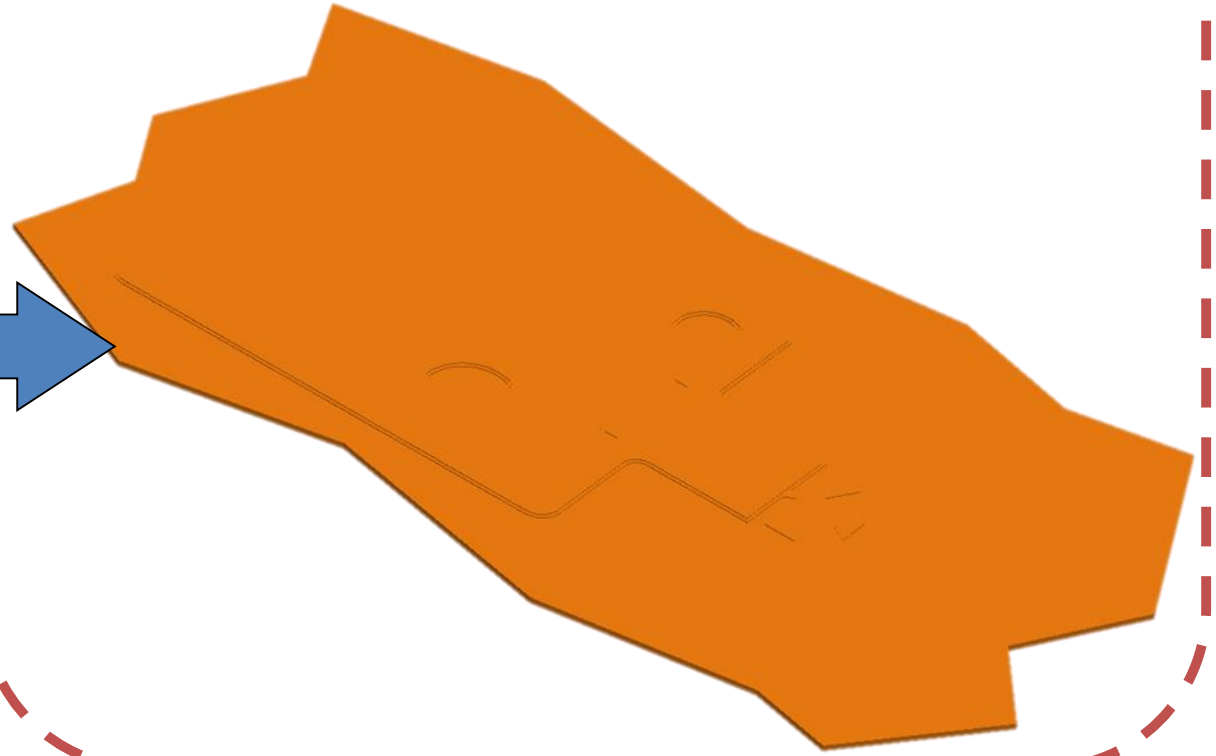
Previous Step

Expose, Develop, Cure Polyimide



Current Step

Sputter Circuit Seed Layer

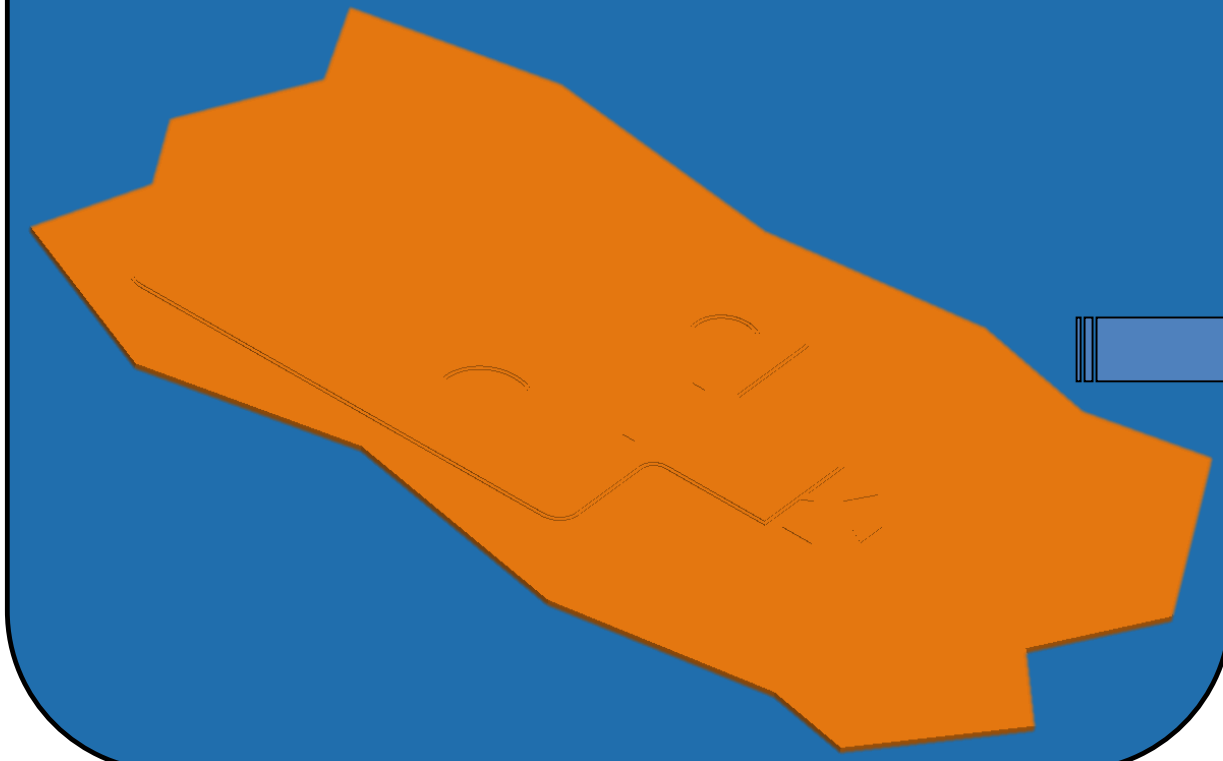


Semi-Additive Process Flow Example

- Fabricate Circuitry

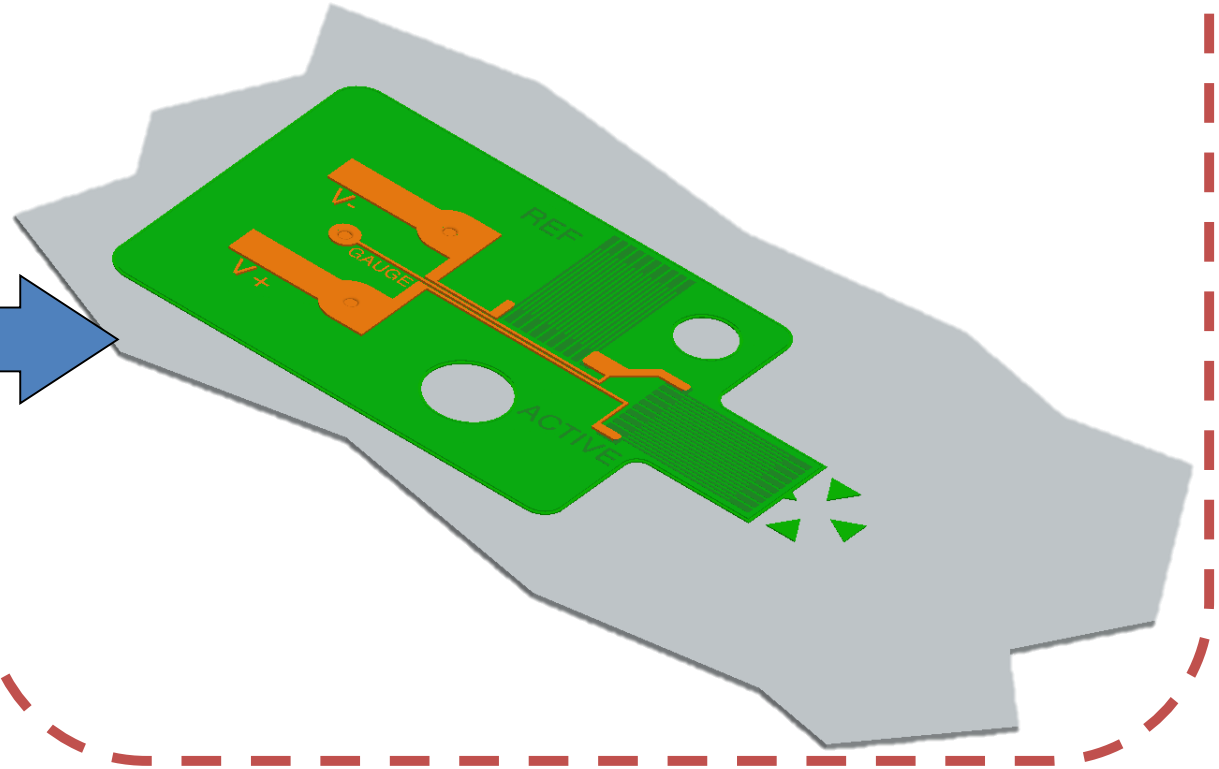
Previous Step

Sputter Circuit Seed Layer



Current Step

Pattern Plate Circuit & Micro Etch Seed Layer

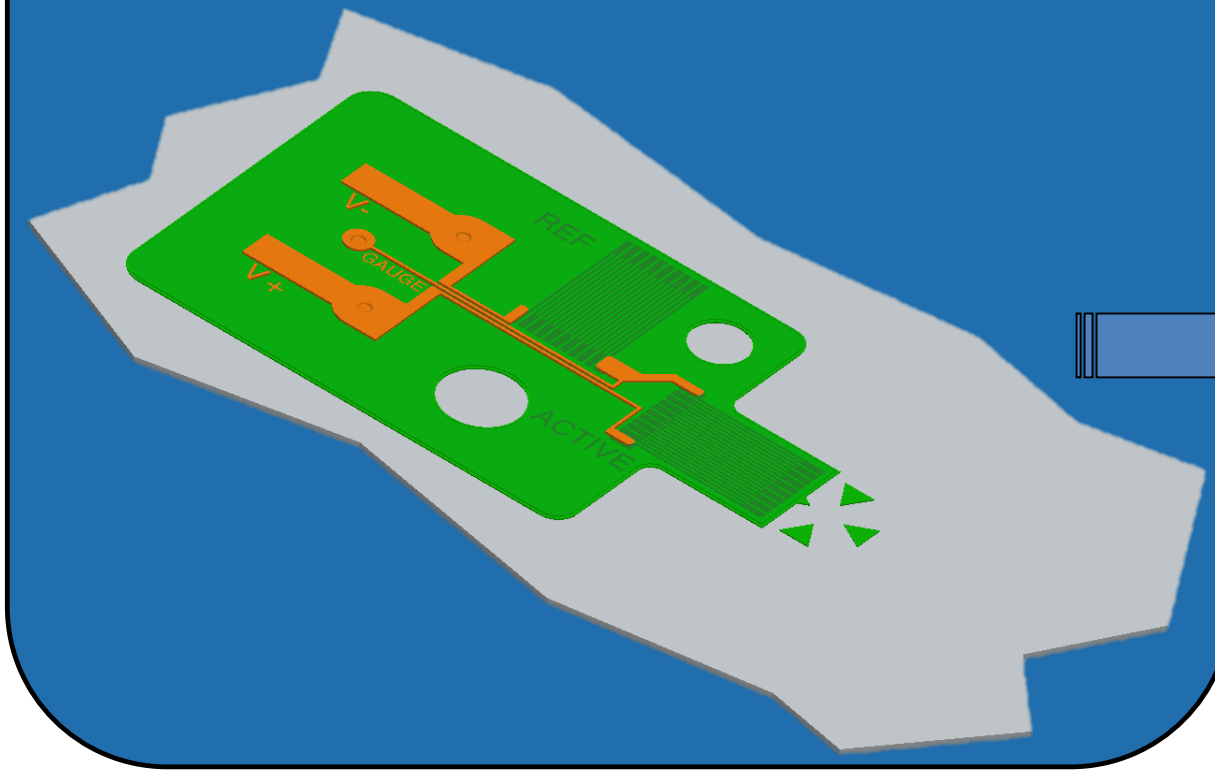


Semi-Additive Process Flow Example

- Photoimageable Polyimide

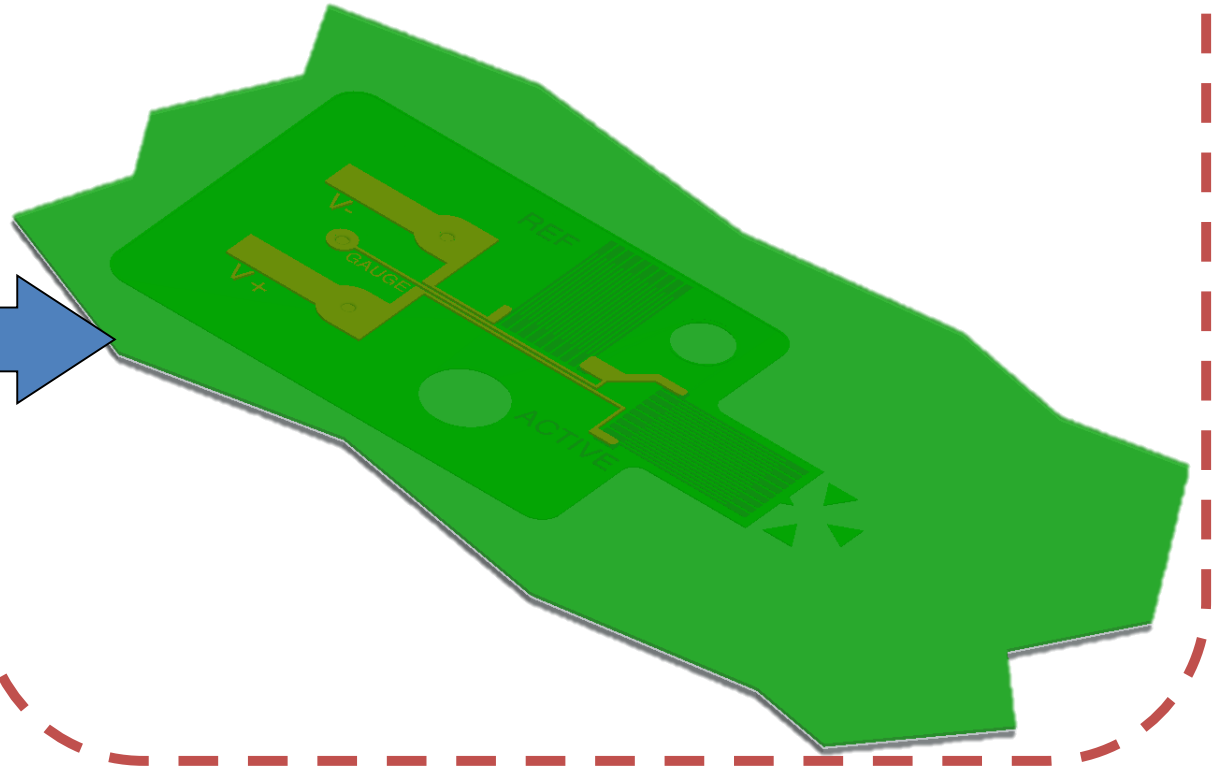
Previous Step

Pattern Plate Circuit & Micro Etch Seed Layer



Current Step

Coat Polyimide

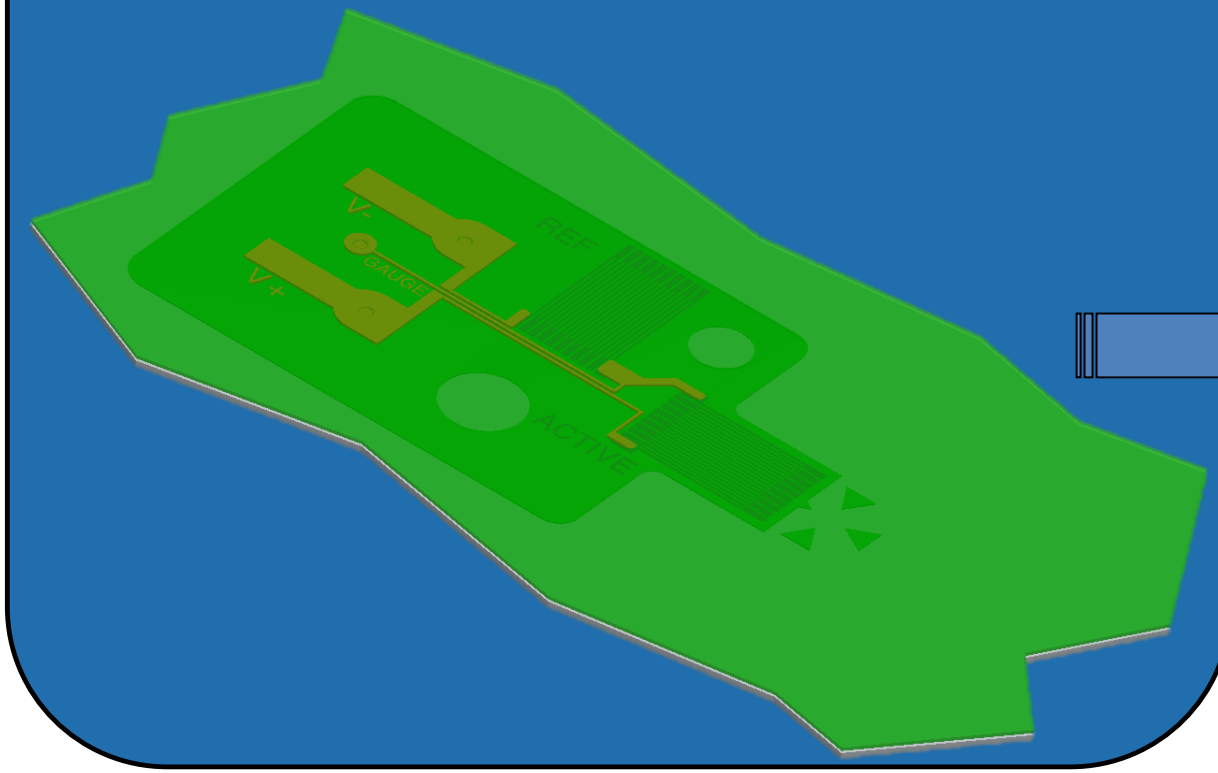


Semi-Additive Process Flow Example

- Photoimageable Polyimide

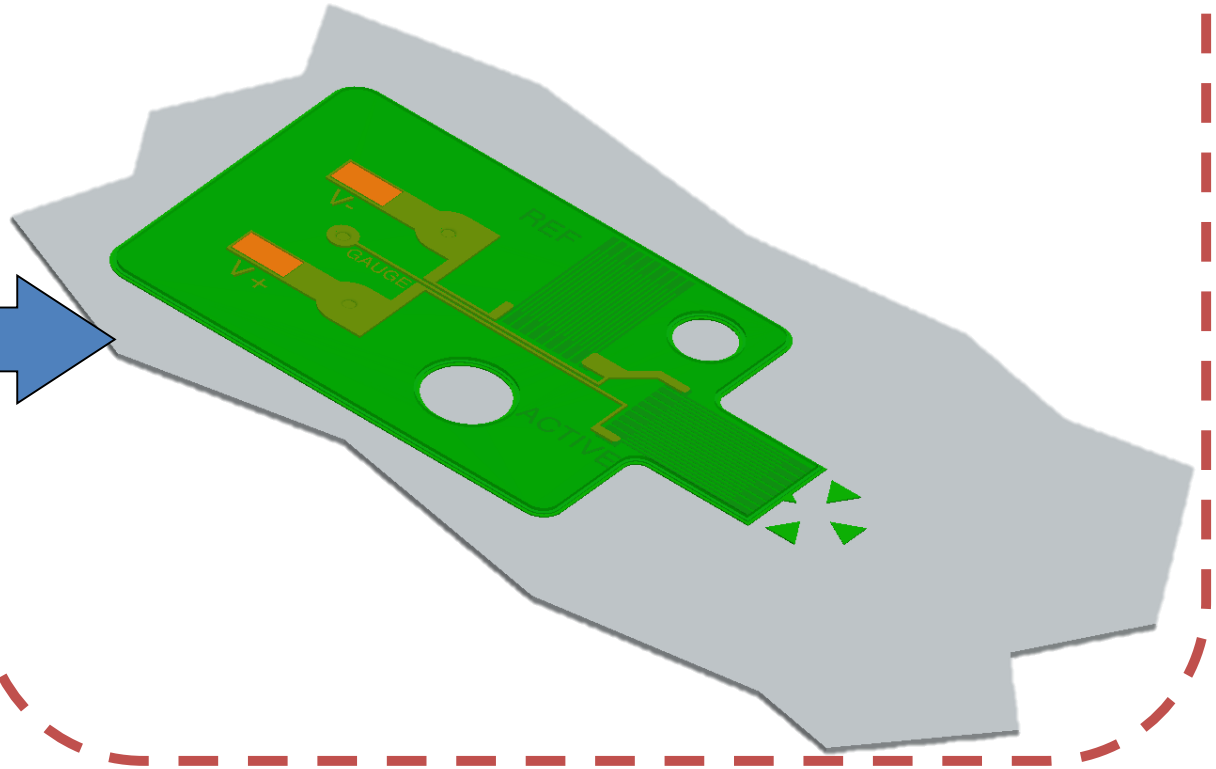
Previous Step

Coat Polyimide



Current Step

Expose, Develop, Cure Polyimide

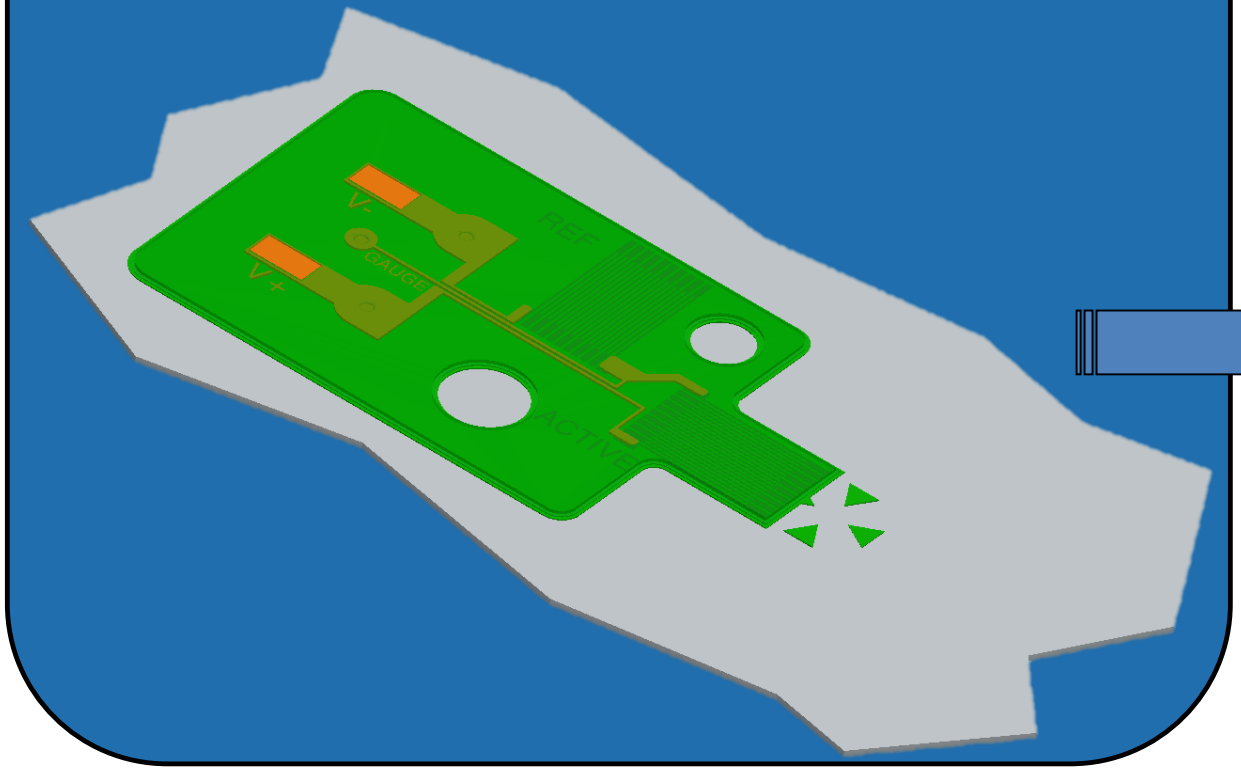


Semi-Additive Process Flow Example

- Gold Plate Copper Pads

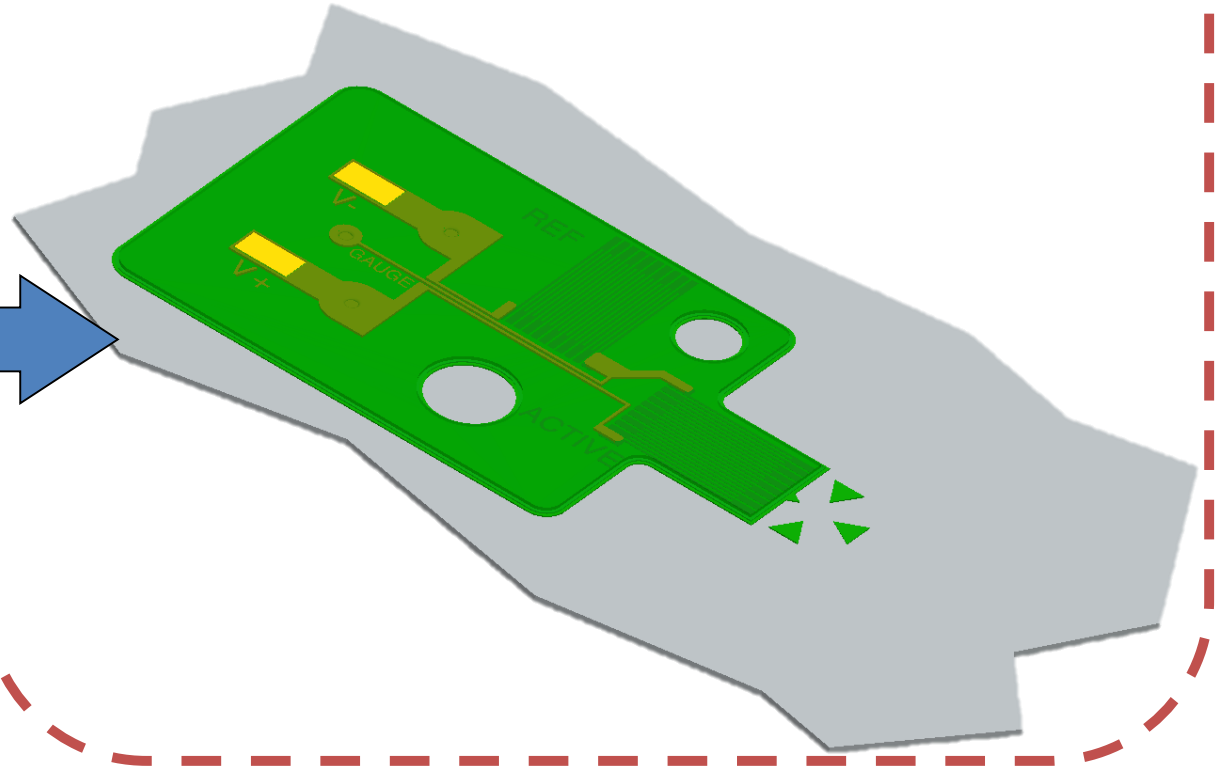
Previous Step

Expose, Develop, Cure Polyimide



Current Step

Gold Plate Copper Pads

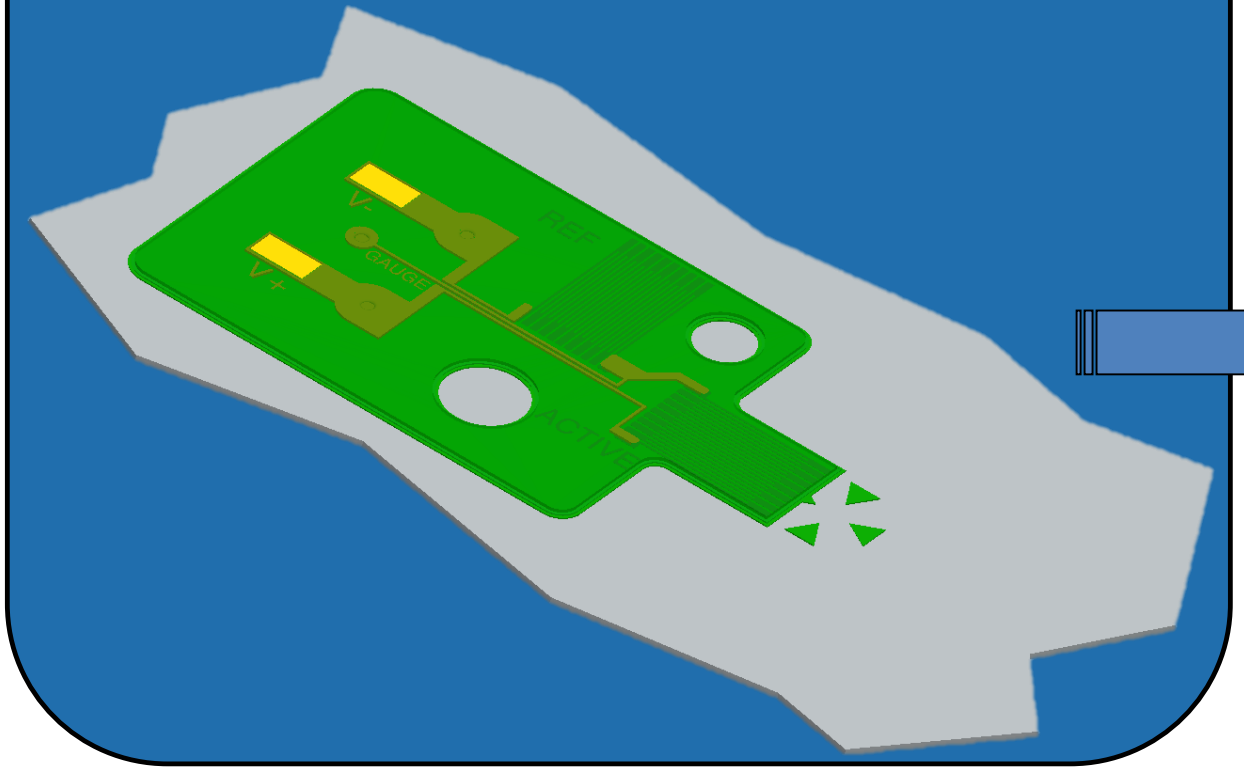


Semi-Additive Process Flow Example

- Gold Plate Pads onto Backside Stainless Steel

Previous Step

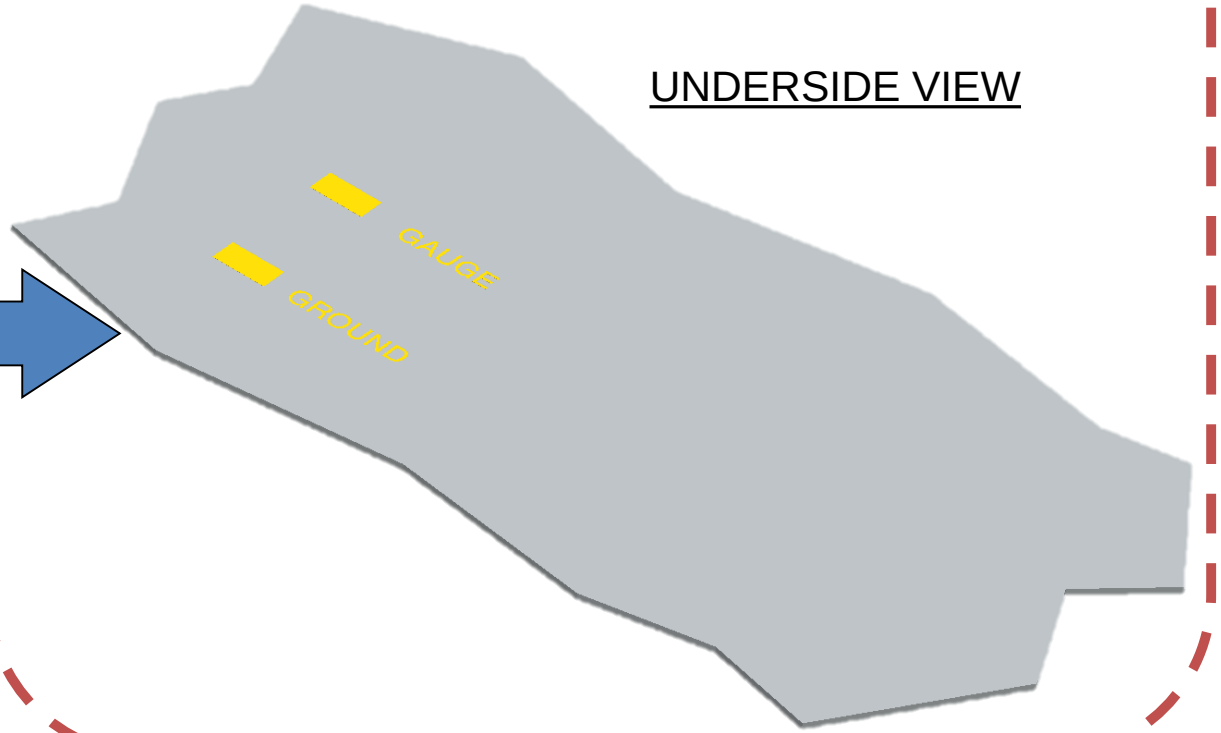
Gold Plate Copper Pads



Current Step

Gold Plate Pads on Backside Stainless Steel

UNDERSIDE VIEW

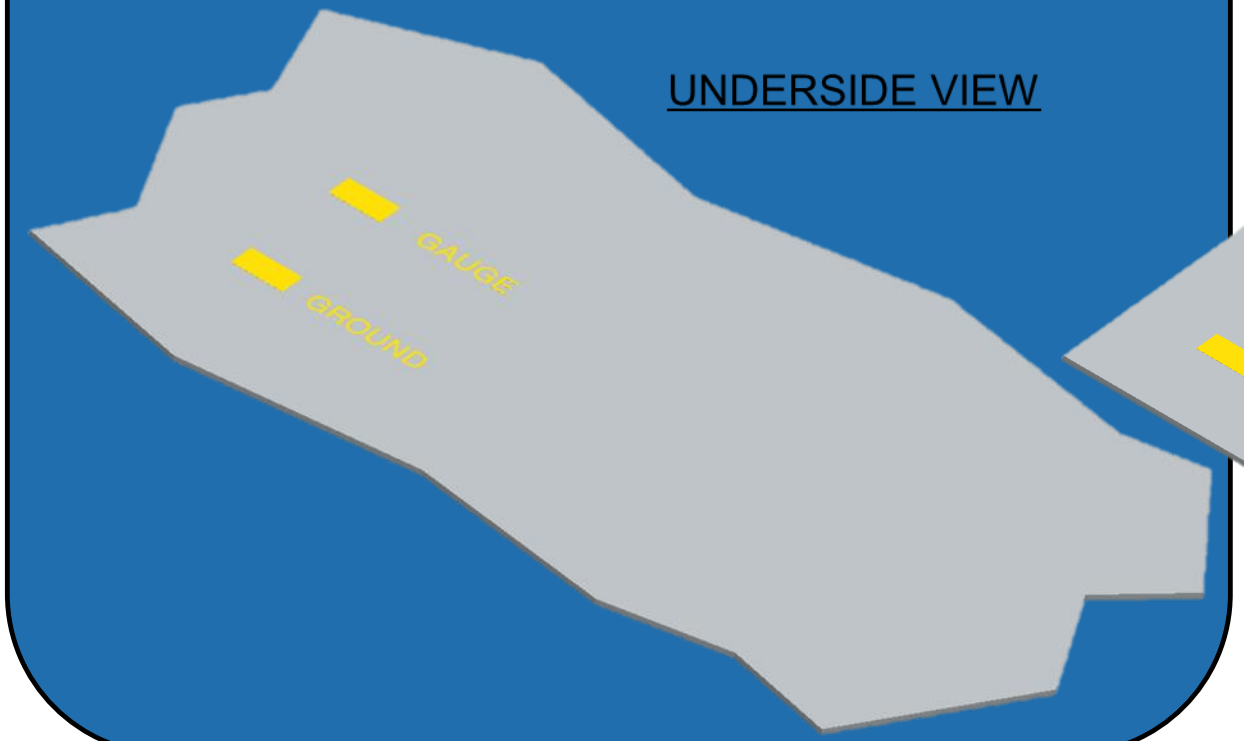


Semi-Additive Process Flow Example

- Stainless Steel Etch

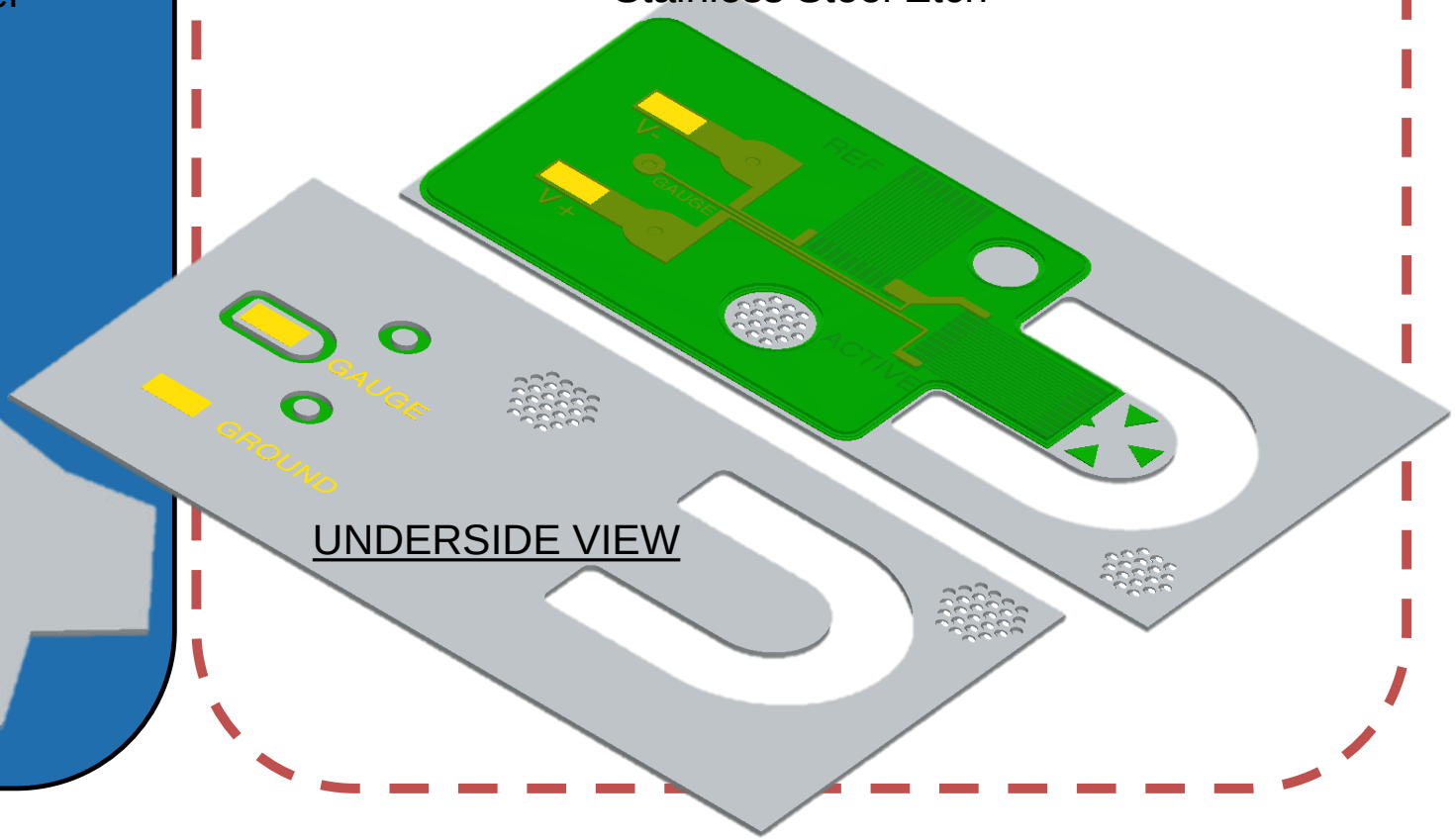
Previous Step

Gold Plate Pads on Backside of Stainless Steel



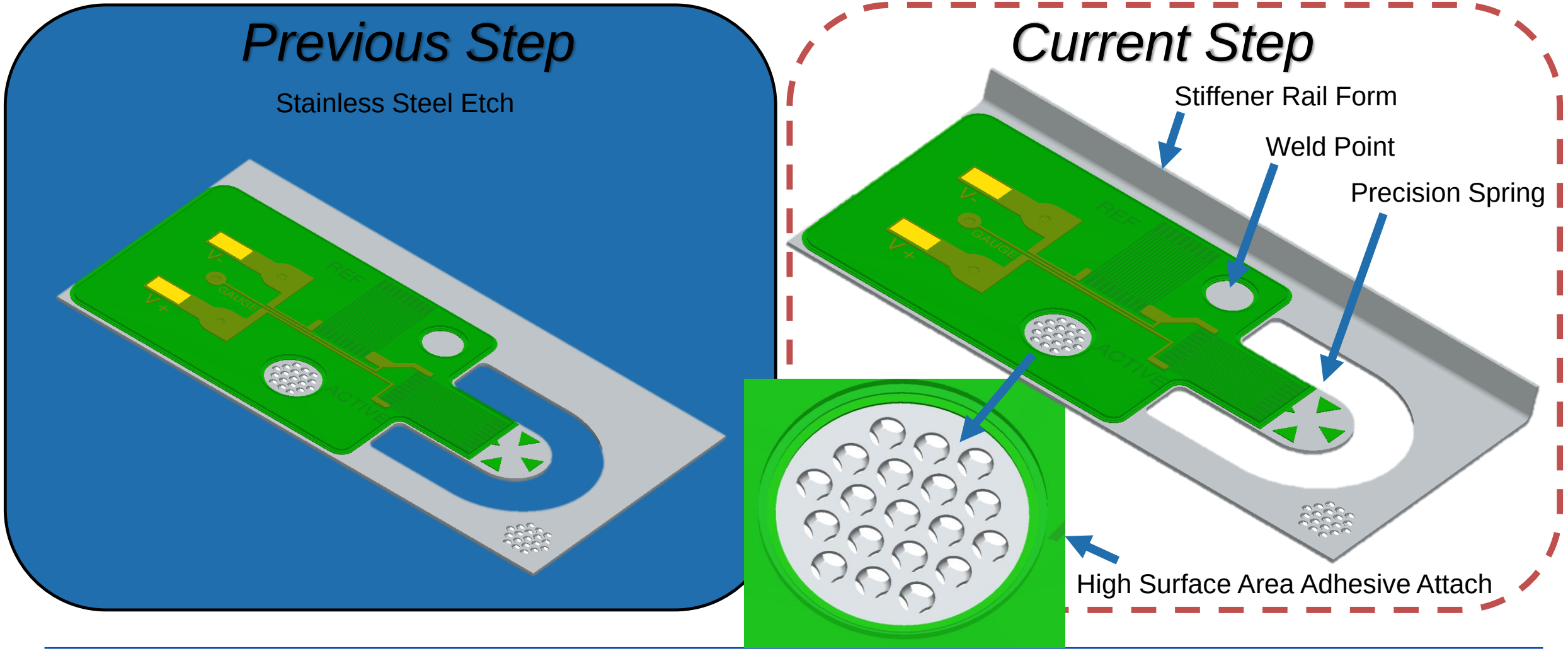
Current Step

Stainless Steel Etch



Semi-Additive Process Flow Example

- Post Processes

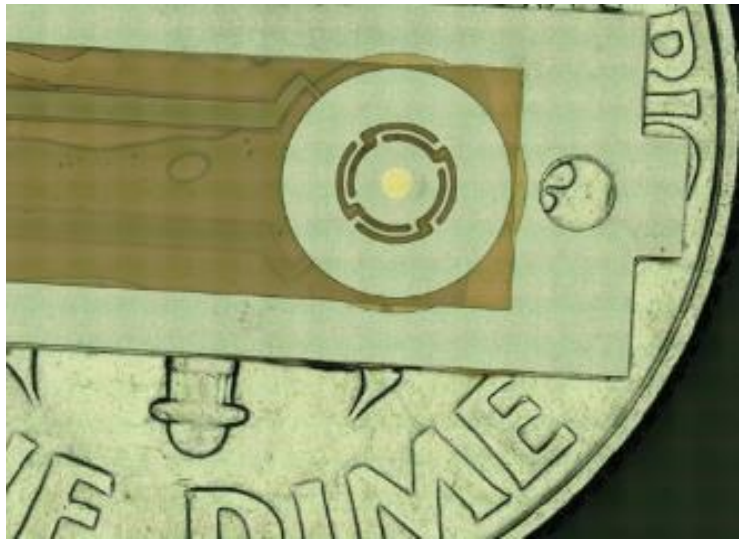


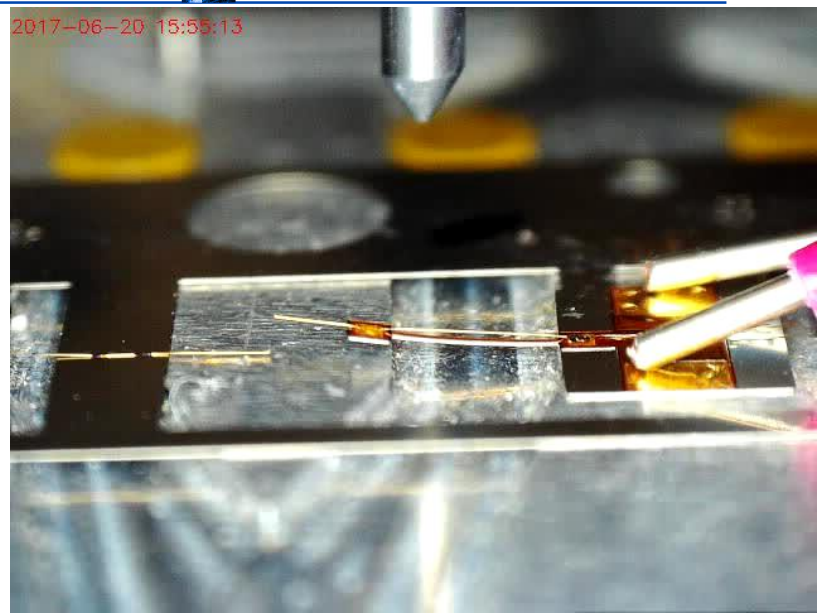
Semi-Additive Process Flow Example

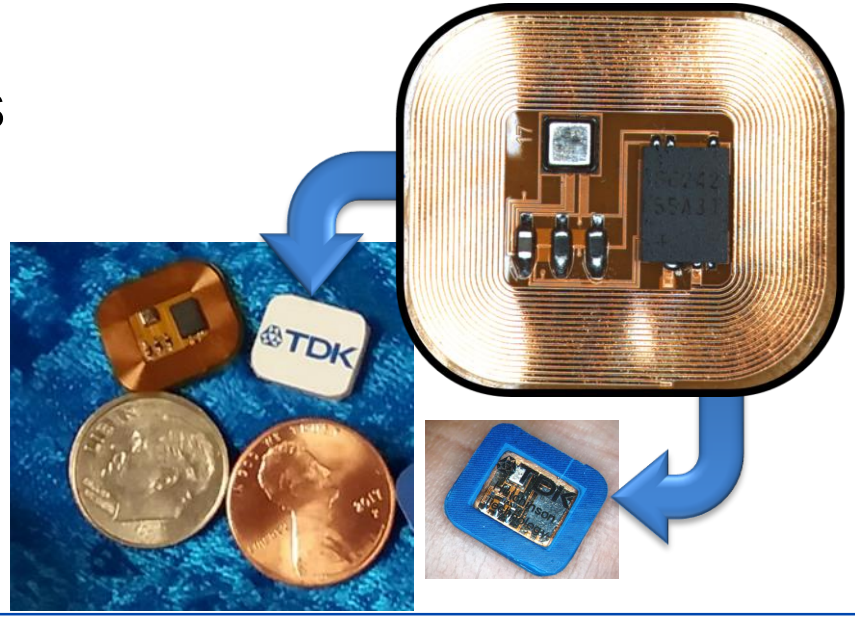
- Relative Size Comparison

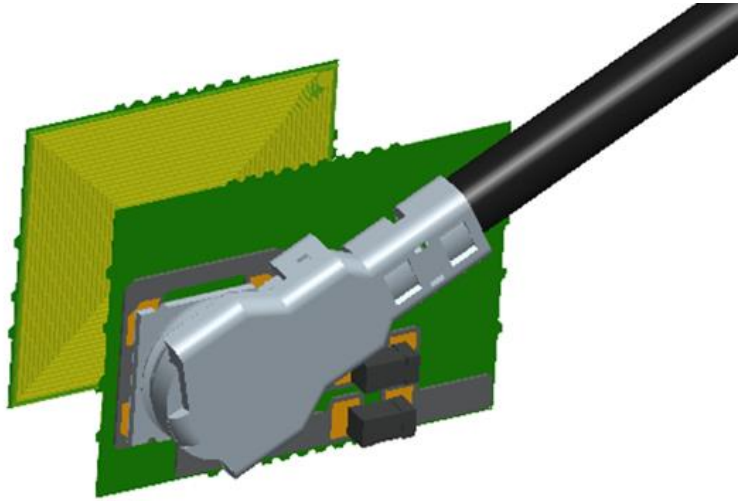
Key IoT Needs

- What does the IoT need?
  - ¬ Key Components
    - Sensors
    - Actuators
    - Wireless Communication
    - Wireless Power
  - ¬ Key Component Attributes
    - Small Form Factor
    - Highly Customized
    - Application Specific



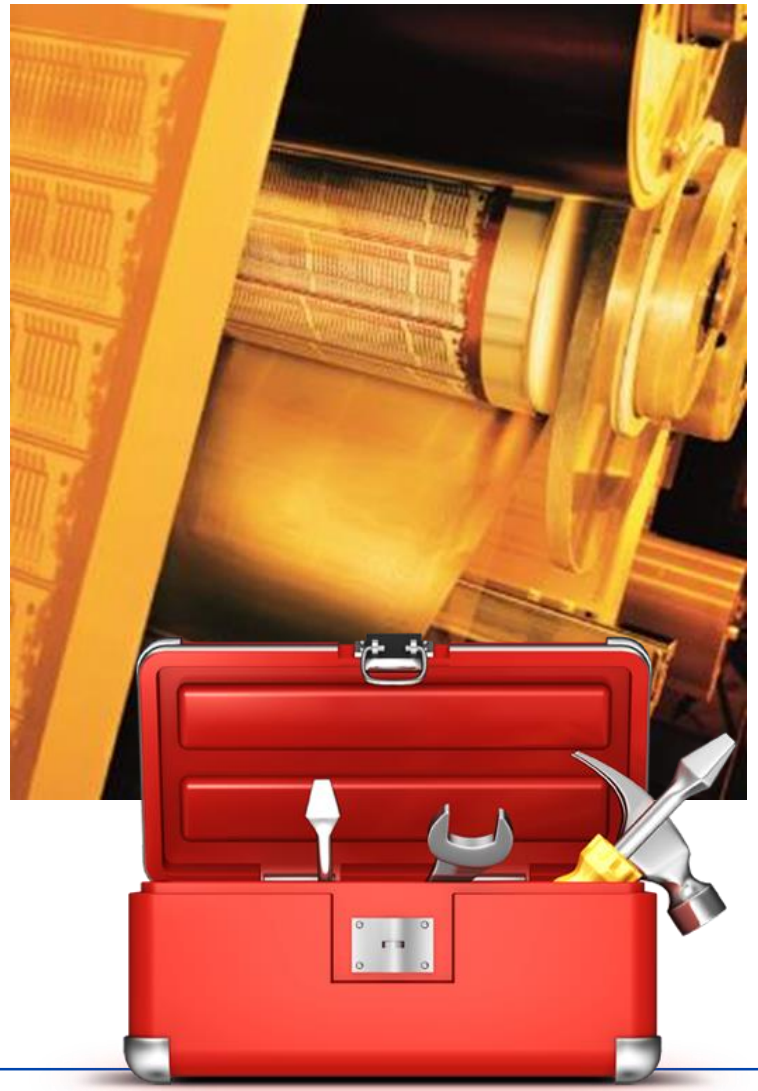






Conclusion

- *Semi-Additive Processing can be a valuable addition to your IoT 'toolkit'*
- *Allowing you to bring complex and novel concepts to market quickly and cost effectively*
- *Without sacrificing your creativity and vision!*



Fine Line / Space Circuitry

Analog Sensors

Integrated Actuators

Mechanical Structures

Wireless Communication

Wireless Power Transmission

Advanced Packaging

Thanks for your attention!

Questions?

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320-587-1460

daniel.roach@hti.htch.com

Thank You!