SUNFEST REU 2021: Novel Soft Sensor Design in the Detection of Normal and Shear Forces

By: Cory Philippe - Stevens Institute of Technology, Mechanical Engineering

Mentor: Christopher Stabile - Department of Mechanical Engineering and Applied Mechanics

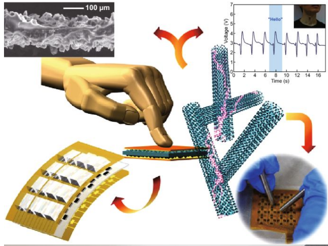
P.I: Dr. Kevin Turner - Department of Mechanical Engineering and Applied Mechanics

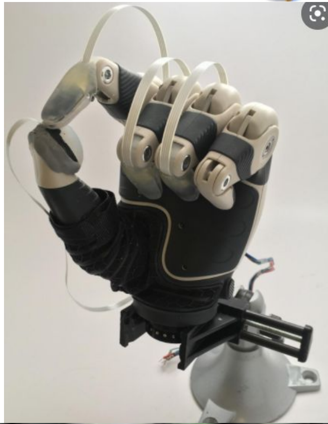
Introduction

Force sensors are a vital component of mechanical engineering and soft robotics with various applications like surgery, human prostheses, and robotic grasping.

Motivation: There has been only limited research on soft sensor designs for distinguishing shear and normal forces, which is highly important for sensing in grasping robots.

Goal: Based on previous studies create a sensor design sensitive to normal and shear forces, along with a fabrication process capable of constructing it.





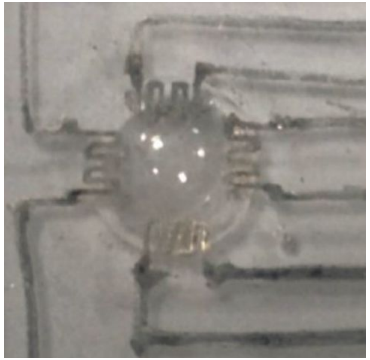
Background

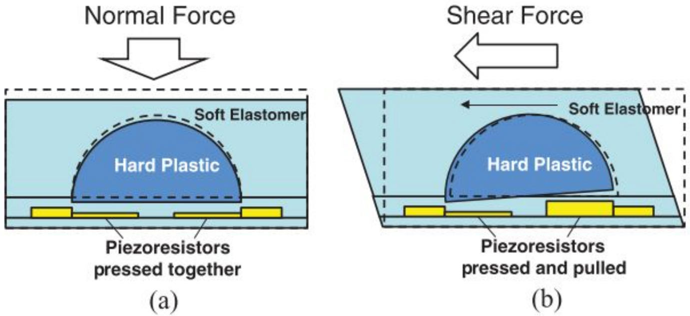
- Reviewed various sensor types
- Piezoresistive sensing was chosen based on compatibility with soft sensor

$$R = \frac{\rho L}{A}$$

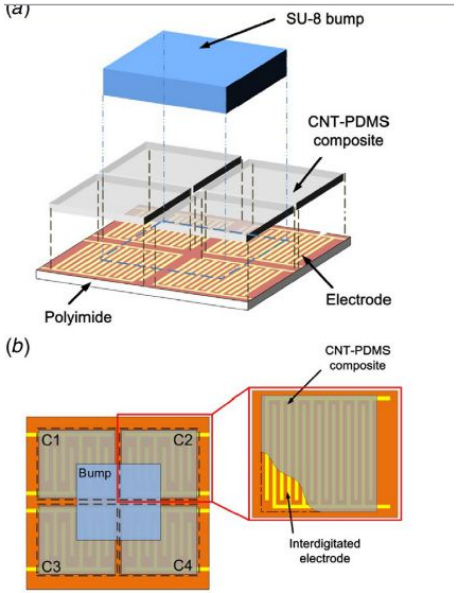
ρ = resistivity
L = length
A = cross sectional area

- Selected designs that allowed for resistance linearity and sensitivity to force in the x, y, and z directions





From: An EGaIn-based flexible piezoresistive shear and normal force sensor with hysteresis analysis in normal force direction by Shi, Xiaomei Cheng, Ching Hsiang, Zheng, Yongping. Wai, P. K.A.



From: Development of a flexible three-axis tactile sensor based on screen-printed carbon nanotube-polymer composite

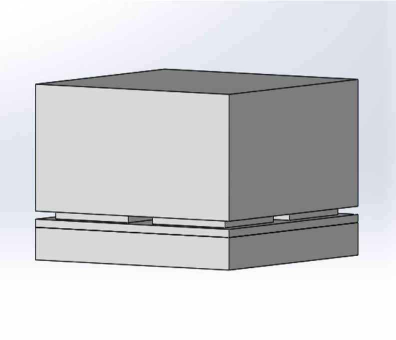
Technical Overview

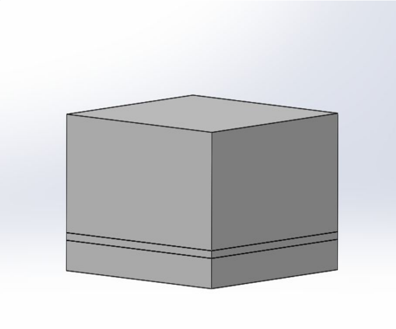
- Model and Analyse Designs on Solidworks
- Modify dimensions and perform parametric study to achieve higher strain
- Refine fabrication process and test viability
- Develop procedure to development sensor capable of normal and shear detection
- Test and evaluate sensor made using the procedure

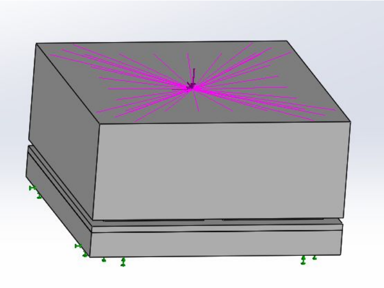
3D Models

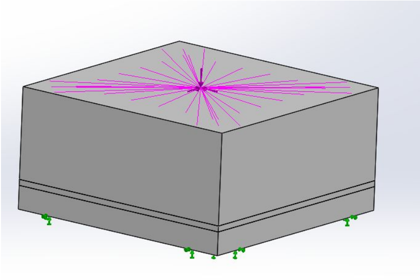
With Bases

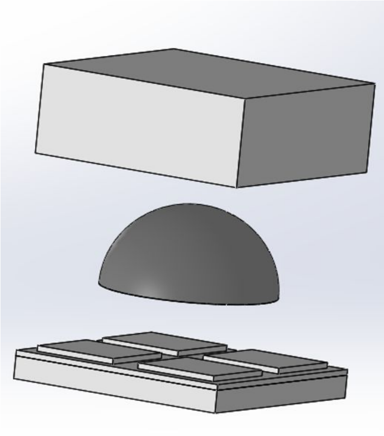
Without Bases

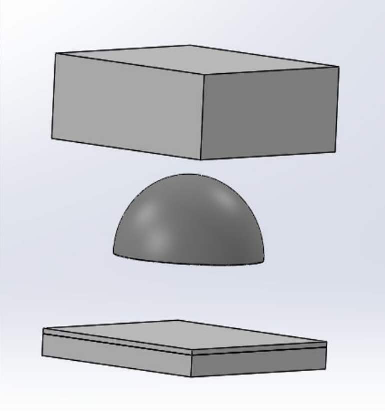


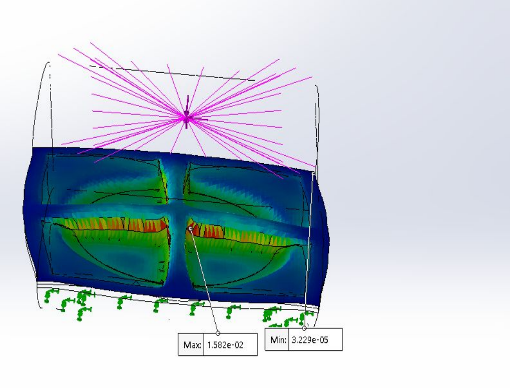


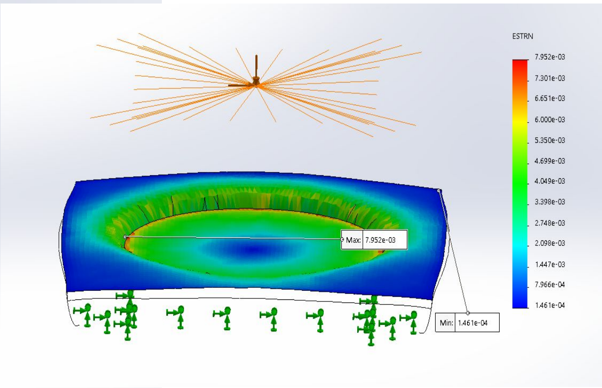




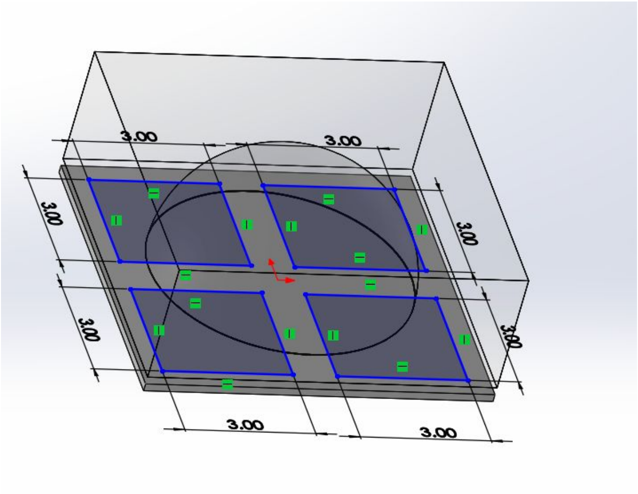


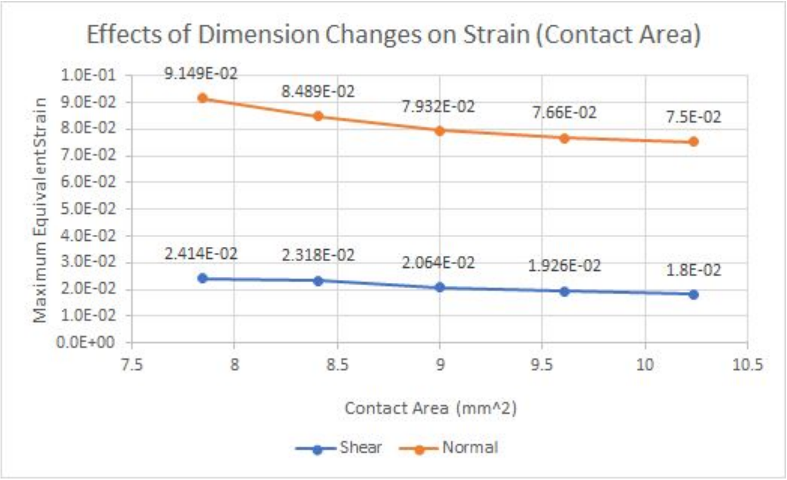






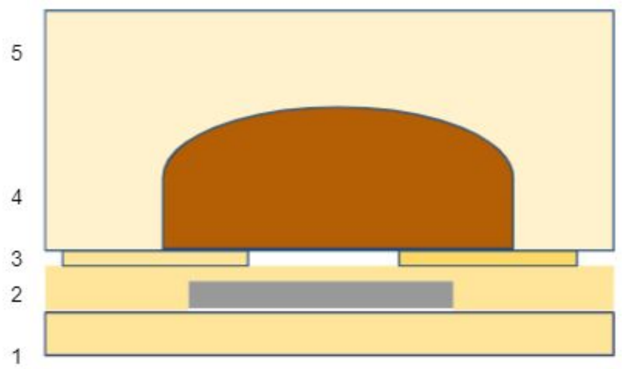
Parametric Study

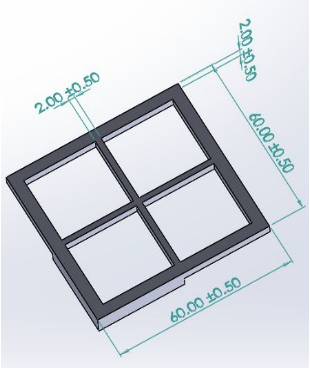


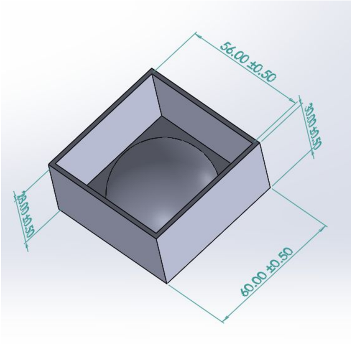


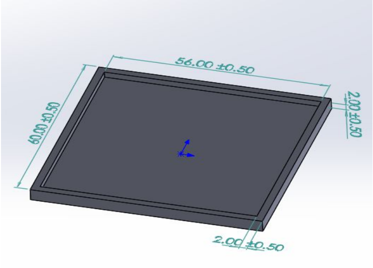
- Studied the effect of changing contact area on the maximum strain.
- Demonstrated that maximum strain and thus, resistance change increase with decreasing contact area.
- Smaller contact area caused higher concentrations of stress and higher strain
- Informed the us on the geometry and scale for the fabricated sensor.

Fabrication Procedure









- Flat base is formed and 4 individual strain paths are printed on.
- Thin encapsulated layer is applied to the top.
- Stencil is then used to create bumps over each encapsulated strain.
- A top mold is than created with an opening for a hard sphere to be made out of shape memory polymer.
- Lastly, the top mold with the sphere is aligned with the base and cured together.

Liquid Metal Properties and Printing Setup/Adjustment

The liquid metal used to form the traces was a 75% Gallium and 25% Indium mixture

Benefits:

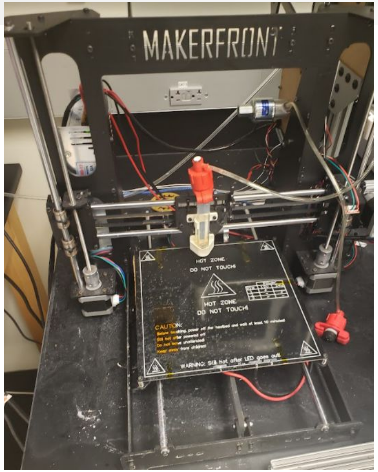
- Liquid at room temperature
- Highly conductive
- Low toxicity

Cons:

- Only wets on specific surfaces and polymers, a series of polymers tested were PET, PDMS, and polyurethane
- Oxidizes quickly

Parameters Adjustment:

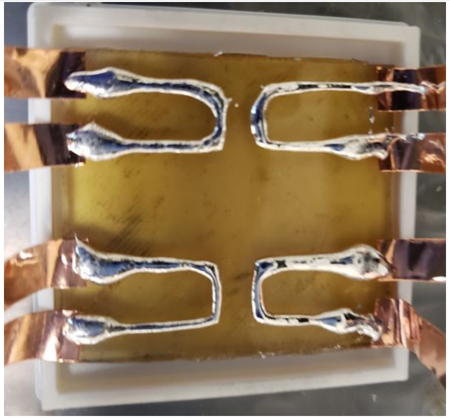
- Choose best height, pressure, and speed to form a complete line
- Higher pressures had better prints and lines
- Higher pressures also had higher bubbling as faster flow rate did not match speed
- Heights too great had insufficient contact while too low disrupted the metal ink flow

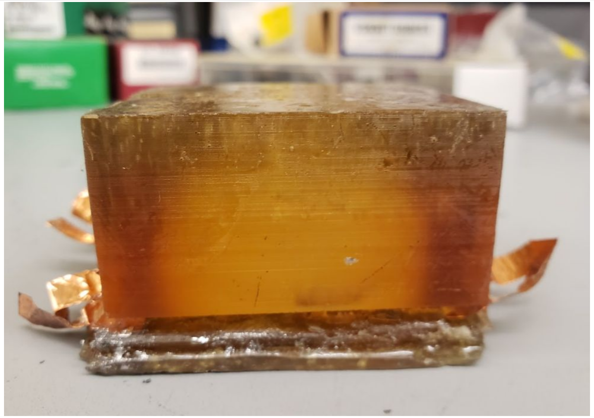


Pressure and Speed Constant while variation in Height

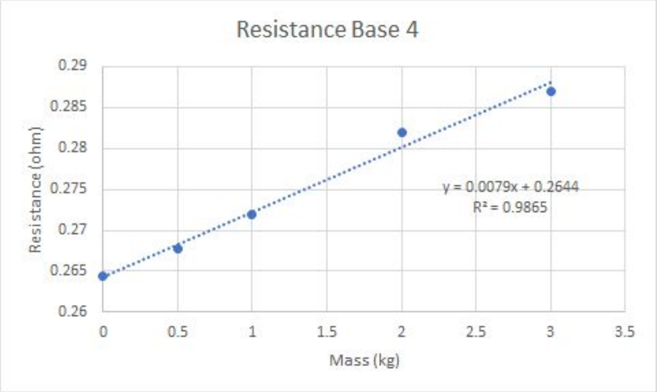
Pressure increases from left to right while height and speed constant

Fabricated Sensor Testing





Mass (Kg)	Resistance (ohm)
0	0.2644
0.5	0.2677
1	0.272
2	0.282
3	0.287



- Some of the resistors did not bond fully to the top showing weakness in our fabrication process
- Resistor returned to original value upon removal of weight so sensor possesses minimal hysteresis
- Resistance change in the shear direction

Summary of Outcomes and Possibilities for Further Research

Outcomes:

- Designed and analyzed a novel sensor configuration
- Developed a viable fabrication process for the sensor using liquid metal and polymer molding
- Built sensor capable of sensing shear and normal

Further Research Possibilities:

- More in depth study on resistance change in shear
- Use a more reliable and consistent printing method
- Scaling down the sensor

Questions?