EMBEDDED SENSING IN ELASTIC PASSIVE ACTUATORS

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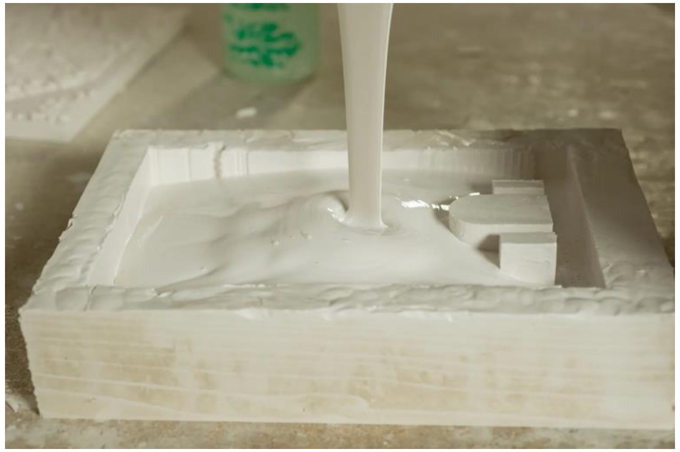
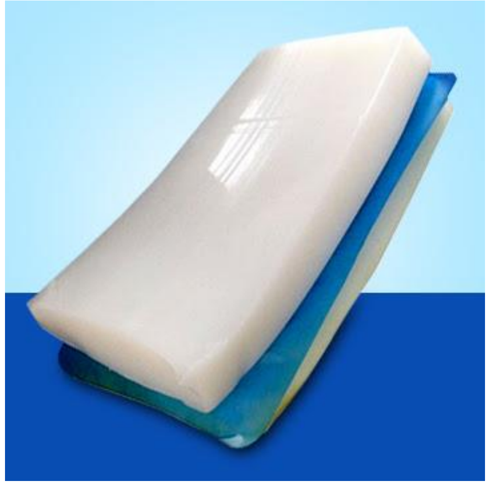
OBJECTIVE

Method of incorporating conductive material into an elastic material to reduce the need of an external sensor
Determining an elastic + conductive material that can easily composited into a passive actuator for hip assistance during active motion



Liquid latex molding Image source https://www.artnews.com



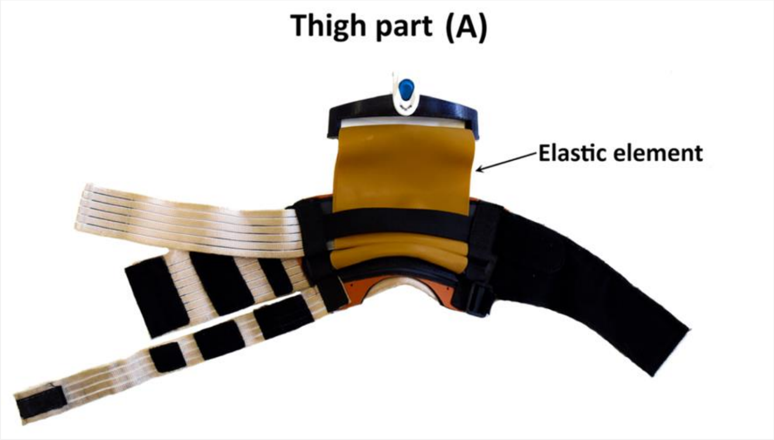
Silicon Rubber. Image source: http://www.teximinternational.com/product/silicon-rubber/

DEVELOPING METHODOLOGY:

Review of existing technology for passive actuations and current embedded sensing technology to develop a novel prototype of both elements. A basic setup to achieve such goal will be developed to create a prototype as well as a method to test mechanical and conductive properties.

CURRENT TECHNOLOGY

- Passive Actuators: use of elastic bands to support movement
- Use of external sensors for monitoring the assistance of an elastic band. Increases weight + cost of actuator



Exoband components and their working principle. Waist belt (a) and thigh part Image source from Panizzolo, F., et. al.

CURRENT TECHNOLOGY

- Embedded sensors in an elastic material. Goal is to increase the force assistance of such material to be viable in use for walking.
- Active Actuators: more often explored. Use of powered actuators Ways to improve user experience by size/placements as well as ways to be more efficient in use of actuators has been and is still being explored

Natural rubber/Pristine 2.8E-7 graphene composite strain sensor. Image source from Liu, H., Gao H., Hu, G.

Load Cell. Image source https://www.vetek.com/

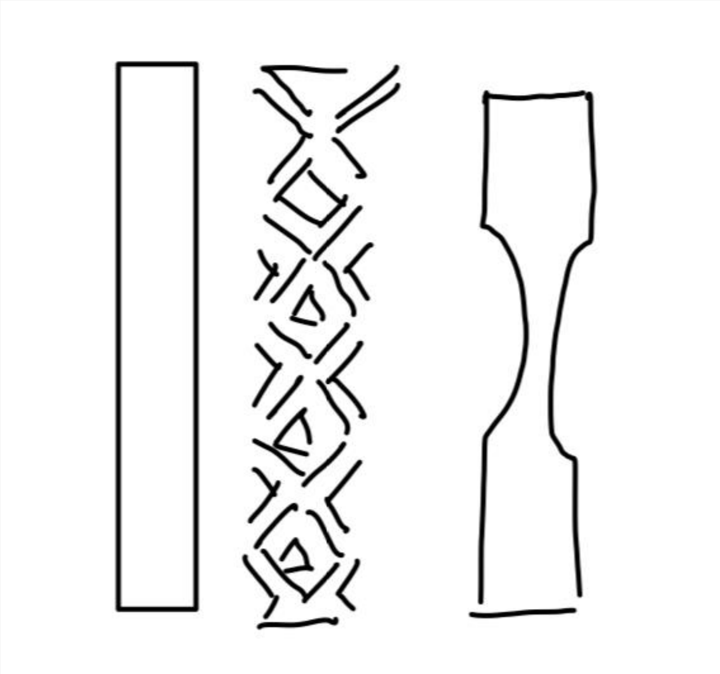
MATERIALS SELECTIONS: 3D PRINTING

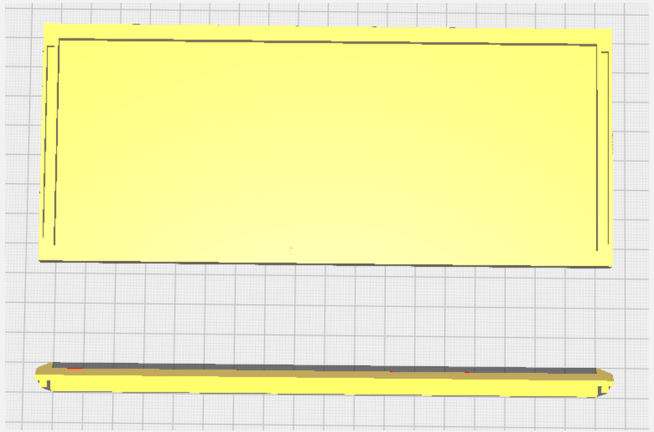
FDM printing – Creating molds to utilize different materials

SLA Printer – allows for more detailed designs to be of high quality while allowing direct integration of conductive materials. Limited by properties of available resins

Ultimaker Connect 2+ image source https://ultimaker.com/3d-printers/s-series/ultimaker-2-connect/

Saturn 3 Ultra image source https://www.elegoo.com





PROTOTYPING

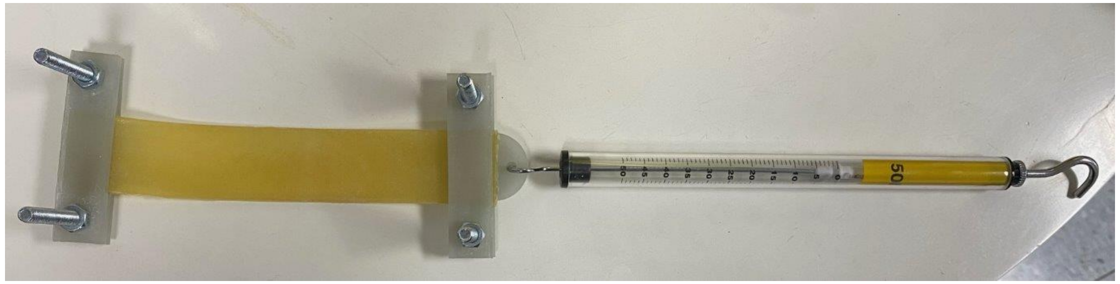
The use of 3D Printing as a means of rapid prototyping. Mold used to easily change dimensions of the band. Future works include changing geometry within the molding process

MATERIAL SELECTION: ELASTIC MATERIALS

Material	Elongation at Break	Max Tensile Strength (MPa)	Elastic modulus (GPa)	Tear Strength (N/mm)	Shore Hardness (A)
TPU	200-1000 %	48-83	.001-.05	50-100	60-95
TPE	8-2000 %	2-56.5	0.0130-2.25	20-70	65-99
Elastic Resin	100-160%	1.61-3.4	0.03	10-30	40-85
Silicon Rubber	300-1500 %	0.135-165	0.0005-0.06	15-50	10-95
Latex	700-1100%	15-30	0.001-0.01	15-30	30-90

ASSISTIVE FORCE TESTING

- Testing without Graphene determining the necessary band for required force. Serves as comparison for change due to graphene additives.
- Assumed parameters: provide an assisted for of 50 N



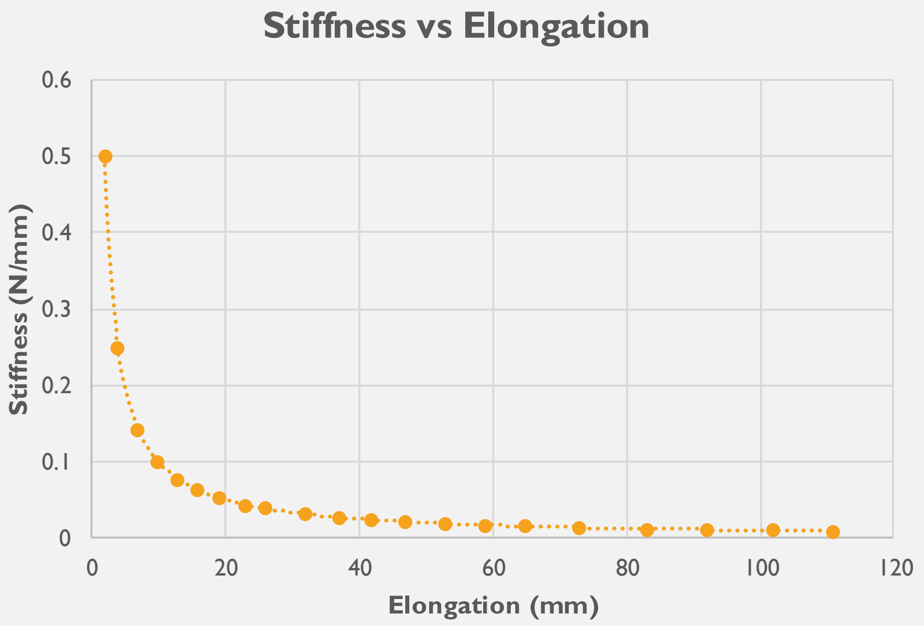
INITIAL MECHANICAL PROPERTIES TESTING

Stiffness coefficient (K): 0.07384 N/mm
Elastic modulus (E): 0.08111 MPa

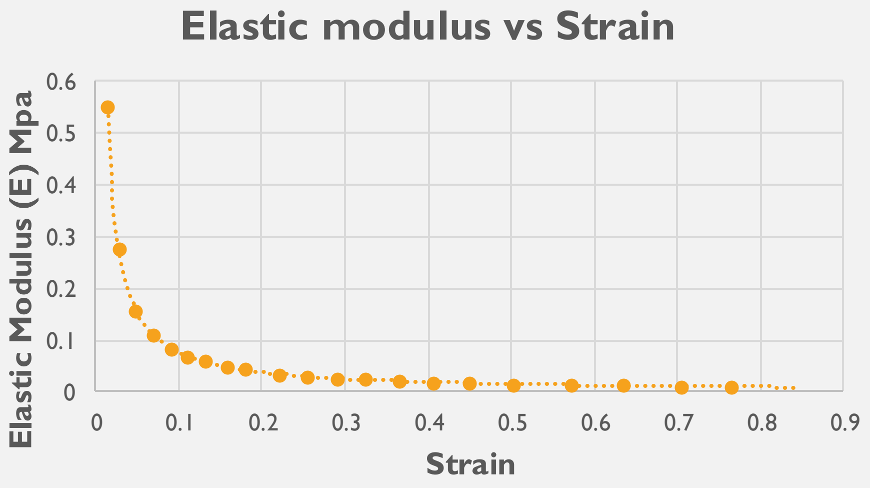
Elongation needed (Maximum flexure):
14 mm

Hooke's Law: $\sigma = E\varepsilon$

$$\frac{F}{A} = E\frac{\Delta L}{L}$$



Plot of slopes of Stiffness vs Elongation giving an average stiffness of 0.07384 N/mm



Plot of slopes of Elastic Modulus vs Strain giving an average Elastic Modulus: 0.08111 MPa

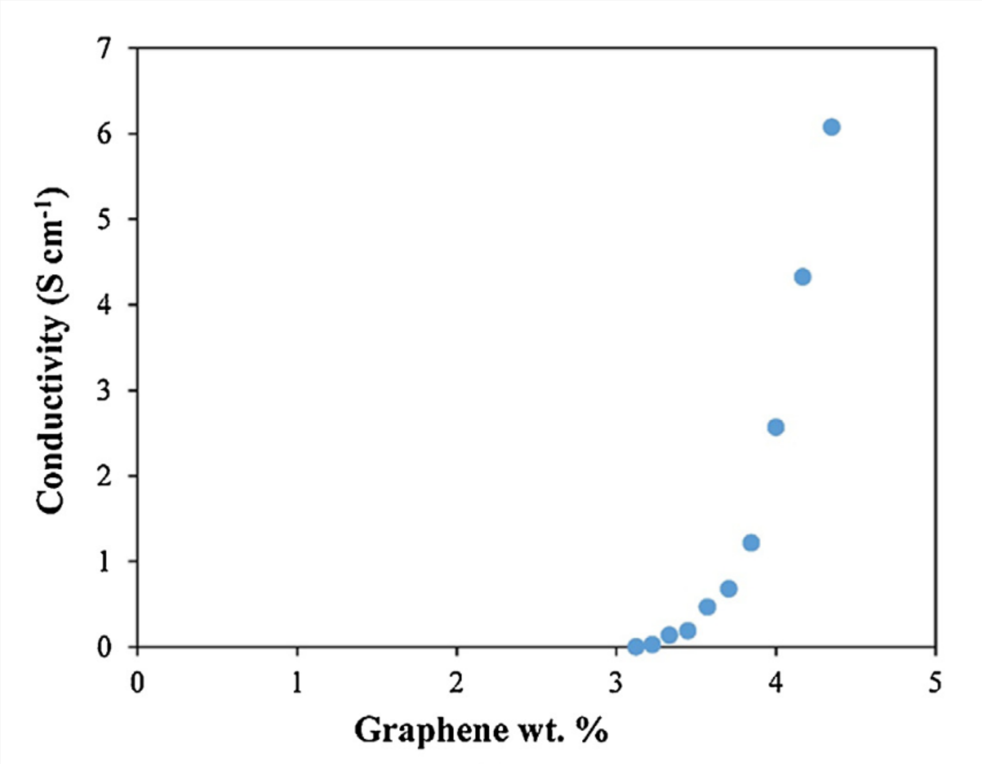
CONDUCTIVE ADDITIVE - GRAPHENE

Changes properties of elastic materials – possible to increase mechanical properties

the strongest, most electrically conductive

Different graphene loading will be tested to determine optimal mechanical and conductive properties

$$GF = \frac{\Delta R/R}{\varepsilon}$$



Conductivity of G/SR composites with different graphene wt. %, . Image source Kuriana, A. S., Mohana V. B., Bhattacharyya, D.

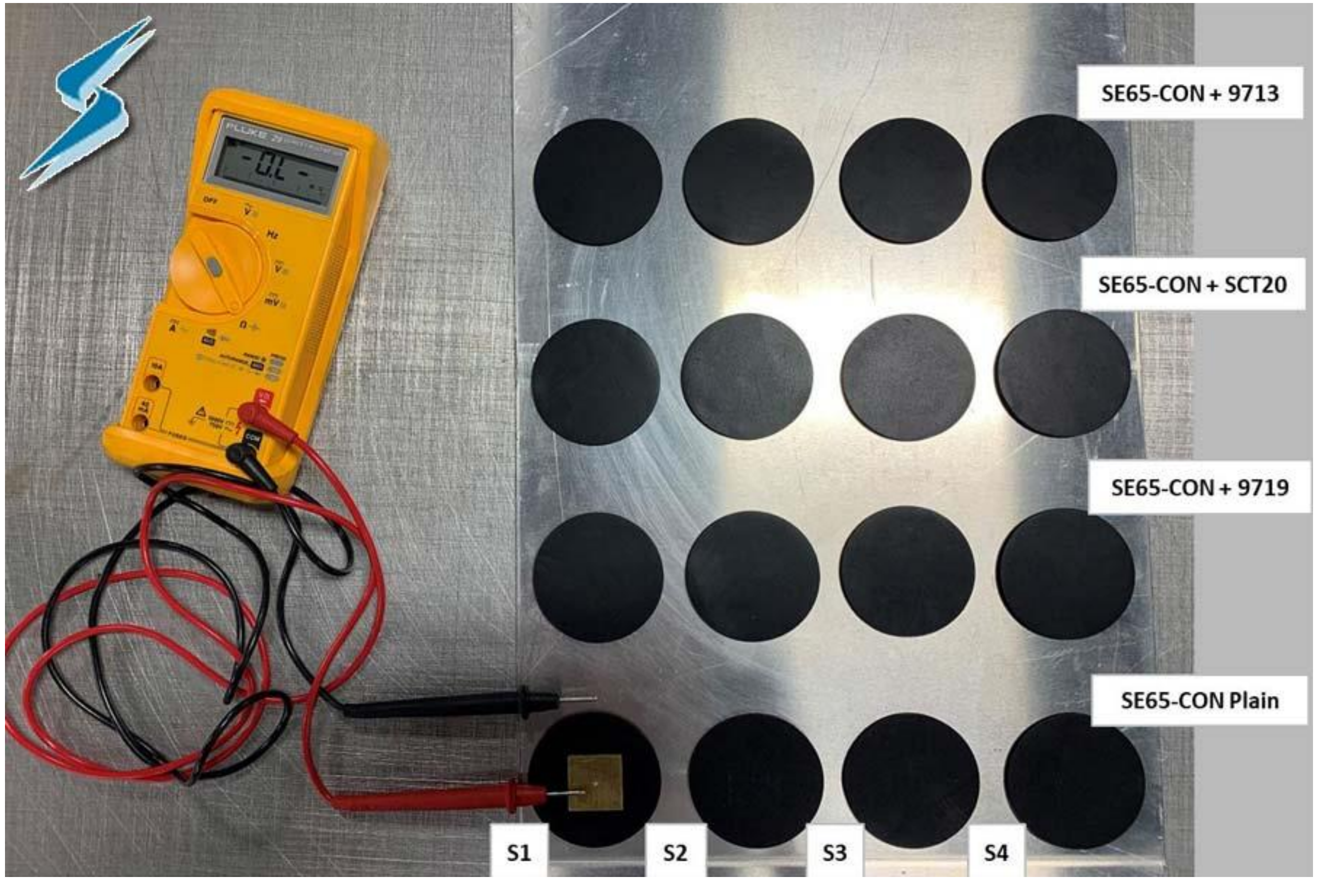
FUTURE WORK

- Conductive testing of the composite materials and finding optimal graphene loading concentration.

- Variation in band configuration to change mechanical properties (assistive force based on geometry)

CONDUCTIVITY TESTING

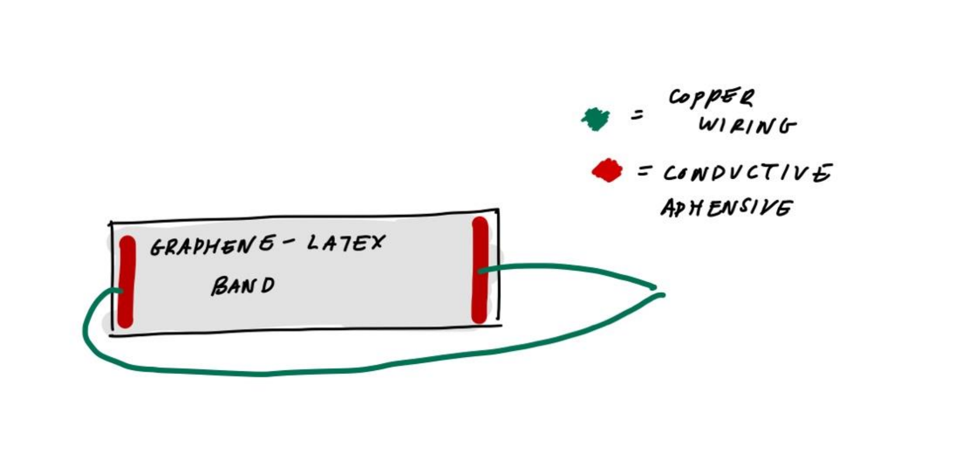
- Materials:
- Digital Voltage Meter
- Copper wiring
- Conductive adhesive



Conductive adhesive testing wuth digital voltage meter. Image source: Stockwell.com

CONDUCTIVITY TESTING

- Conductive testing to determine proper graphene concentration.
- Use of adhesive for accounting for the stretching of passive actuator.
- Configuration setup to achieve linearity for analyzing the data.



Setup for future conductive testing of the graphene/latex band

PRESENTATION ENDING

Thank You

References >>

REFERENCES

- *Blackwell Plastics, Custom Plastic Injection Molding & Extrusion Professionals* , Available at: http://www.blackwellplastics.com/TPU.html#:~:text=Physical%20Properties%3A&text=Tensile%20Strength%20%2D%206960%20to%2012000,to%2010.1%20ft%2Dlb%2Fin (Accessed: 02 May 2024).
- Che, W.M. *et al.* , "The effect of graphene loading on natural rubber latex/graphene stretchable conductive material," *IOP Conference Series: Materials Science and Engineering*, 670(1), p. 012041, 2019, doi:10.1088/1757-899x/670/1/012041.
- Jones, J. , *The properties of TPU material and its application in 3D printing*, *Affordable 3D Printing Filaments and Resins*. Available at: https://www.sunlu.com/blogs/products-knowledge/the-properties-of-tpu-material-and-its-application-in-3d-printing#:~:text=Flexibility%20and%20Elasticity&text=During%20stretching%2C%20TPU's%20soft%20segments,far%20surpassing%20that%20of%20PLA. (Accessed: 02 May 2024).
- Kurian, A., Mohan, V.B. and Bhattacharyya, D. ,"Embedded large strain sensors with graphene-carbon black-silicone rubber composites," *Sensors and Actuators A: Physical*, 282, pp. 206–214, 2018, doi:10.1016/j.sna.2018.09.017.
- Kowalczyk, K., Mukherjee, M. and Malcolm, P., "Can a passive unilateral hip exosuit diminish walking asymmetry? A randomized trial," *Journal of NeuroEngineering and Rehabilitation*, 20(1), 2023, doi:10.1186/s12984-023-01212-w.

REFERENCES

- Liu, H., Gao, H. and Hu, G., "Highly sensitive natural rubber/pristine graphene strain sensor prepared by a simple method," *Composites Part B: Engineering*, 171, pp. 138–145, 2019, doi:10.1016/j.compositesb.2019.04.032.
- Mao, Y., Wang, C. and Liu, L., "Preparation of graphene oxide/natural rubber composites by latex co-coagulation: Relationship between microstructure and reinforcement," *Chinese Journal of Chemical Engineering*, 28(4), pp. 1187–1193, 2020, doi:10.1016/j.cjche.2020.01.015.
- Pagac, M. *et al*., "A review of VAT photopolymerization technology: Materials, applications, challenges, and future trends of 3D printing," *Polymers*, 13(4), p. 598, 2021, doi:10.3390/polym13040598.
- Panizzolo, F.A. *et al*., "Reducing the energy cost of walking in older adults using a passive hip flexion device", *Journal of NeuroEngineering and Rehabilitation*, 16(1), 2019, doi:10.1186/s12984-019-0599-4.
- Sanz-Pena, I., Hopkins, M., Carrero, N. R., Xu H., "Embedded Pressure Sensing Metamaterials Using TPU-Graphene Composites and Additive Manufacturing," in IEEE Sensors Journal, vol. 23, no. 15, pp. 16656-16664, 1 Aug.1, 2023, doi: 10.1109/JSEN.2023.3283460.