Smart 3D Prints

University of Victoria

Chase Swanson, Abigail Drews, Sravya Tekumalla*, Bosco Yu*

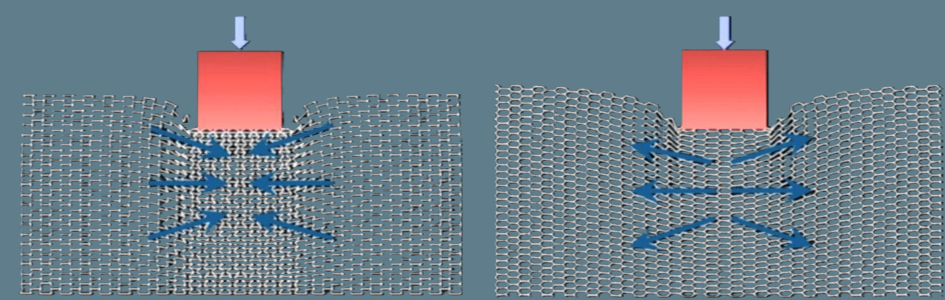
SMART Sustainable Metal Additive Research Team

Hybrid 3D Lab

Introduction

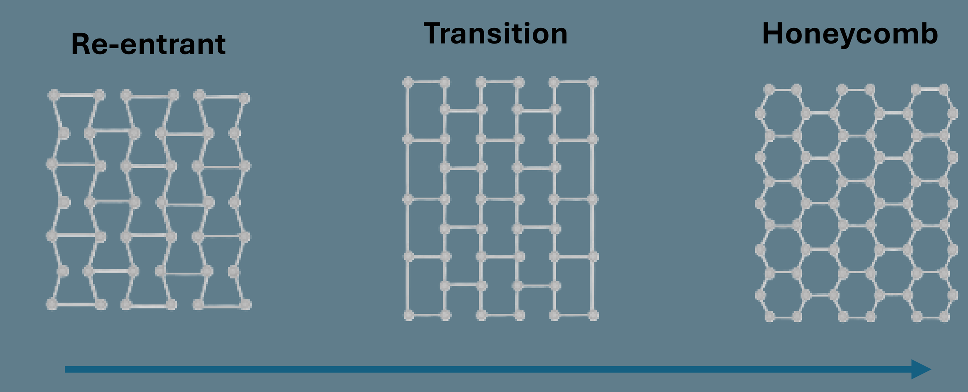
Background

Architected lattice structures enable tunable mechanical behavior through geometric design, offering lightweight systems with tailored stiffness and energy absorption. Conventional honeycomb geometries provide high structural rigidity, while re-entrant lattices accommodate larger deformation through ligament rotation mechanisms. When fabricated using shape memory polymers (SMPs), these structures gain thermally activated reconfiguration capabilities, enabling adaptive and recoverable mechanical systems.



Re-entrant Honeycomb   Honeycomb   [1]

Deformation Process of Re-entrant Honeycomb

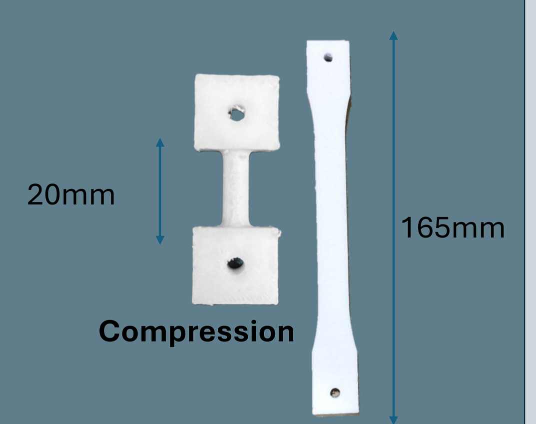


Research Objective

- Design and 3D print a re-entrant honeycomb lattice using a thermally activated shape memory polymer (SMP).
- Experimentally demonstrate thermally induced shape programming and recovery of the lattice structure.
- Characterize the mechanical properties of the SMP material prior to lattice testing.
- Evaluate repeatability and stability of the shape memory response over multiple activation cycles.
- Establish a proof-of-concept framework for thermally reconfigurable lattice structures.

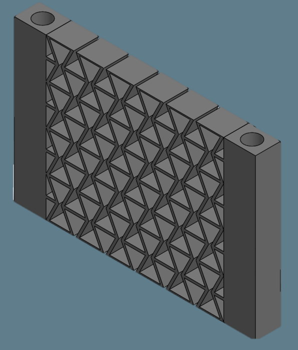
Material Characterization

Material	3D printing SMP Filament
Elastic Modulus:	510 MPa
0.2% Yield Stress:	32.82 MPa
Density:	1039.96 $\frac{Kg}{m^3}$
Program Temperature:	$> 60°C$
Set Temperature:	$< 30°C$

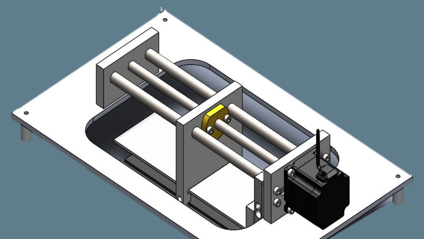


Design

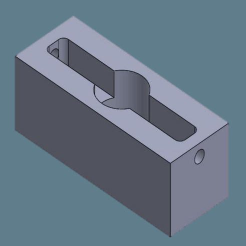
3D Printing of Lattice
All lattices were 3D printed using a Bamboo Lab P1S printer with careful tuning of print settings.



Displacement Jig
Developed to accurately and repeatably deform the samples while submerged in a heated water bath at constant temperature.



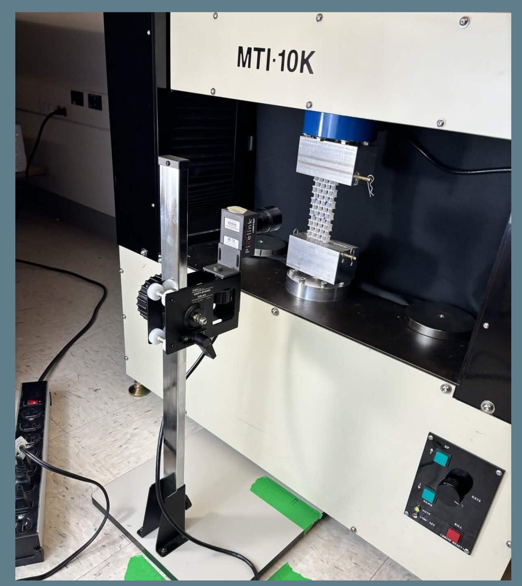
Material Properties of SMP
Before and after the deformation process occurs, the material is characterized using an MTI machine in both tension and compression, using a custom designed mounting block.



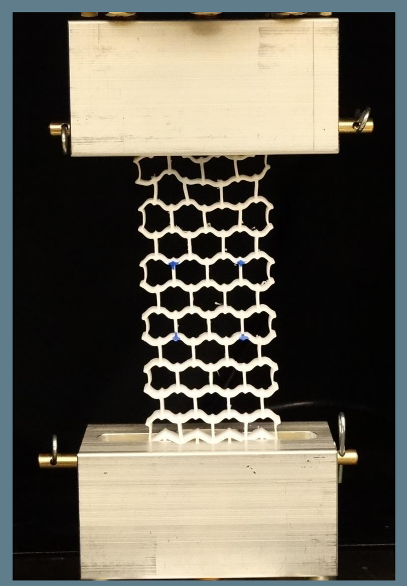
Data Collection
During the deformation process the sample is continuously photographed to characterize its deformation path, strain, and Poisson ratio throughout the process and final state.

Results & Discussion

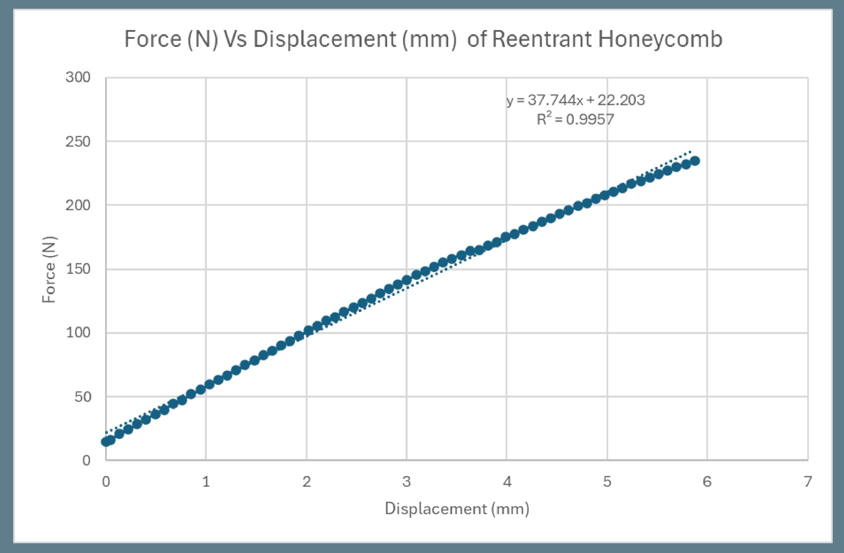
Displacement Jig



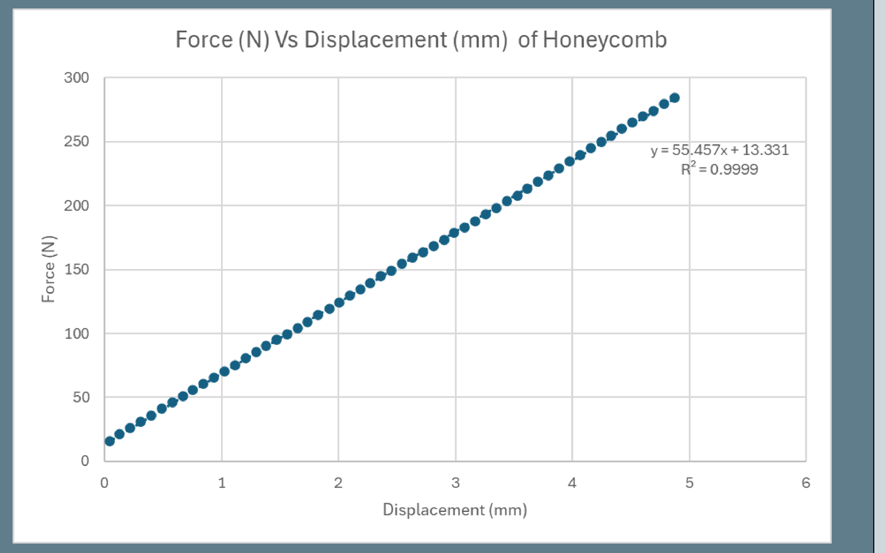
Testing Setup



Material Testing



- Stiffness (K) $= 37.744 \frac{N}{mm}$
- Work (U) $= 0.780\ J$
- Key Takeaway: Low stiffness allows for greater displacement, resulting in higher total energy absorption.



- Stiffness (K) $= 55.457 \frac{N}{mm}$
- Work (U) $= 0.722\ J$
- Key Takeaway: Stiff structural response but low total energy absorption.

Our testing revealed that while the Honeycomb structure exhibited 64% higher stiffness (K), the Re-entrant Honeycomb demonstrated superior energy storage, absorbing 8% more Work (U). This largely aligns with theoretical expectations. These results suggest that it is possible to create a 3D printed SMP architected lattice structures which can transform between different mechanical properties.

*Detailed data available upon publication.

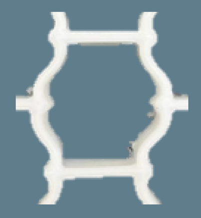
Future Work

Comparative analysis of Deformed honeycomb with traditional Honeycomb

- Compare a printed honeycomb to the deformed honeycomb to show the relative material properties.

Optimize Node Geometry for reliable Phase Transition

- Improve the node radii to ensure a more accurate transition between re-entrant and honeycomb states.



Post Deformation Honeycomb Geometry

Thermal Mechanical Cycling Analysis

- Preform a series of heating/cooling cycles to quantify durability, hysteresis, fatigue, and long-term shape memory performance.

Investigate applications

- Personal Protective Equipment. [3]
- Mechanical Actuators.
- Biomedical Applications. [2]

Acknowledgement

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References

[1] X. Xue, C. Lin, F. Wu, Z. Li and J. Liao, "Lattice structures with negative Poisson's ratio: A review," *Journal name unknown*. Received 21-Oct-2022; revised 30-Nov-2022; accepted 08-Dec-2022; Available online 09-Dec-2022, Version of Record 12-Dec- 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352492822019730

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