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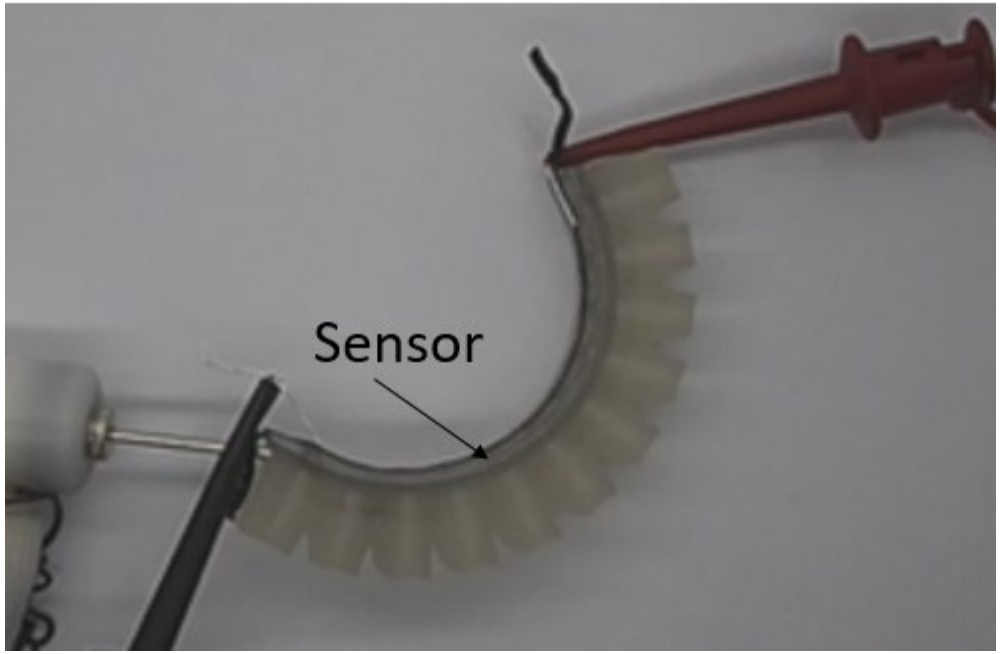
SHERO



A soft pneumatic actuator with integrated deformation sensing elements produced exclusively with extrusion based additive manufacturing

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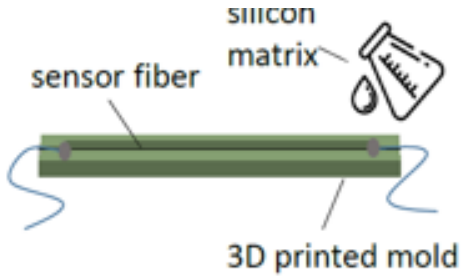
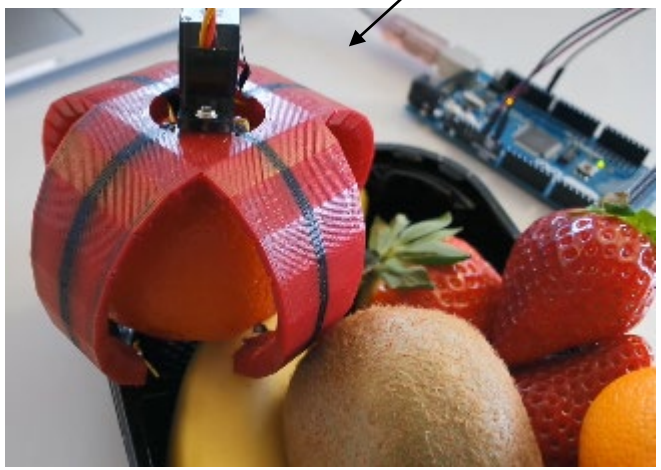
A soft pneumatic actuator with integrated deformation sensing elements produced exclusively with extrusion based additive manufacturing

The most common method for fabrication of soft robots is casting:



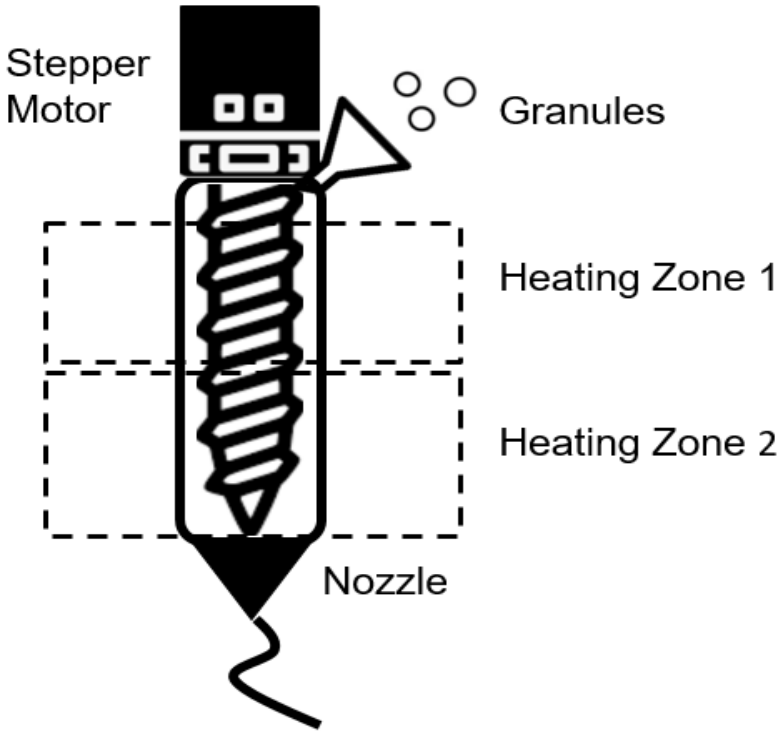
However, there it can be time consuming especially when integration of soft sensors is involved.

Additive Manufacturing is a interesting alternative to molding because it allows the integration of sensors in situ.



Conventional filament based fused deposition modeling (**FDM**) is not compatible with thermoplastic elastomers of low shore hardness, required for pneumatic actuators.

Pellet-Based Fused Deposition Modeling(FDM)



- Allows to print thermoplastic elastomers of low shore hardness.
- Allows to print composites with large filler concentration.
- Compatible with multi-material printing. Allows to integrate functional elements like sensors in-situ.

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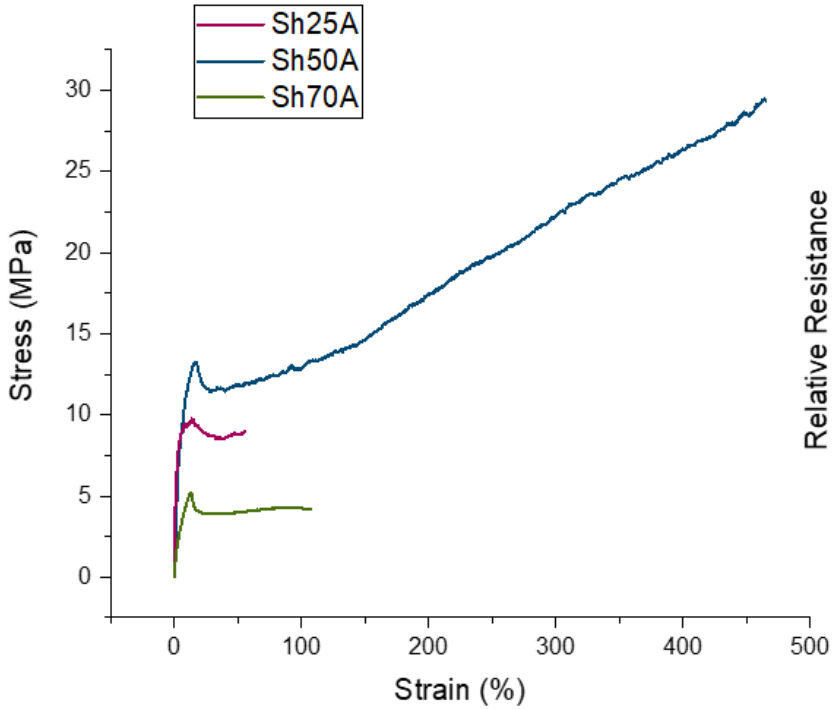
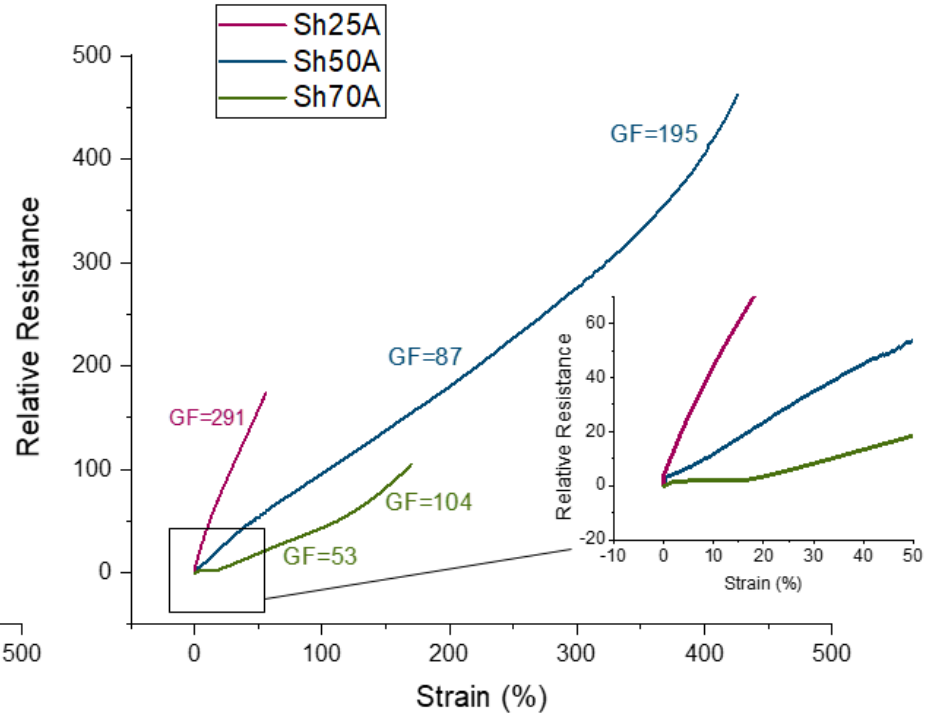
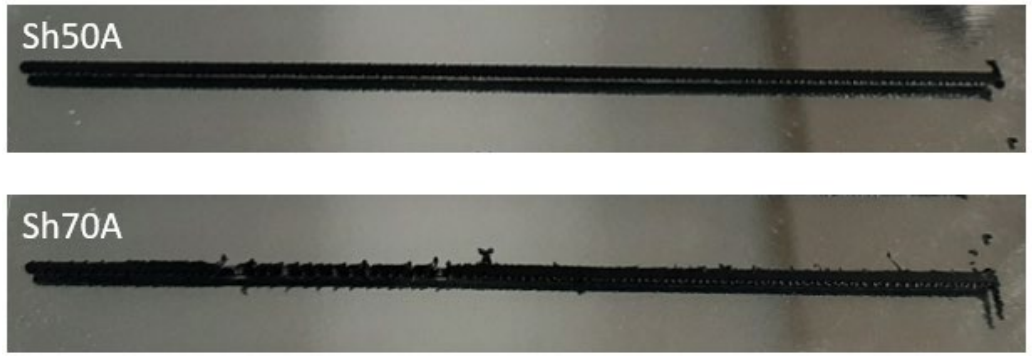
Choosing the matrix material for the conductive composite

For the sensor, carbon black in mixed with a TPS thermoplastic elastomer in 1:1 mass ratio.





Composite of lowest shore hardiness became brittle after mixing



The composite with the higher shore hardness could not produce a continuous line during printing.

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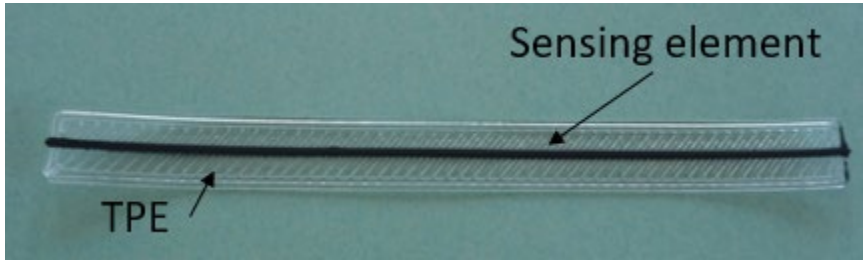
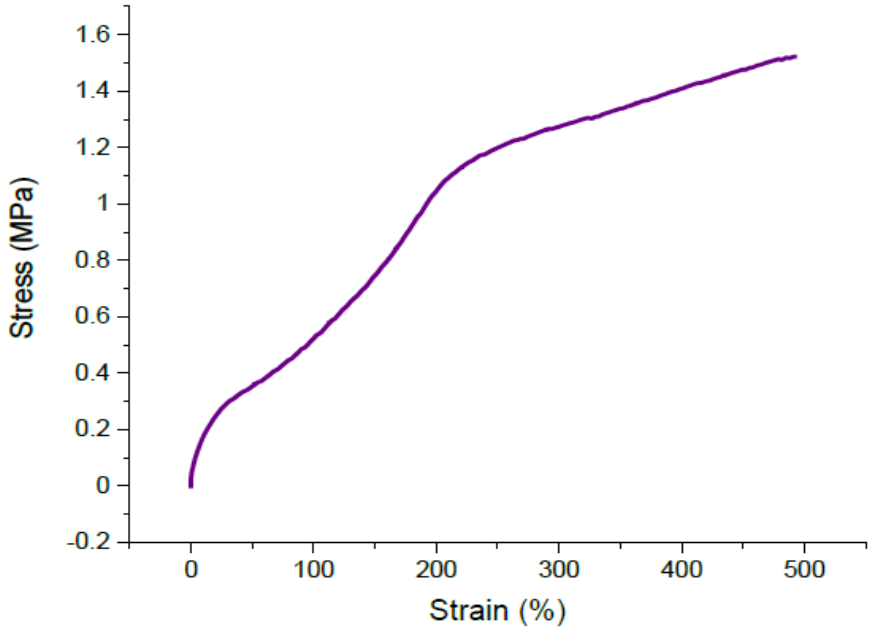
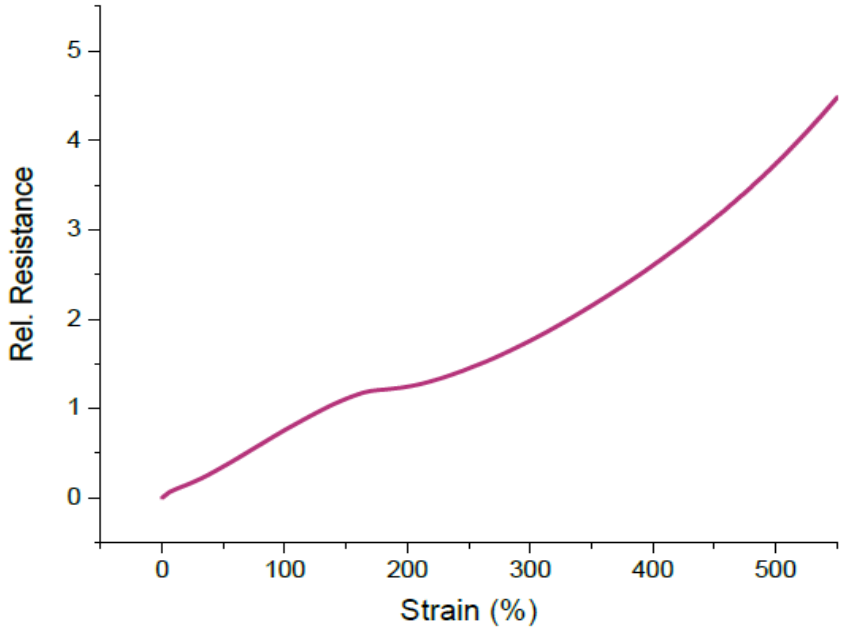
Tensile Testing up to the Point of Fracture



The Sh50A composite was printed on Sh18A TPS.

$$R_{rel} = \frac{R - Ro}{Ro}$$





Monotonic response below 200% strain.

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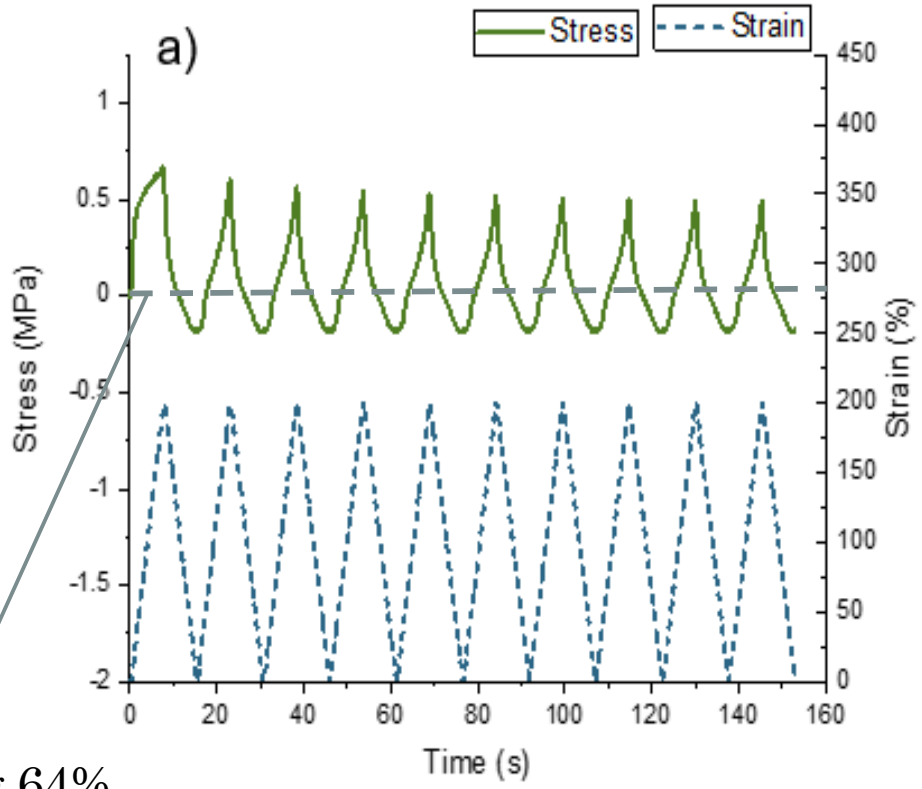
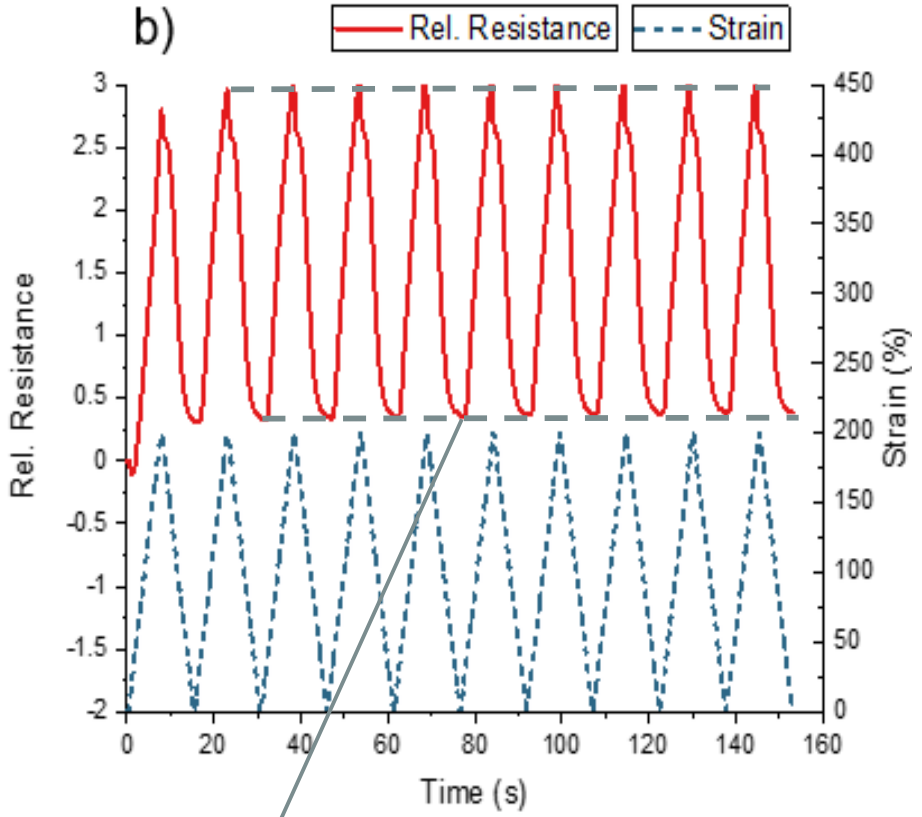
Dynamic Testing

$$R_{rel} = \frac{R - Ro}{Ro}$$



Buckling 64%



Drift 1%

GF=6

$$GF = \frac{R_{rel}}{\Delta\varepsilon}$$

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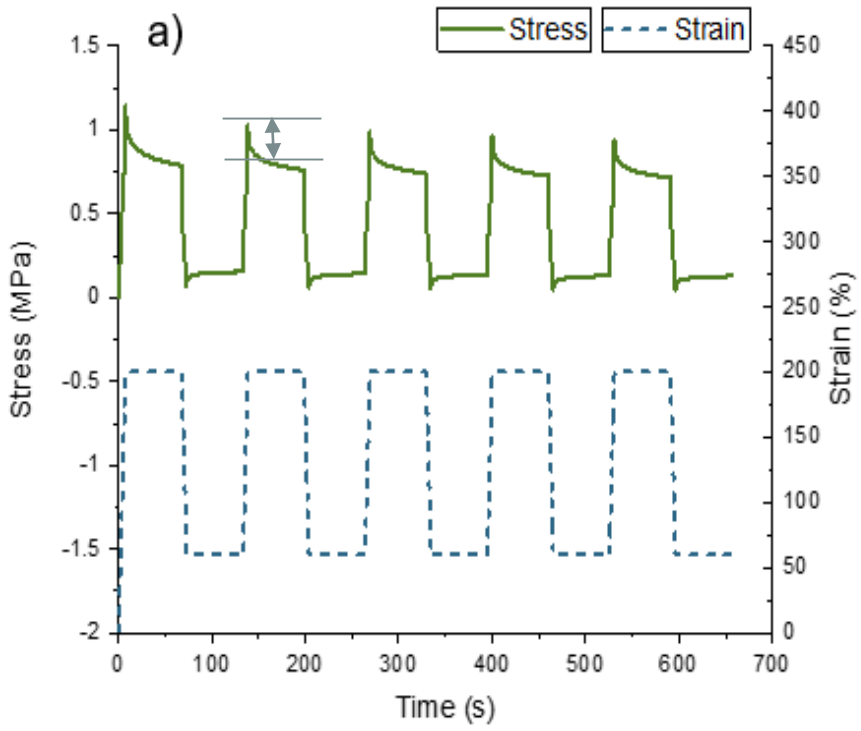
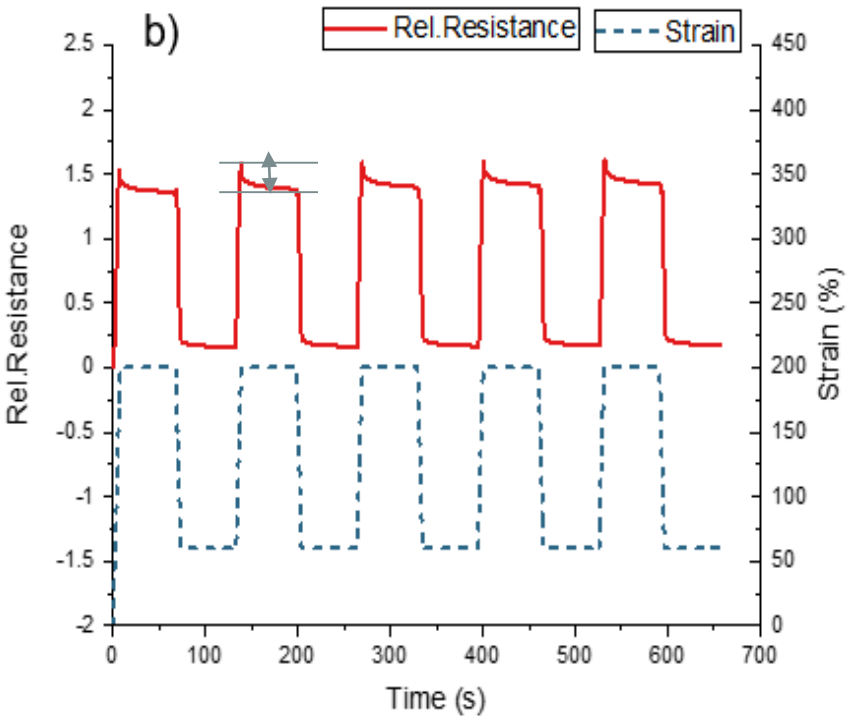
Quasi-Static Testing



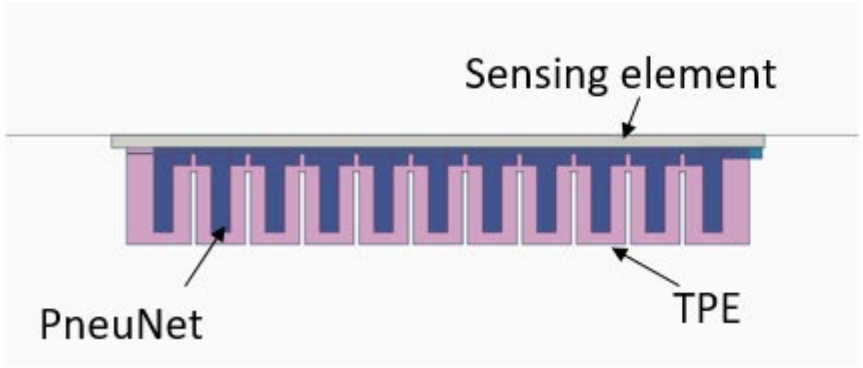


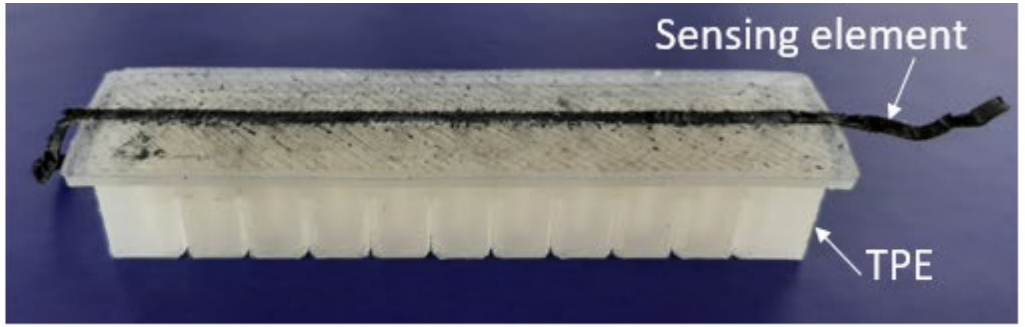
$$R_{rel} = \frac{R - Ro}{Ro}$$

Mechanical Relaxation: 29%

Signal Relaxation: 32%

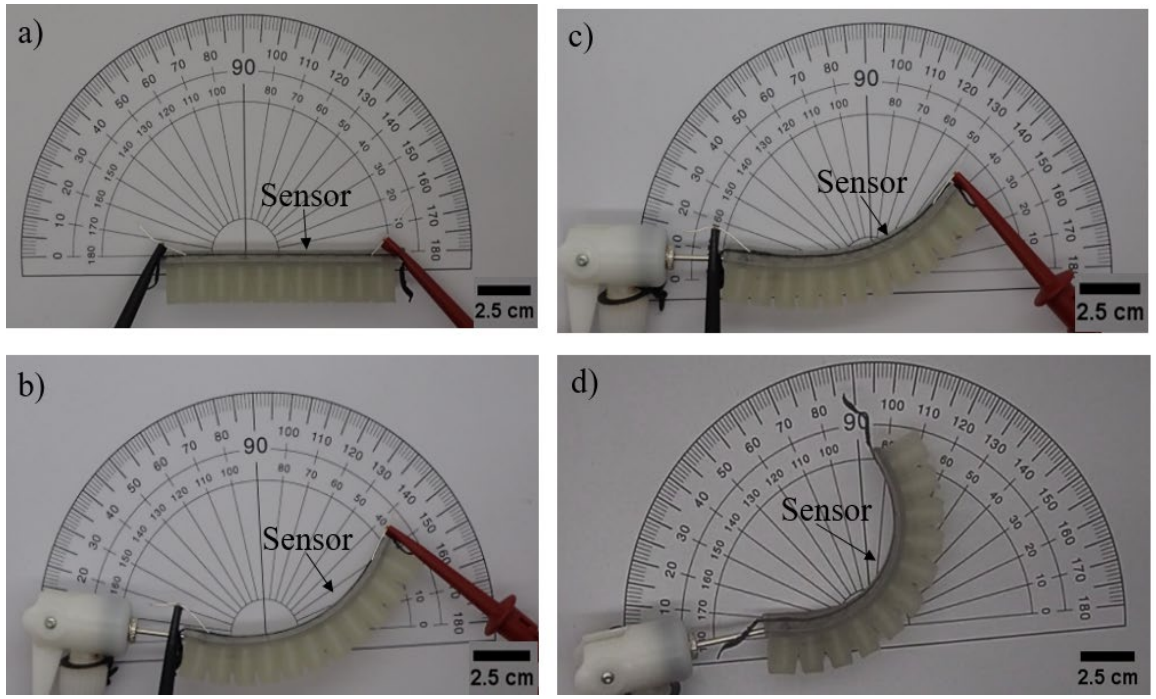
Pneumatic Bending Actuator

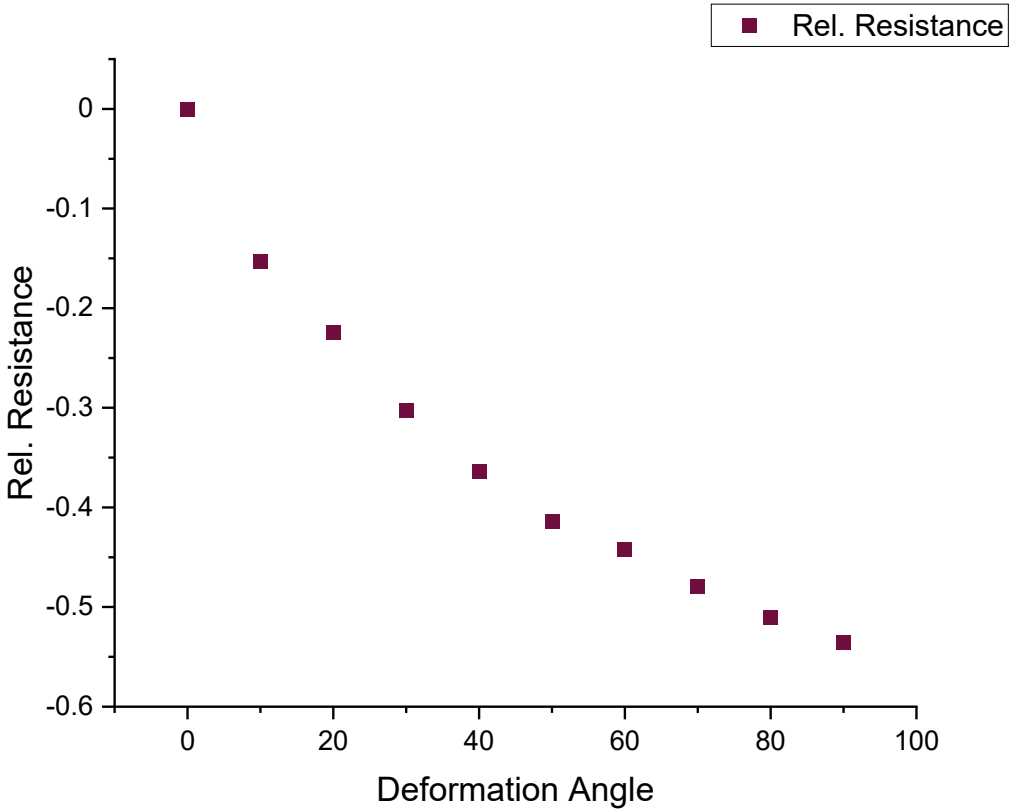




- The pneumatic actuator was produced in one step process.
- The total fabrication time was 3 hours.
- The sensing element was integrated in Situ.
- The resulting actuator was air-tight.

Pneumatic Bending Actuator: Bending angle

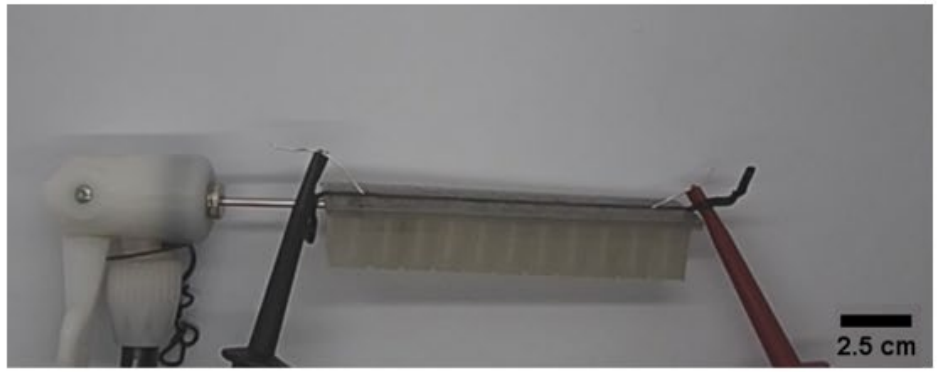


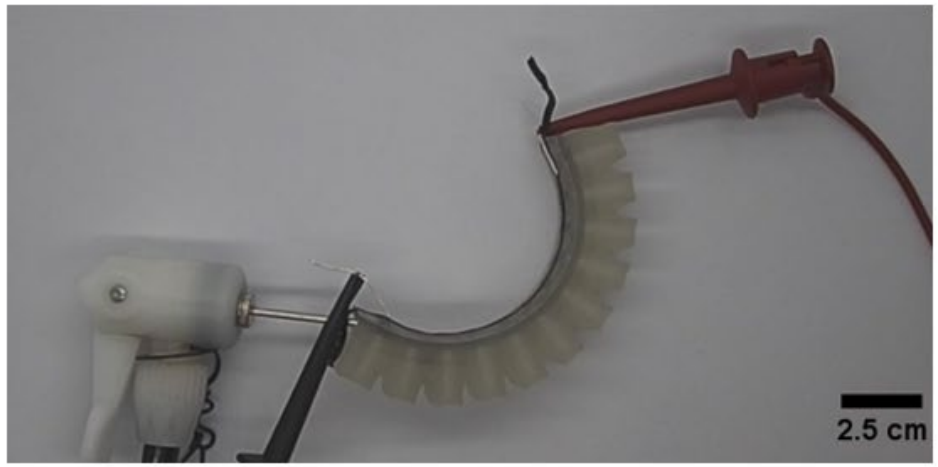


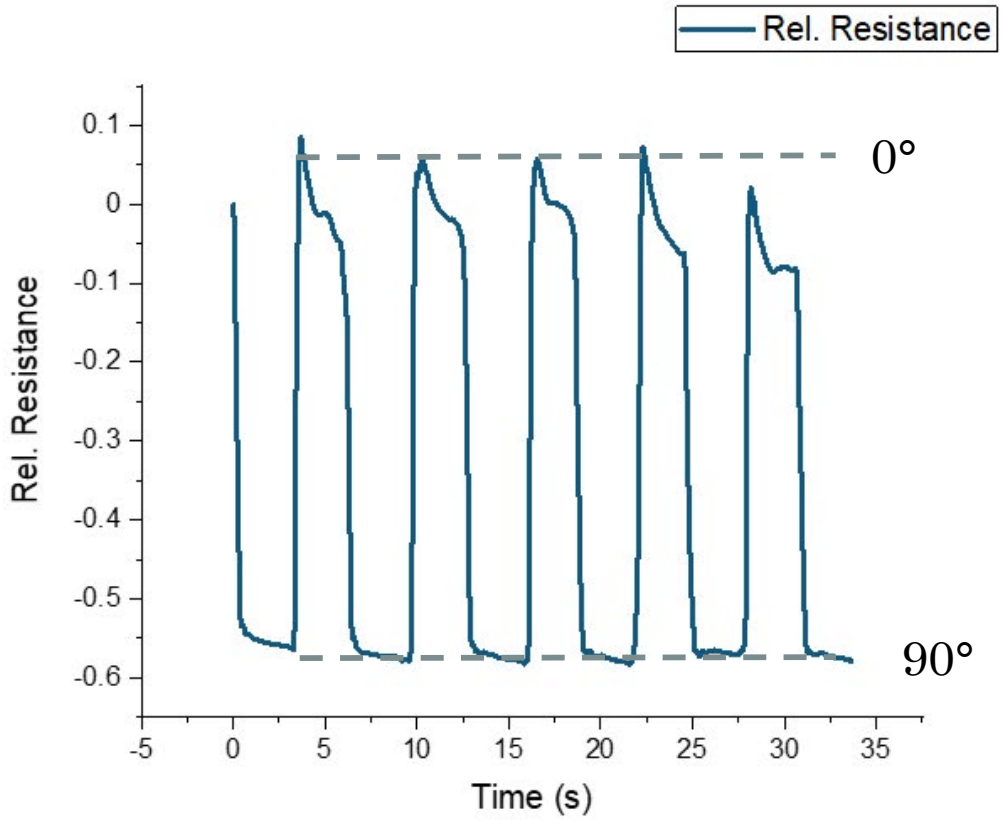
Every value of the resistance correlated with a distinctive bending angle.

Reverse piezoresistivity was expected because the sensor was under compression.

Pneumatic Bending Actuator: Quasi-Static Test







Despite the relaxation, it was possible to distinguish between position 0° and 90°.

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Conclusions

- The Sh50A composite combined good printability with a large functional range.
- Sensor strips printed with the Sh50A showed a reproducible response with very low drift 1%.
- There was significant relaxation for the stress and the sensor signal.
- The sensor was integrated in the bending actuator and it was used to monitor the bending angle of the actuator.
- The sensor integrated in the actuator showed a monotonic response and reverse piezoresistivity because the sensor was under compression.

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Acknowledgments

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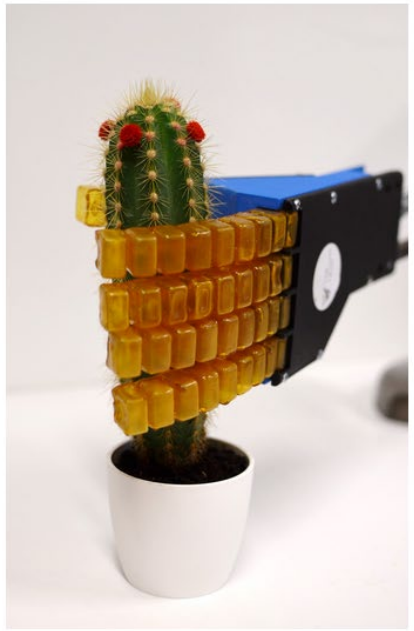

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