28th Annual Student Research Symposium
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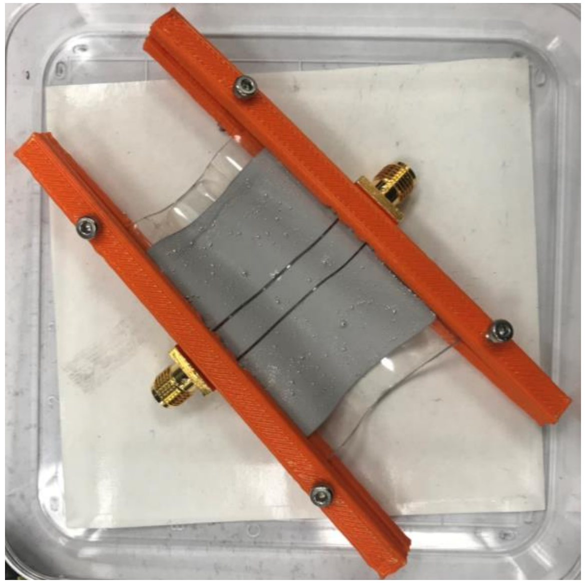
2020

University of Dayton

Polymerized Liquid Metal Network Characterization for Stretchable RF Devices



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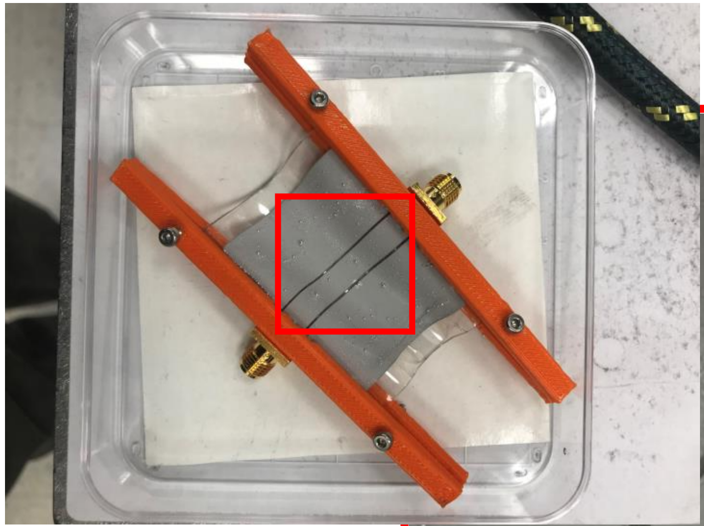
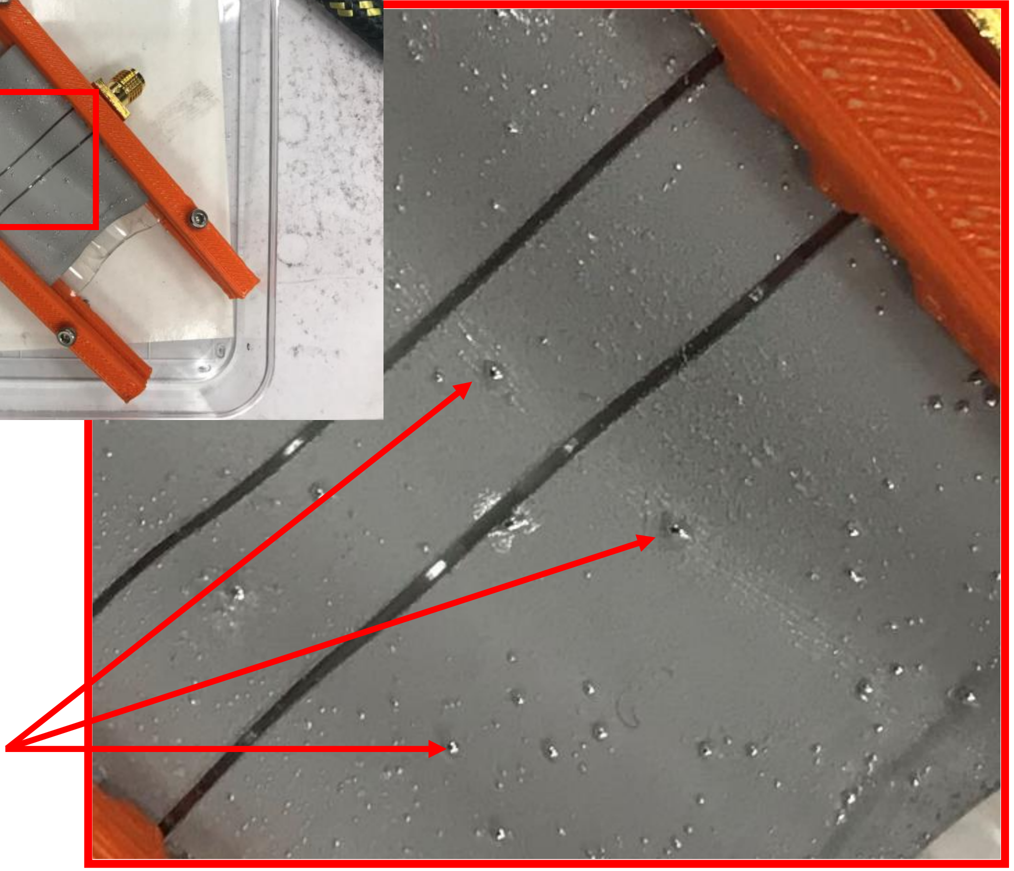
Outline

Motivation

- Air Force Research Lab developed highly stretchable conductive material.
- Polymerized Liquid Metal Networks [1]
  - Gallium metal alloys liquid at room temp.
- Conductive at extreme strains greater than 500%.
- AC and DC resistance is consistent over this range.





Liquid metal that appears upon activation

1. Thrasher, C. J., Farrell, Z. J., Morris, N. J., Willey, C. L., Tabor, C. E., Mechanoresponsive Polymerized Liquid Metal Networks. *Adv. Mater.* 2019, 31, 1903864. https://doi.org/10.1002/adma.201903864

Context

- Highly stretchable conductors are not well developed or characterized especially in RF electronics.
- Radio frequency device design requires very specific geometries and dimensions to achieve impedance matching.
- When stretching anything, all dimensions are changing especially for extreme strains.
- Need to understand intrinsic properties and precise geometries of the device.

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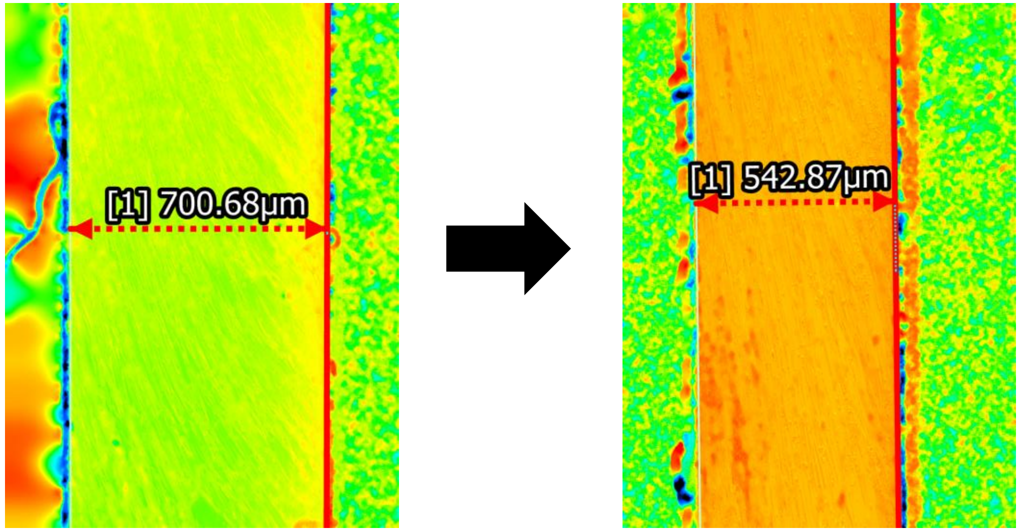
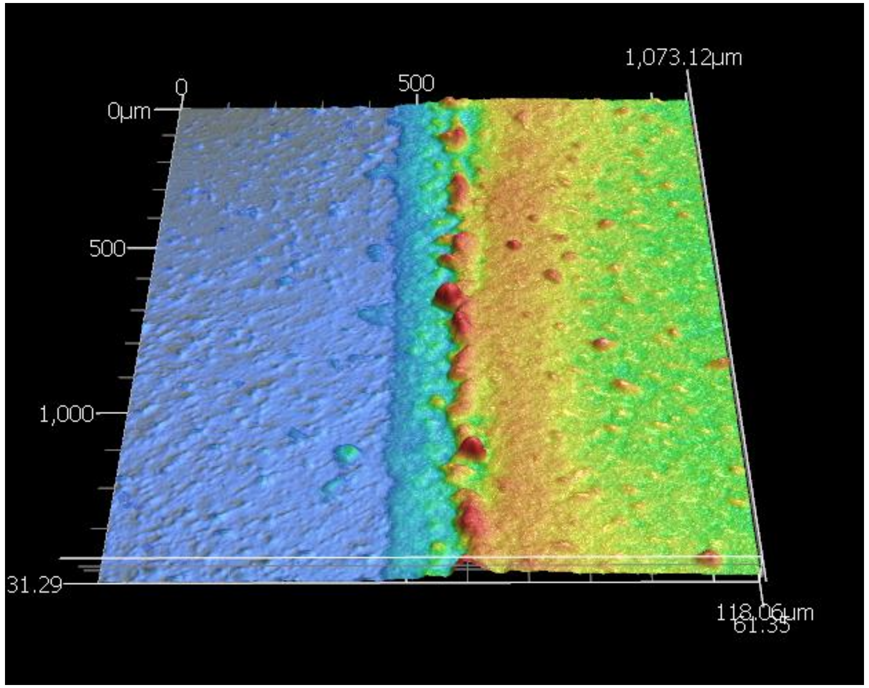
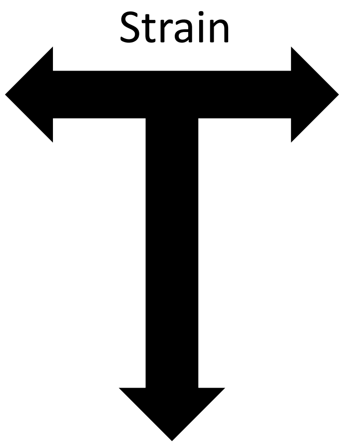
Objective

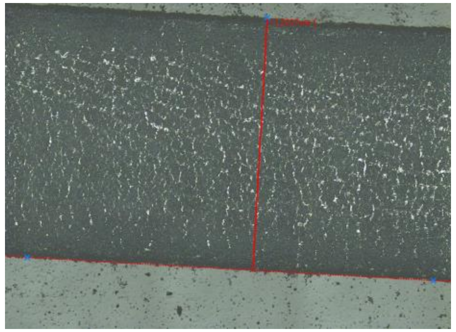
To investigate the effect of strain on Poly-LMN intrinsic properties as well as precise geometries needed for RF circuits.





Experimental Setup (Impedance under strain)





$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\frac{W}{H} + 1.393 + \frac{2}{3}ln\left(\frac{W}{H} + 1.444\right)\right]}$$

Where ε_{eff} = dielectric constant; W = width of the signal line, mm; H = height of the dielectric, mm;

Measured height of substrate and width of trace

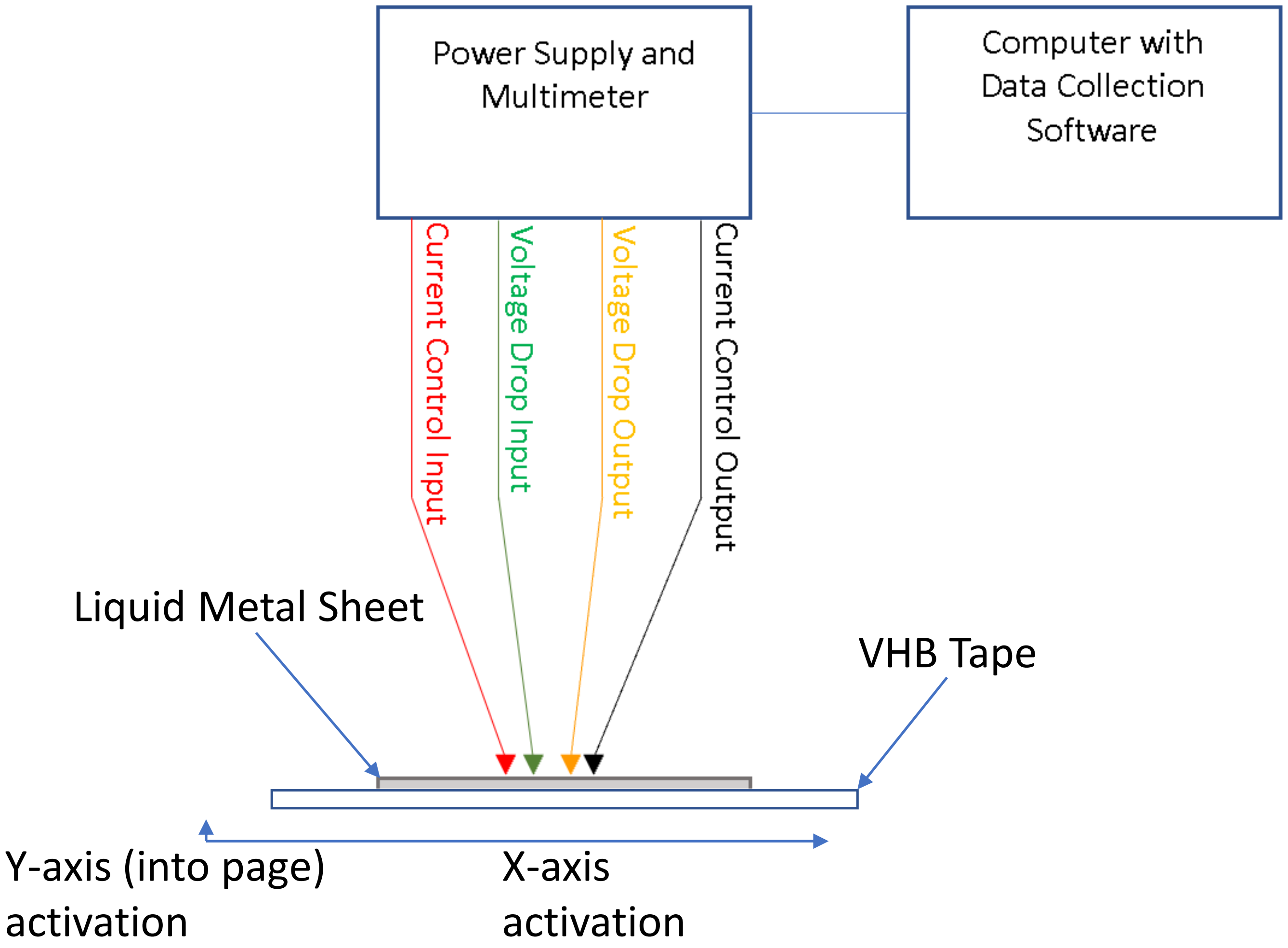
Permittivity of Poly-LMN = 2.68

Strains above 300%

Random Strain Increments

Microstrip Calculator, Pasternack, www.pasternack.com/t-calculator-microstrip.aspx.

Experimental Setup (Resistivity)



5 samples of 1 sq. inch Poly-LMN

X activation and X then Y activation

Probe aligned along X then remeasured along Y.

Measurements per sample: 30 for each activation and probe axis.

300 total measurements

Results of Impedance Under Strain

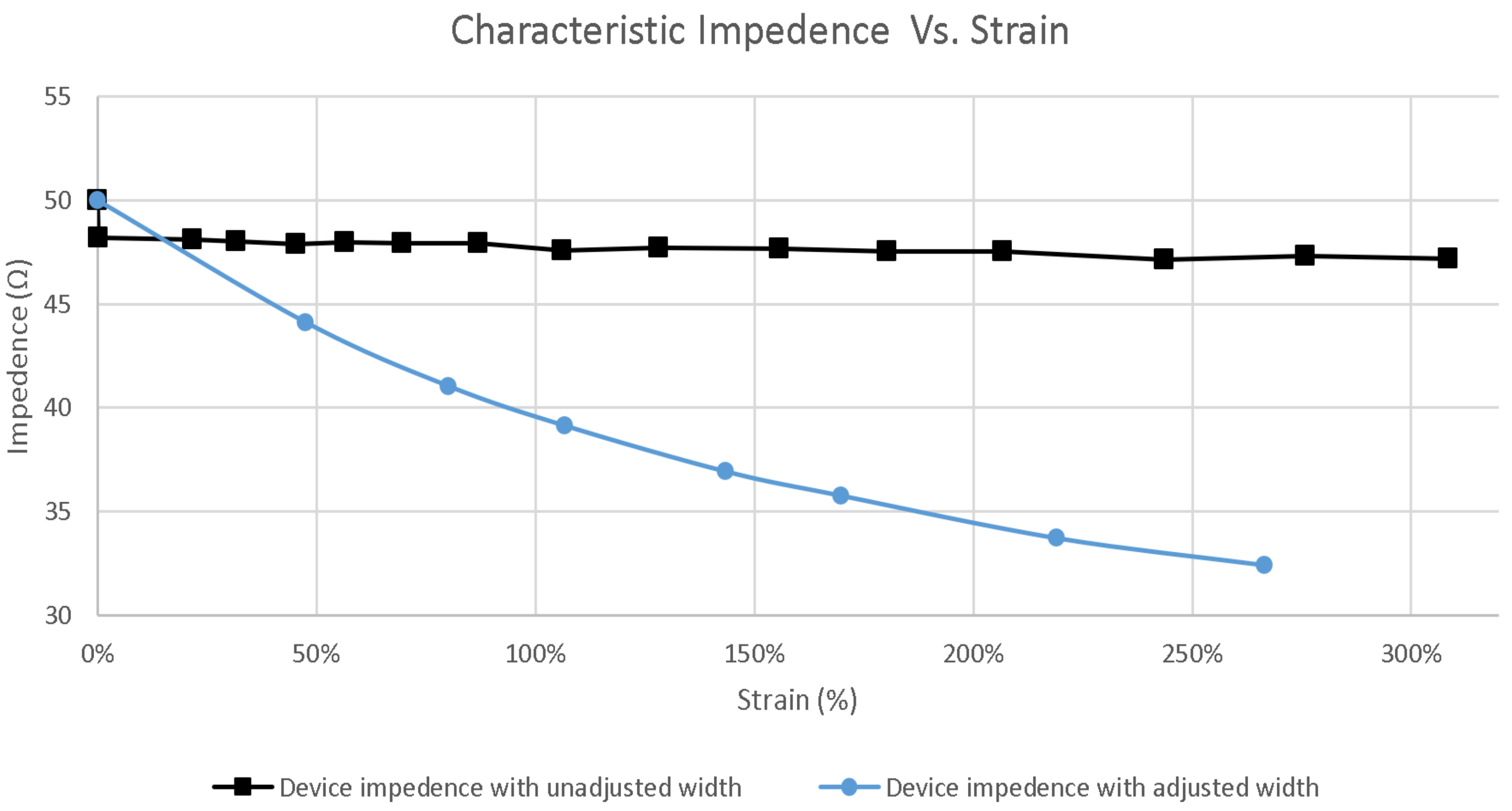


Figure 2: Characteristic impedance of a grounded microstrip line on 3M™ VHB™ Tape as it is strained.

Experimental Setup (Resistivity)

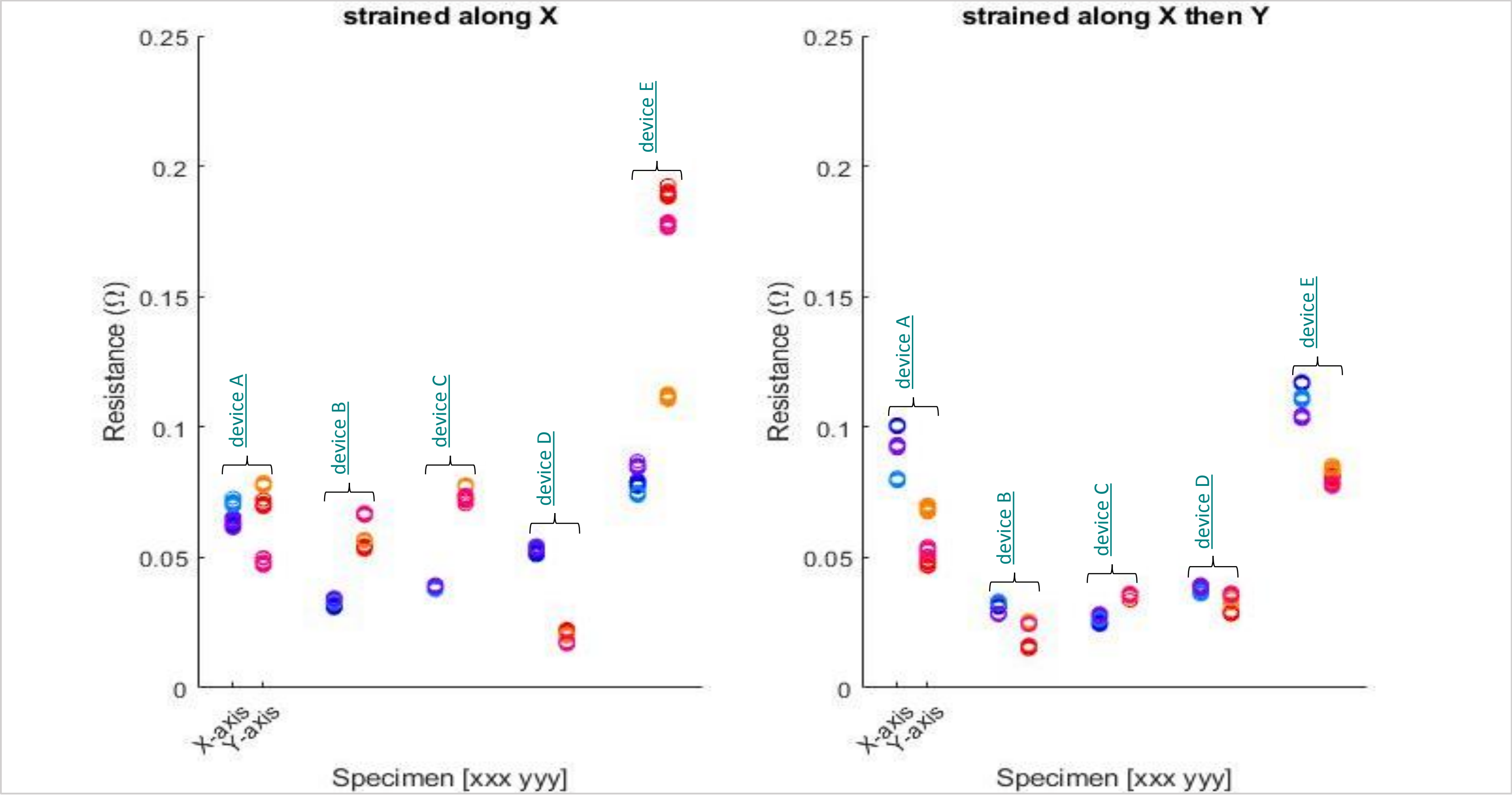


Figure 3: Resistivity of Poly-LMN dielectric based on activation axis and measurement axis.

Conclusions

Objective
To investigate the effect of strain on Poly-LMN intrinsic properties as well as precise geometries needed for RF circuits.

1. **Both width and height decreases of stretchable microstrip traces on 3M VHB Tape under strain are beneficial to maintaining impedance matching.**

2. **Width and height changes of 3M VHB Tape are nearly proportional to one another producing a nearly consistent device impedance over a large strain range.**

3. **Poly-LMN RF dielectric properties are isotropic and independent of strain axis.**

Acknowledgements

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Thank You