Additive Manufacturing Circuitry on Rigid and Flexible Substrates for Space Applications

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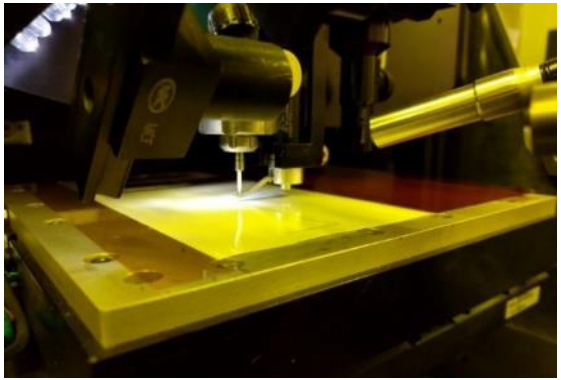
To be presented by Beth Paquette at the SMTA Additive Electronics Conference, San Jose, CA, October 24, 2019

Outline/Agenda

- Introduction: Additive Manufacturing Techniques
- Next Generation X-Ray Polarimeter
- Next Generation Microshutter Array
- Future Work
- Acknowledgements
- Q & A

Introduction: Additive Manufacturing Methods Used

Printed Hybrid Electronics: Deposit inks onto substrate



Aerosol Jet

Why?

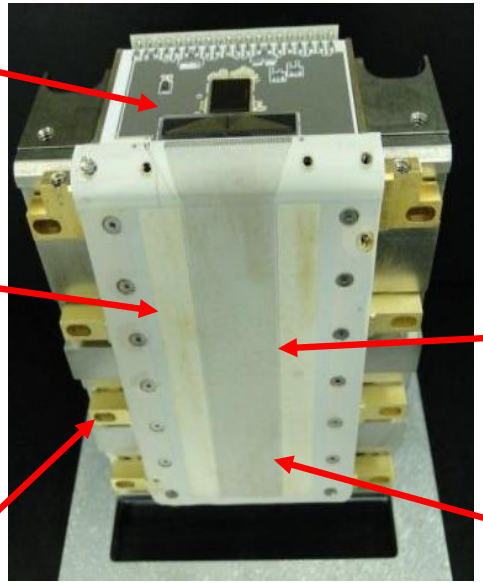
- Feature sizes down to 10 microns
- Variety of substrates – flexible, rigid, 3-dimensional non-planar

➢ ***Has the potential to reduce mass and volume***

Next Generation X-Ray Polarimeter (NGXP)

ASIC Board

3 in x 5 in Liquid Crystal Polymer (LCP)



Frame

Fan-out area

Traces: 121µm pitch, copper cladding etched

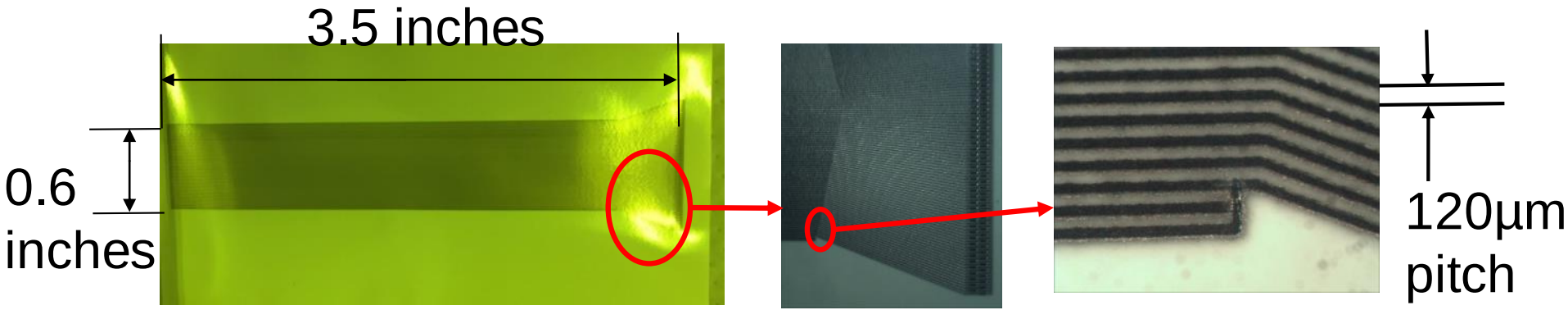
Photoelectron tracks imaged using strip detectors in a gas environment

Original Strip Detector

NGXP Flexible Prints

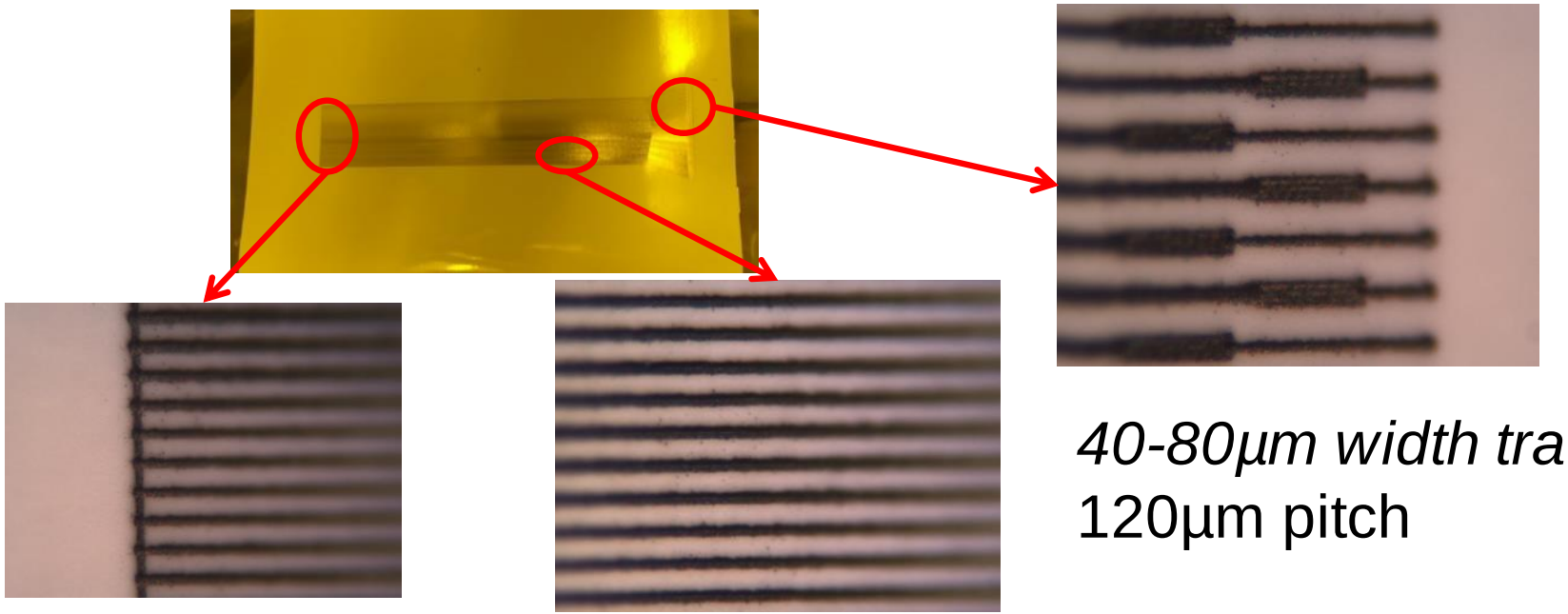
- Materials:
  - Gold and silver inks
  - Kapton and Liquid Crystal Polymer (LCP) Substrates
- Printer:
  - Optomec AJ200
  - Pneumatic atomizer for silver ink
  - Ultrasonic atomizer for gold ink

NGXP Flexible Prints



Silver printed on Liquid Crystal Polymer with pneumatic atomizer. 200µm tip used.
Traces 60-80µm throughout print.

NGXP Flexible Prints



40-80µm width traces
120µm pitch

Silver printed on LCP with pneumatic atomizer and 100µm tip

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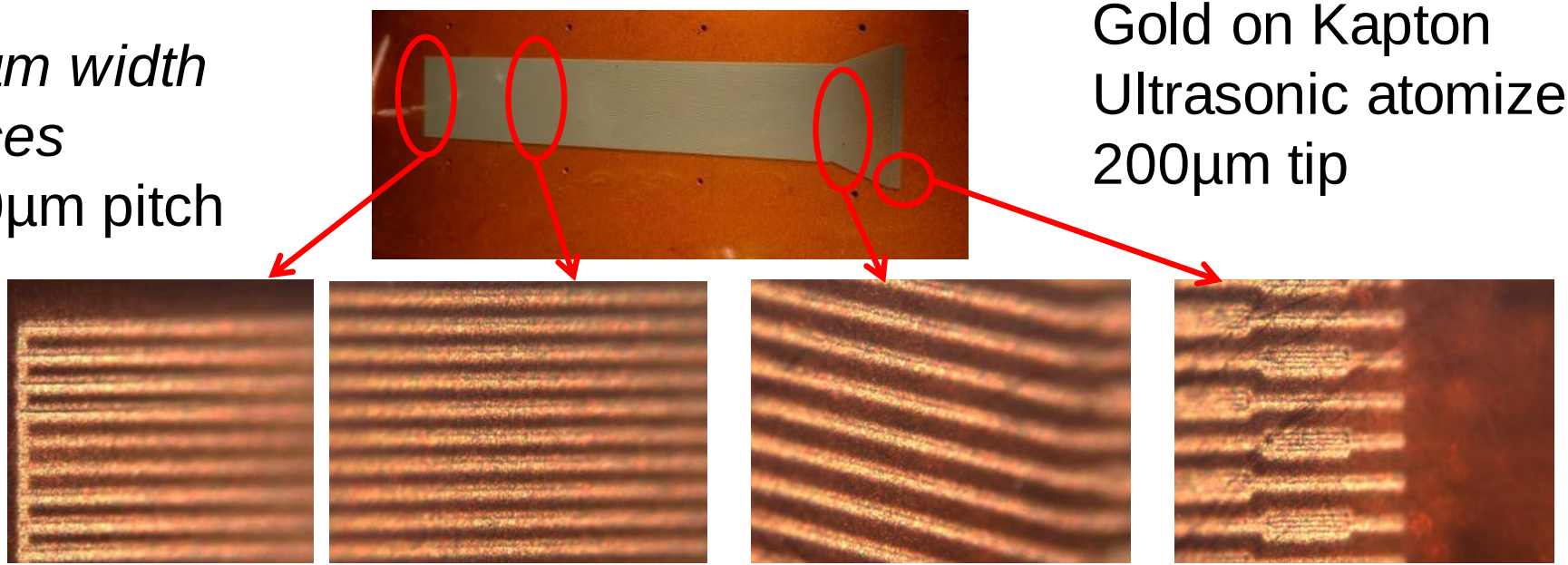
NGXP Flexible Prints

80µm width traces
120µm pitch



Gold on Kapton
Ultrasonic atomizer
200µm tip

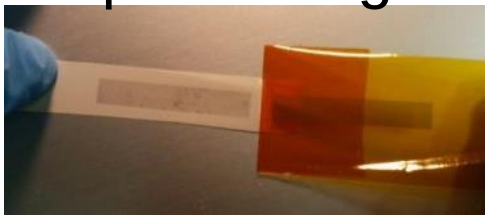
Ink appeared dry and powdery. Overspray observed

NGXP Flex Mechanical Tests

Bend Testing

Tensile Testing

Tape Testing

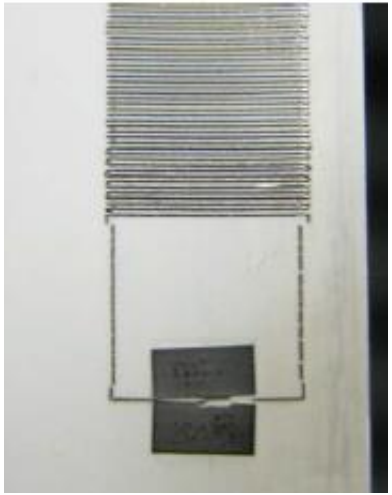


Pull directions

NGXP Flex Mechanical Tests

Tape Tests

Tensile Tests



Trace, bond and LCP breaks observed

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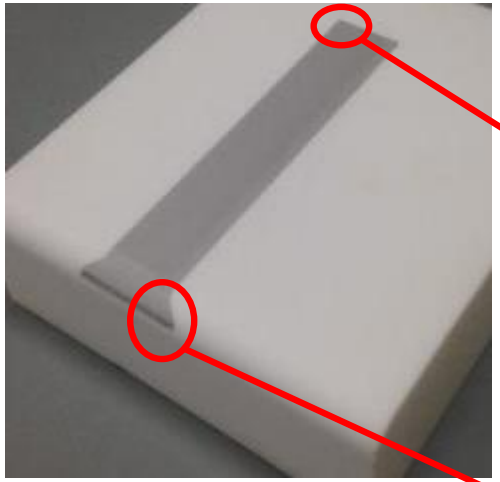
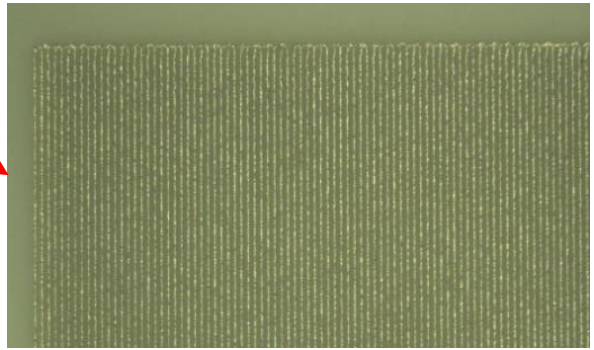
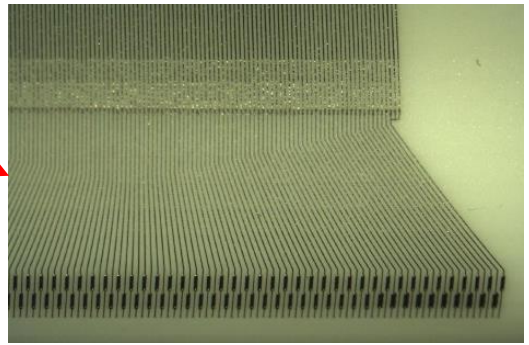
NGXP Flex Observations

- Printing parameters need to be adjusted over length of print
- Results vary between printer operators
- Gold ink more cumbersome to use, store
- Adhesion of inks to LCP needs improvement

NGXP Rigid Prints





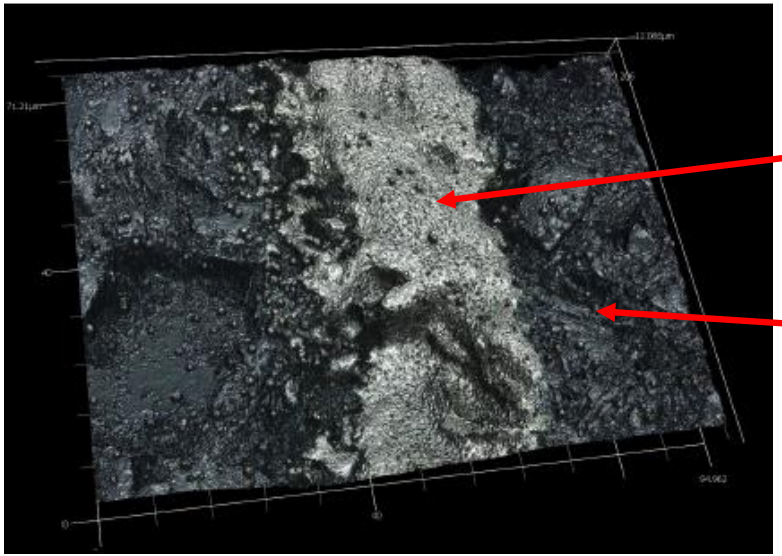


Aerosol Jet Printed Silver Traces on Macor

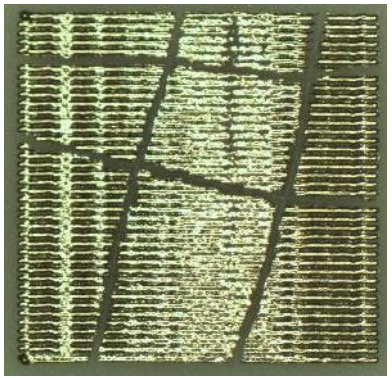
45µm width traces and 120µm pitch

NGXP Rigid Print Tests

Visual and topography imaging



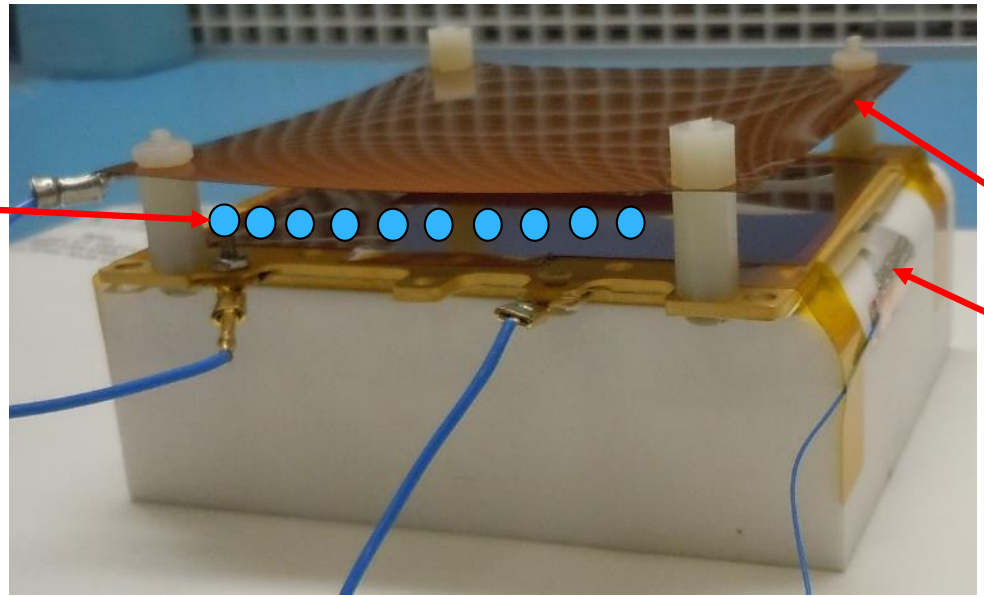
Traces measured 45.5µm+/-4.4µm



ASTM Adhesion Class 5B and 4B observed

NGXP Rigid Print X-Ray Tests

X-Rays move perpendicular to traces



Electrode layer

Printed Strip

Strip survived 16 hours of X-Ray testing

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NGXP Rigid Print Observations

- Prints on rigid substrates yielded ASTM Class 4B and 5B adhesion (minimal material removed)
- Substrate topography may impact trace structure and conductivity
- Prints survived X-Ray chamber

Next Generation Microshutter Arrays (MSA)

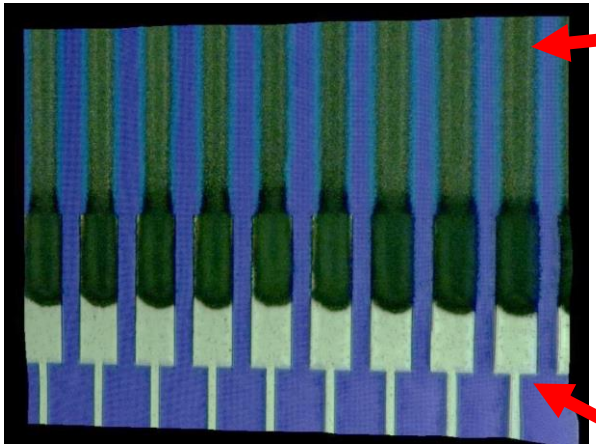
Microshutter Array

128 pairs of metal pads

Silicon Substrate

High-resolution spectroscopy: *Microshutters select many objects in one viewing for simultaneous observation*

MSA Aerosol Jet (AJ) Test Prints

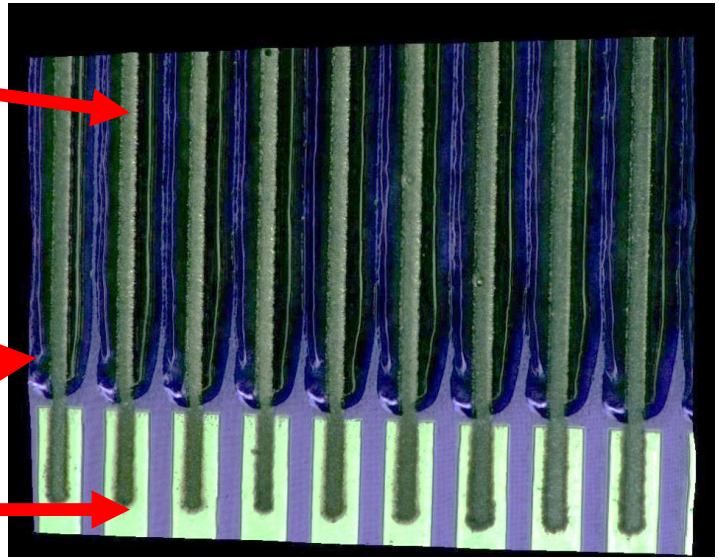


Sample without insulator

Printed Silver Lines

Printed Insulator

Metal Pads

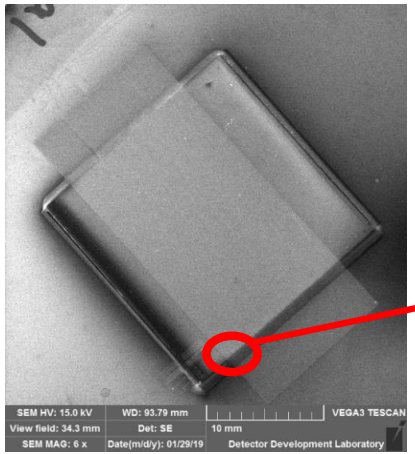


Sample with insulator

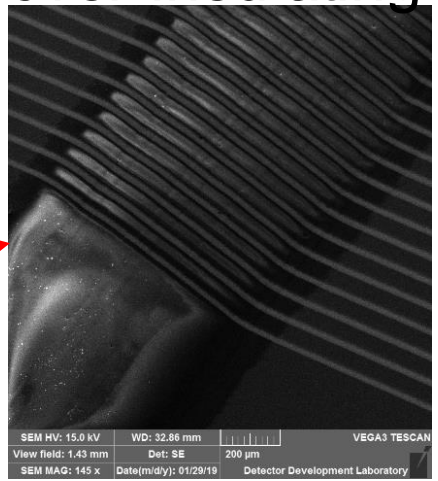
Conductivity tests were successful

MSA AJ Test Prints

Printed Sample on Silicon Squares attached to Wafer



Printed silver lines with 20um width over insulating fillet/”ramp"



Scanning Electron Microscope Images by GSFC

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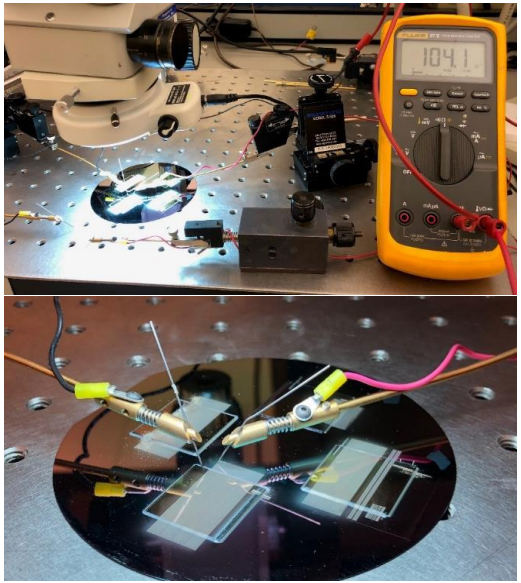
MSA AJ Test Prints



Probe setup (Optomec)

- **Resistance measured across conductive traces: 12Ω**
- Between traces:
  - Resistance on order of MΩ, but needs to be on order of GΩ
  - Trying plasma treatment to increase resistance
  - Printing a second set of interconnects on a new wafer

Future Work

Syringe Print
3D Flexible, Inc

- Work with syringe printer
- Continue Testing
- Integrate ASIC board design into NGXP
- ***Additional potential applications:*** CubeSat circuits, flexcircuit and printed interconnect applications, mass spectrometer applications - ion funnels and reflectron tube electrodes

Acknowledgements

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Thank You!

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Acronyms

Acronym	Definition
AJ	Aerosol Jet
ASIC	Application Specific Integrated Circuit
ASTM	American Society of Testing and Materials
LCP	Liquid Crystal Polymer
MSA	Microshutter Array
NGXP	Next Generation X-Ray Polarimeter
PEEK	Polyetheretherketone