

Thermomechanical Properties of Architected Materials

Renato Villacres, Cecilia D. Treviño Quintanilla, Guillermo Sotelo Flores and Benjamín A. Moreno Núñez

Renato Villacres ^a, Guillermo Sotelo^b, Cecilia D. Treviño-Quintanilla ^a and Benjamín A. Moreno-Núñez ^a.

^aSchool of Engineering and Sciences, Tecnológico de Monterrey, Queretaro, Mexico, ^bDivisión de Materiales Avanzados, Instituto Potosino de Investigación Científica y Tecnológica (IPICYT), ^cInstitute of Advanced Materials for Sustainable Manufacturing, Tecnológico de Monterrey, Queretaro, Mexico

Problem solving

PROBLEM STATEMENT

- EV demand is rising → higher risk of thermal runaway .
- Passive heat-dissipation materials are needed → lightweight + thermally efficient + mechanically stable.
- TPMS architected structures show potential → but their real performance in polymers is unknown

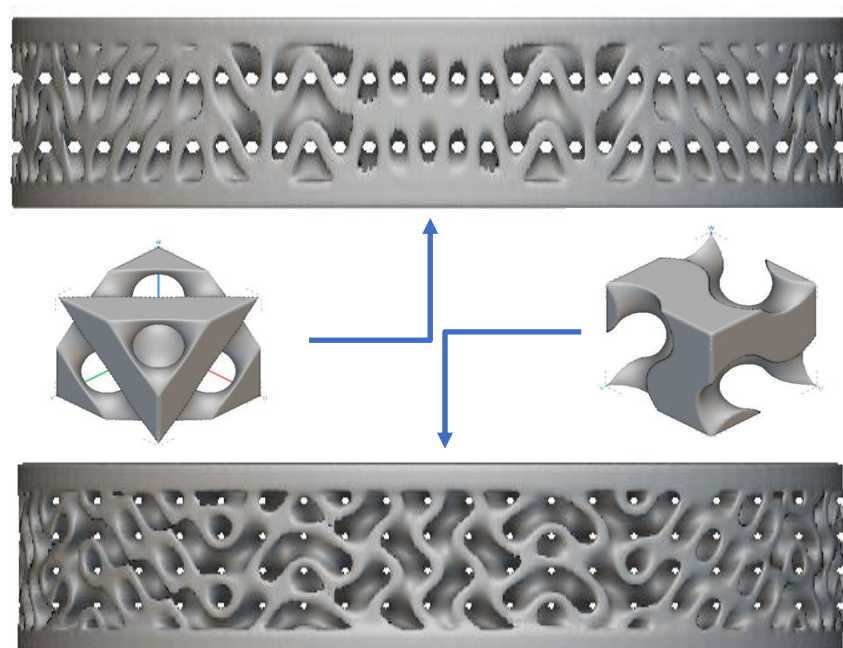
GENERAL OBJECTIVE

Thermo-mechanically characterize architected porous TPMS samples (Onyx and Diamond) manufactured in Onyx and Nylon, determining how topology and base material influence their effective thermal conductivity and mechanical performance.

SPECIFIC OBJECTIVES

- To **design** Gyroid and Diamond TPMS test samples.
- To **build** a functional thermal conductivity testing apparatus.
- To **3D-print** architected samples in Onyx and Nylon.
- To **perform** thermal and mechanical testing on each sample.
- To **compare** performance across materials and topologies.

Methodology



CAD Desing & Modeling

Gyroid and Diamond TPMs structures were modeled using nTOP software with controlled porosity and fixed geometry.

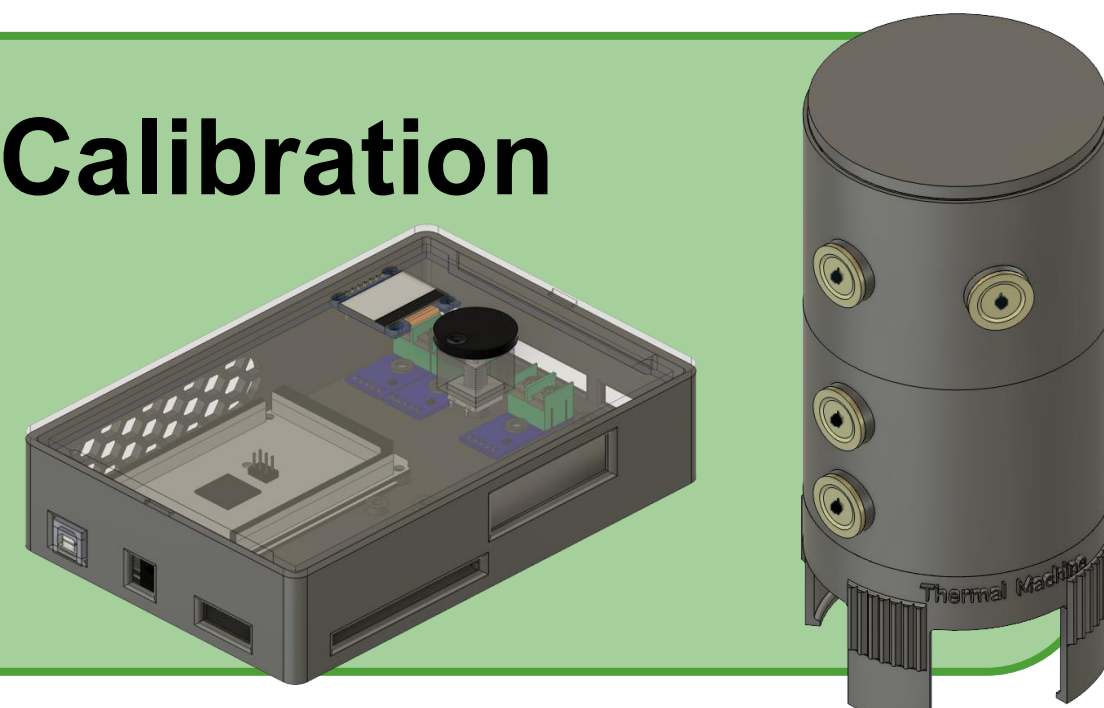
Sample Preparation

7mm samples were printed in Onyx and Nylon using consistend and conrolled surface layers.



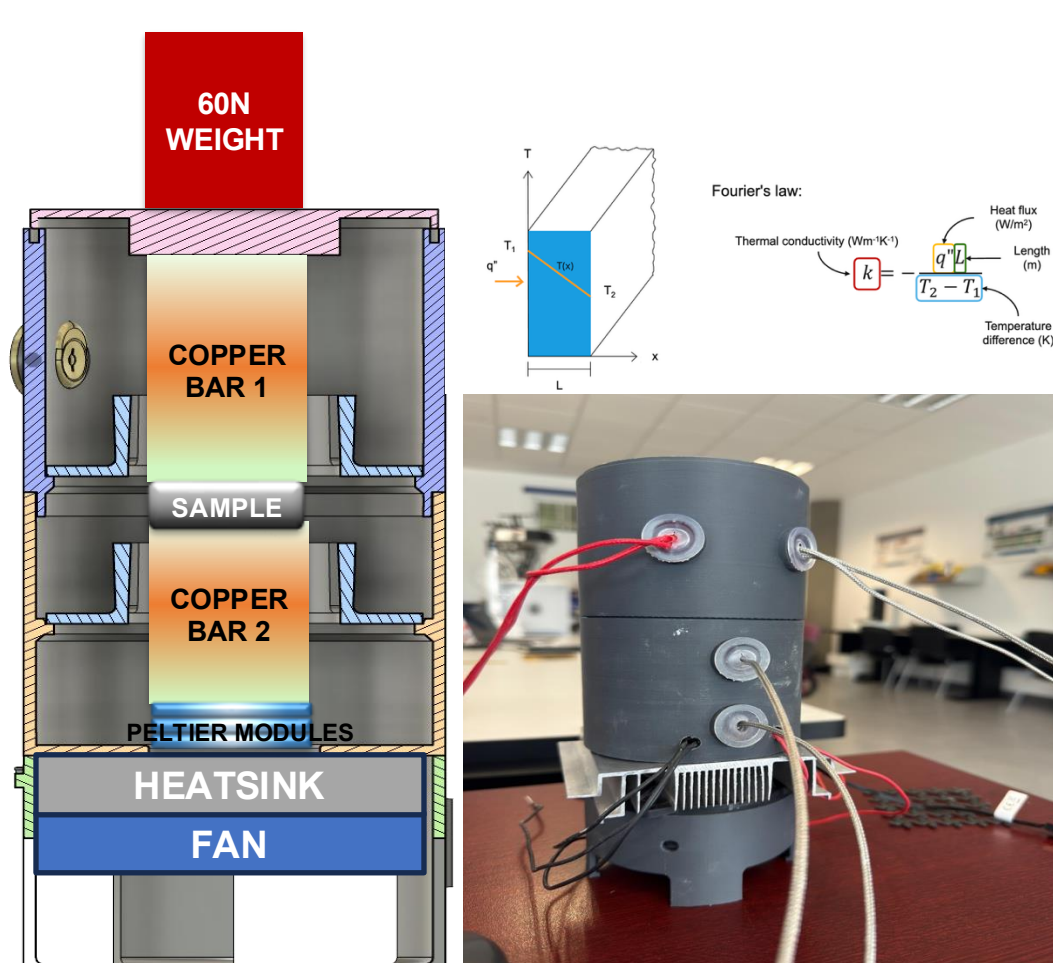
Machine Design Assembly & Calibration

A custom thermal conduction testing device was desingn and assembled using copper bars, abs guards, thermocouples, peliters, fan, heatsink and circuits casing.



Thermal Conductivity Testing

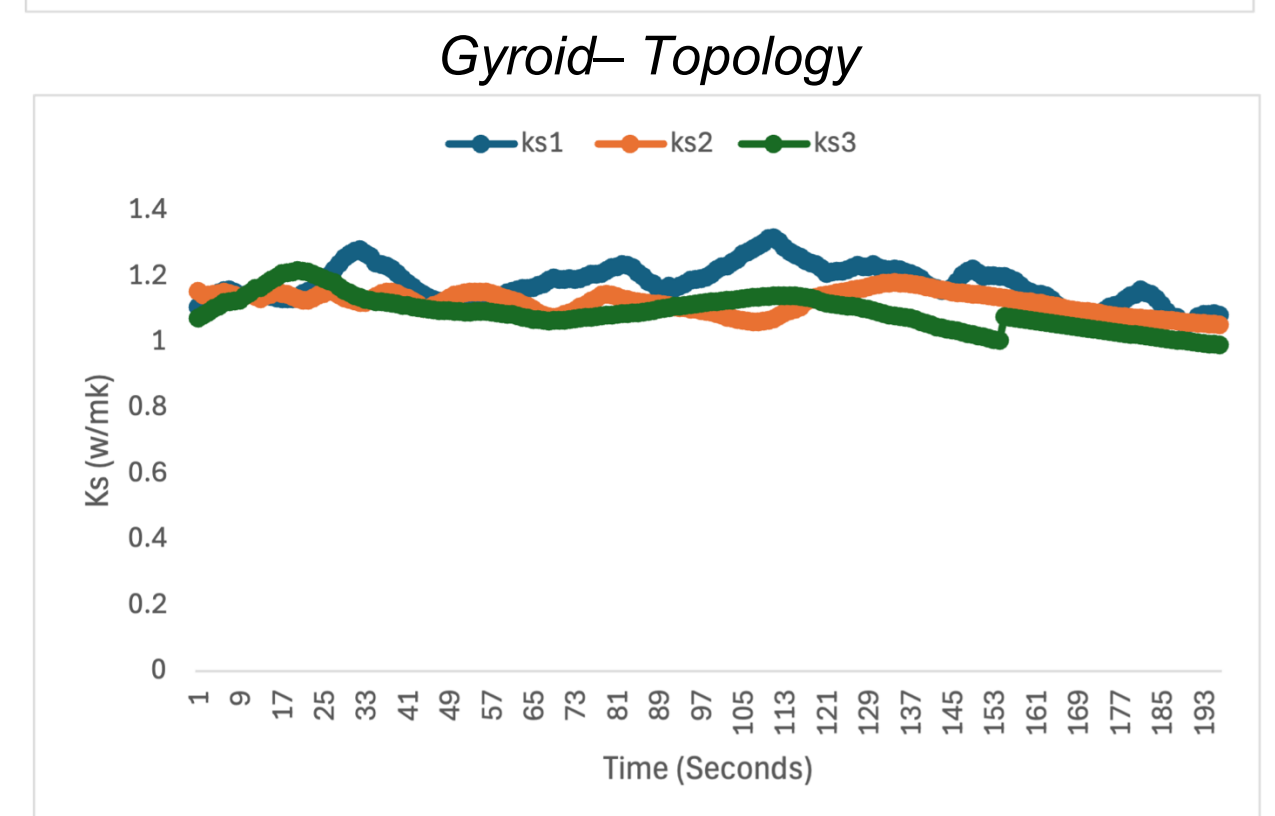
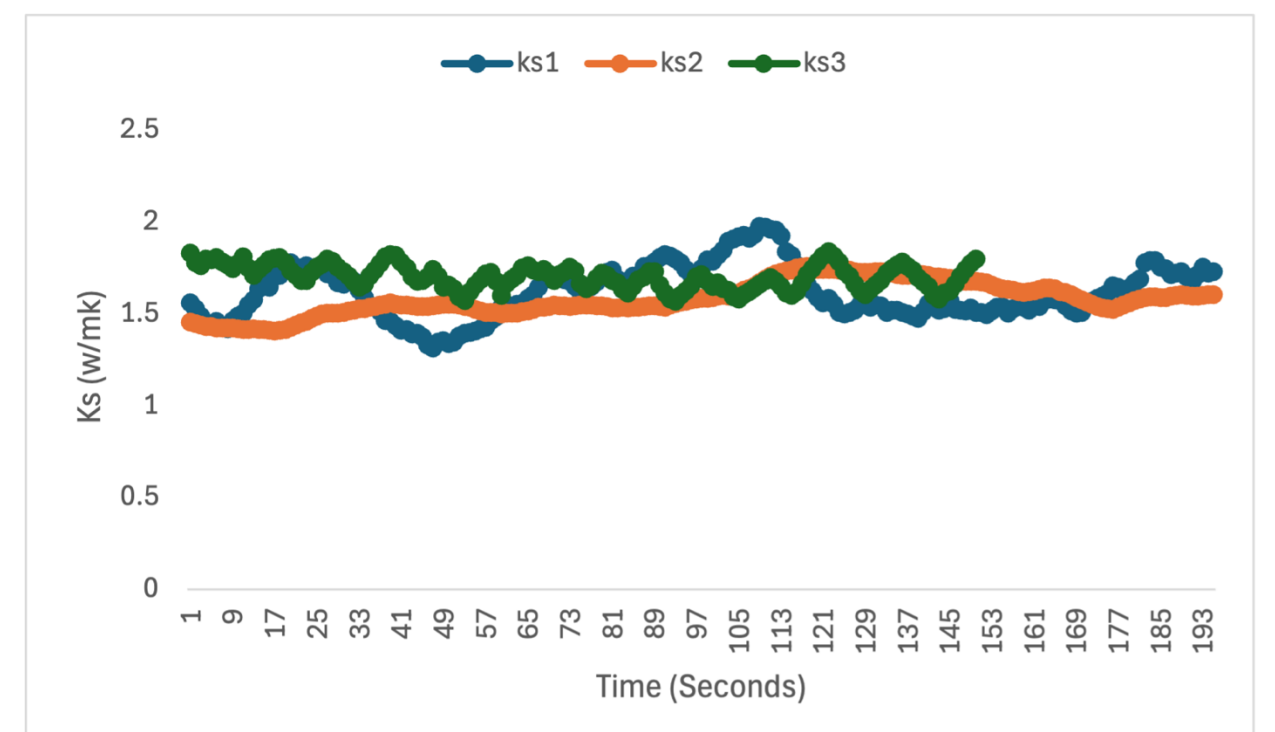
Samples were clamped between heated and cooled copper bars under a controlled 60 N load to ensure consistent thermal contact. Thermocouples embedded in the bars monitored the temperature gradient until steady-state was reached, allowing effective conductivity to be calculated. A guard assembly minimized radial losses and enforced one-directional heat flow. Each run lasted ~200 seconds, and a 60-second moving average was applied to suppress thermocouple noise. System calibration was performed before testing to verify bar alignment, contact resistance, and sensor response.



Results and contribution

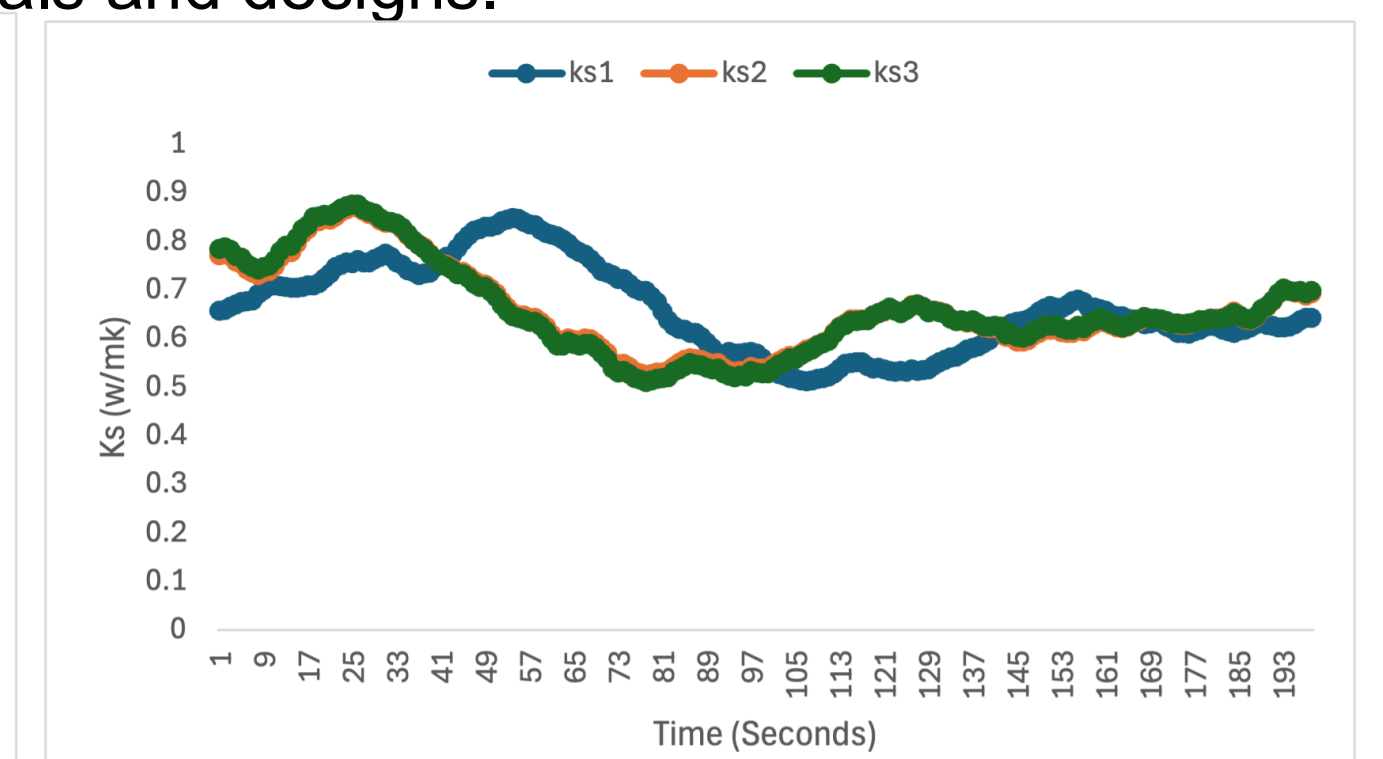
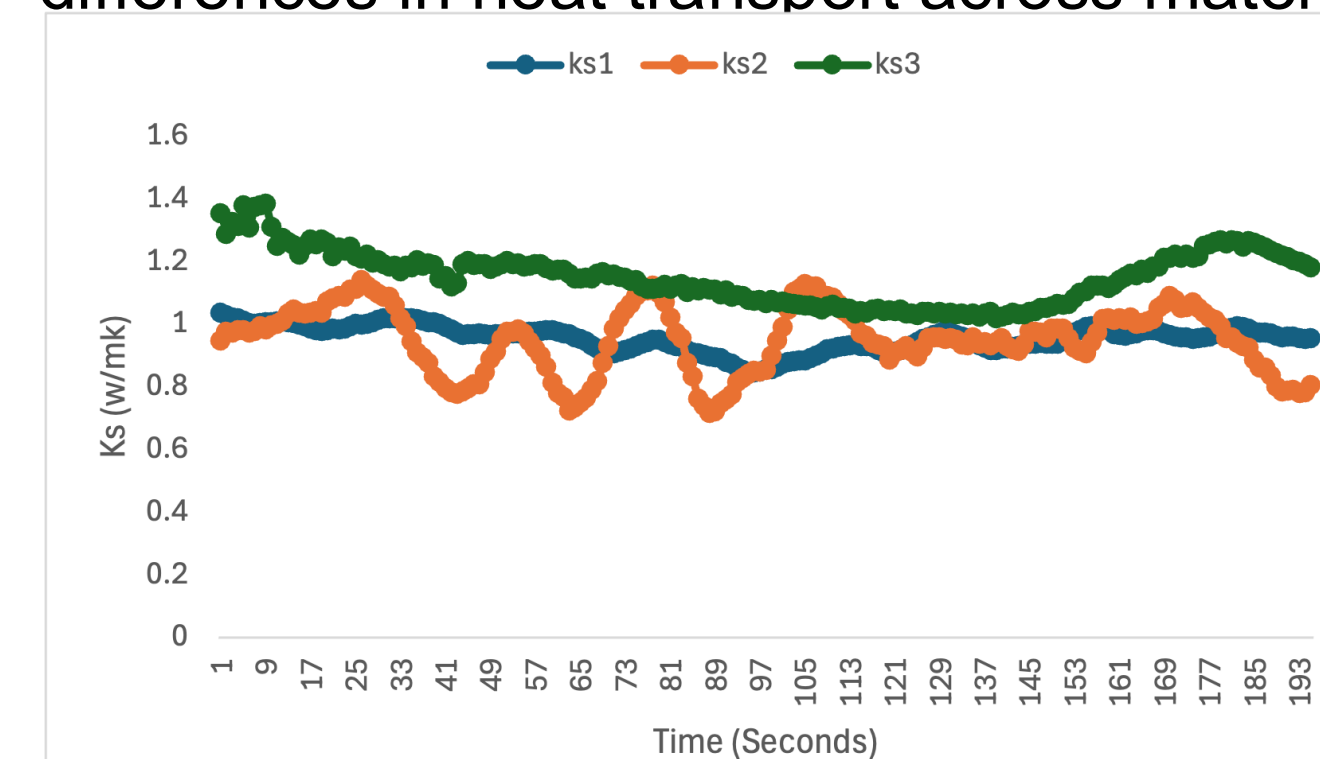
Onyx Thermal Testing Results

For Onyx, the thermal results reveal stable and repeatable conduction behavior across both architected topologies. After applying a 60-second moving average to suppress intrinsic signal noise, the Gyroid samples converged to an average effective thermal conductivity (K_s) of approximately 1.605 W/m·K, confirming that this topology promotes smoother and more continuous heat-flow pathways. The Diamond samples, while still stable, reached a lower mean conductivity of ~1.033 W/m·K, indicating that its geometry presents slightly higher resistance to heat transport. Despite the difference in magnitude, both topologies showed tight run-to-run alignment, validating good manufacturing repeatability, strong machine reliability, and effective thermal contact.



Nylon Thermal Testing Results

For Nylon, lower values were expected based on its intrinsic thermal properties, yet the results remained coherent and topology-dependent. The Gyroid-Nylon configuration stabilized at an average conductivity (K_s) of ~1.039 W/m·K, mirroring its Onyx counterpart in relative trend but at reduced magnitude. The Diamond-Nylon samples produced the lowest mean conductivity of ~0.694 W/m·K, reflecting both the lower conductivity of Nylon and the increased pathway resistance of the Diamond architecture. Despite the smaller gradients involved, the repeatability between runs remained consistent, reinforcing that the platform can resolve subtle differences in heat transport across materials and designs.



Conclusions

- The upgraded apparatus produced repeatable thermal measurements across materials and topologies, validating its functional reliability. Thermal conductivity calculations were highly dependent on thermocouple readings and equation sensitivity, making results susceptible to noise, hence the use of 60-second smoothing to stabilize interpretation.
- Onyx Gyroid structures reached an average of ~1.60 W/m·K, about 55% higher than Onyx Diamond (~1.03 W/m·K), showing topology significantly influences heat transport.
- Nylon Gyroid samples averaged ~1.04 W/m·K, roughly 50% higher than Nylon Diamond (~0.69 W/m·K), echoing the geometry-dependence across materials.
- Across both materials, Onyx consistently exhibited ~35–50% higher thermal conductivity than Nylon for a given topology, suggesting a clear material-geometry interaction effect.

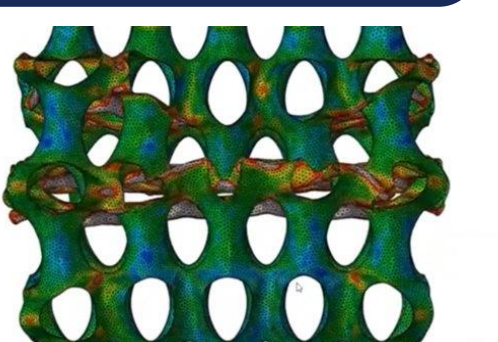
Future Work

First stage of the project:

- FEA to validate the results from the strain energy.

- FEA to validate the thermomechanical results from the architected materials.

- Test the thermomechanical properties of new topologies.



Second stage of the project:

- Adapt the best architected material to battery cases at a small scale and test them against high temperatures and impacts to reducing the probability of a thermal hazard to occur in LIB.

