Silicone Foam Development for Thermal Management in Electric Vehicles

Rodolfo Martinez & Jessica Lavorata

Department of Engineering, Carthage College

CARTHAGE COLLEGE

CELEBRATION of SCHOLARS

Introduction

This research aims to develop a cost-effective and easily manufacturable material solution to prevent heat propagation during a thermal runaway event in an electric vehicle battery (**Figure 1**), ensuring passenger safety. Silicone foam was investigated as a potential barrier material through characterization and fabrication.

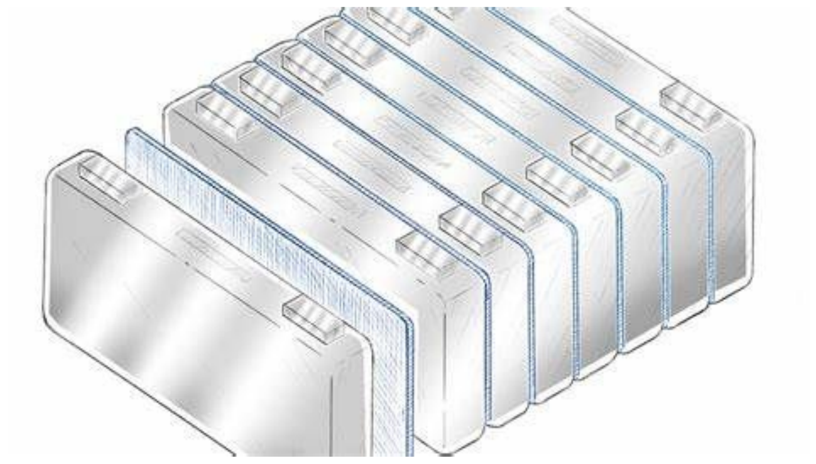


Figure 1. Battery Pack Anatomy

Methods

Requirements

- Cost-effective fabrication and assembly process
- Thickness requirement of 6.7mm @ 25kPa (3.63 PSI)
  - Composite (structural support) : 2.5mm
  - Silicone Foam (thermal barrier) : 2 x 2.1mm
- Minimize heat transfer to adjacent cells

Fabrication

Two methods were used for the fabrication of the silicone foam.

Method 1: **mold** - constrained. The silicone was poured into a mold and clamped to contain the silicone to a uniform thickness.

Method 2: **rolled** - unconstrained. The silicone was poured then flattened using a roller. After curing was cut to size (**Figure 3**).

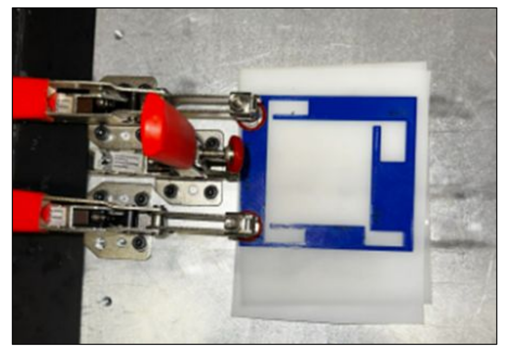


Figure 2. Foam Fabrication set up for Mold 2mm samples.

Figure 3. Foam Fabrication set up for Rolled 2mm samples.

Material Characterization

- Density
  - ASTM C303-21
- Hardness
  - Durometer Shore 00 using ASTM D2240
- Heat Capacity
  - Differential Scanning Calorimeter (DSC) using ASTM E1269
- Thermal Stability
  - Thermogravimetric analyzers (TGA) using ASTM E2550
- Thermal Conductivity
  - C Therm machine, using ASTM E2550 & MTPS method
- Compression
  - Instron using ASTM D3574 Test C
- Hot-side Cold-side
  - Representative test to simulate thermal event propagation

Results and Discussion

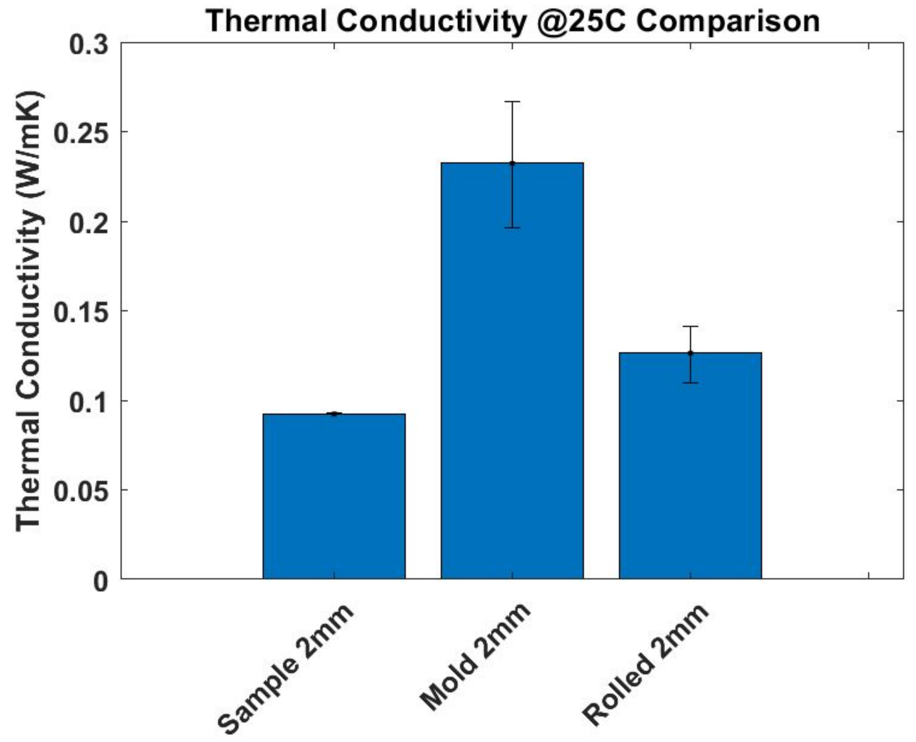


Figure 4. Thermal Conductivity test results using ASTM D7984, MTPS method. Low conductivity is desired to slow heat transfer to adjacent cells, reducing the risk of thermal runaway.

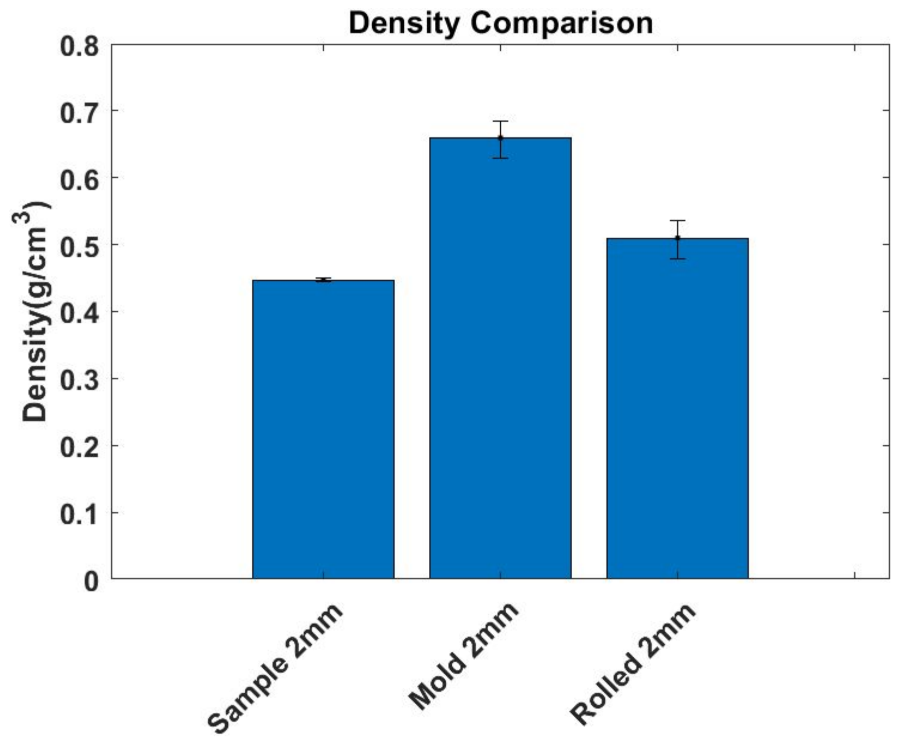


Figure 5. Density comparison results using ASTM C303-21. Low density is desired to improve thermal insulative properties.

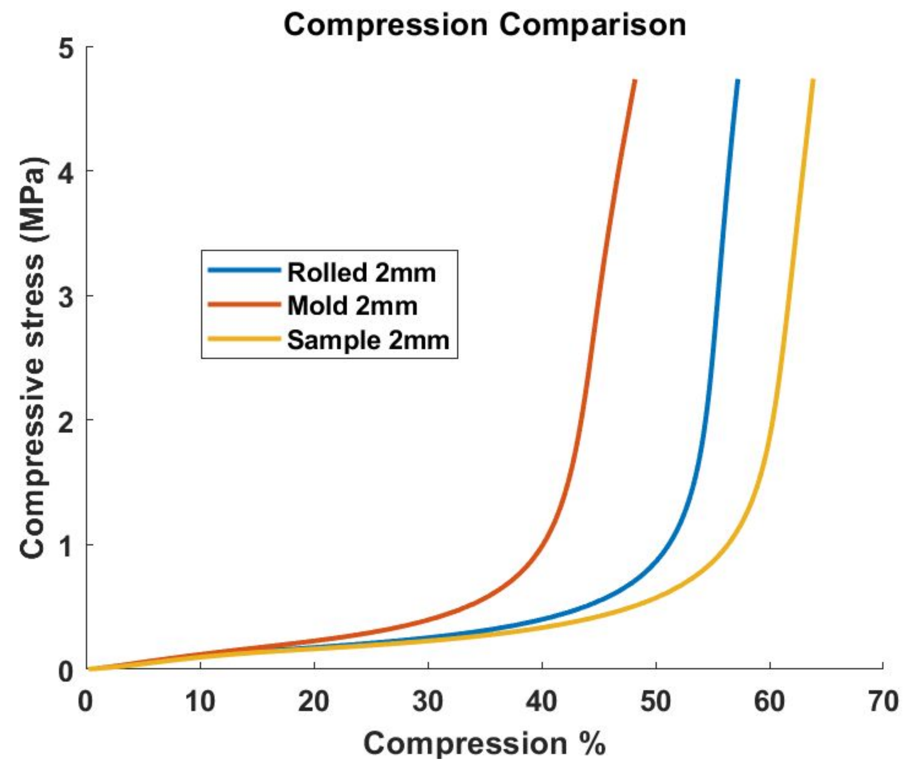


Figure 6. Compression test results using ASTM D3574 Test C. Low compressibility is desirable to slow heat transfer to adjacent cells.

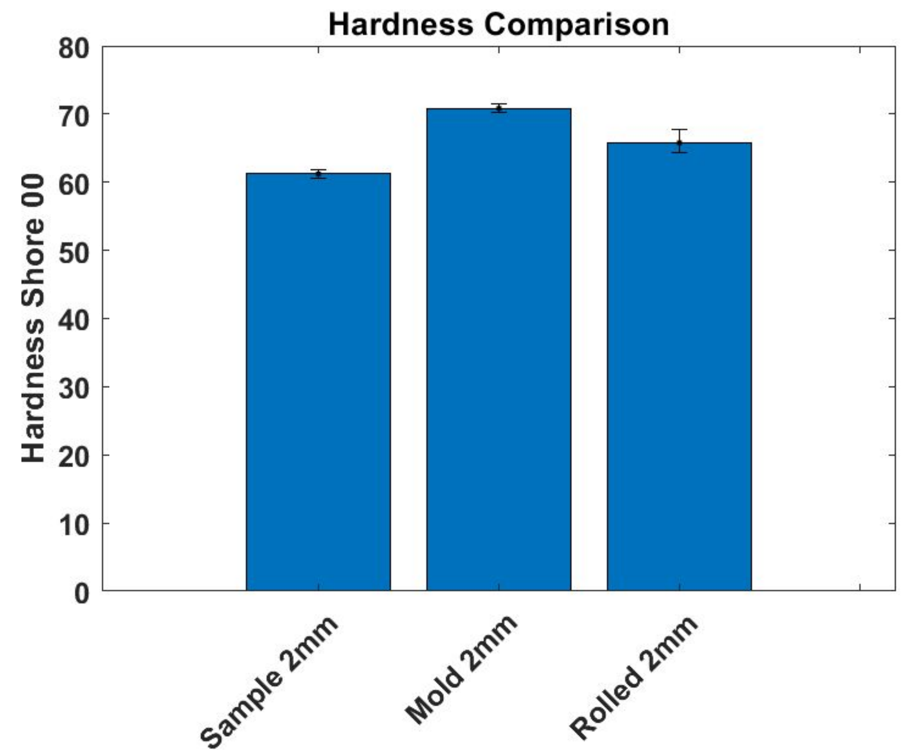
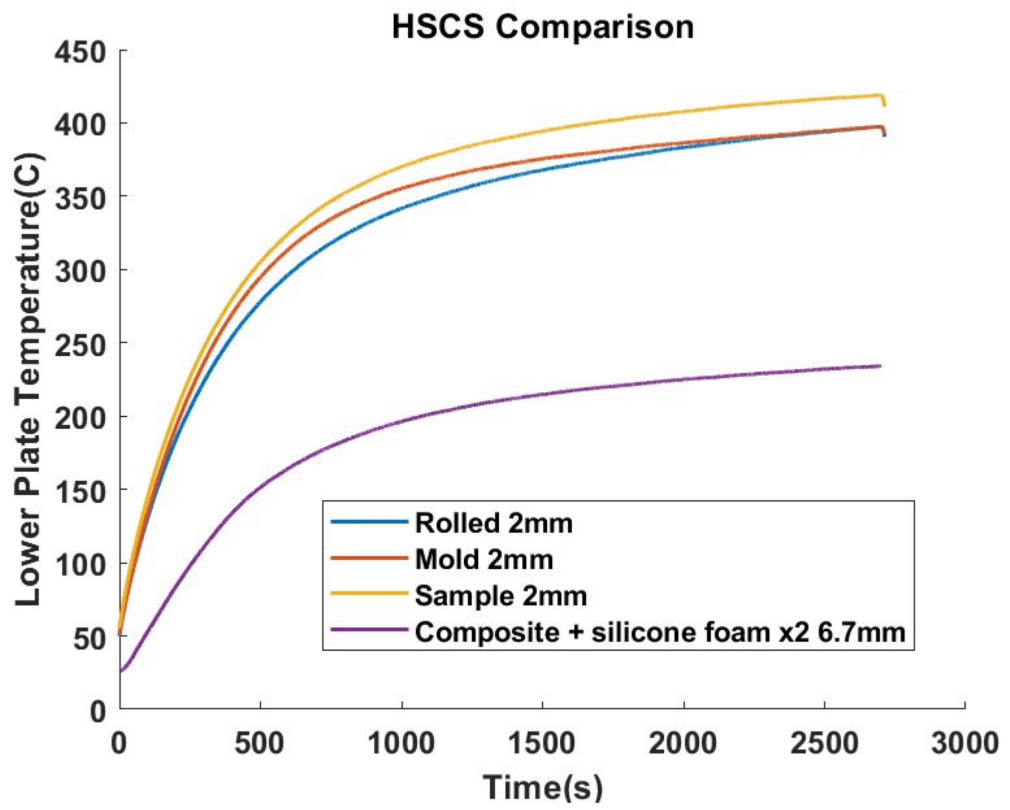


Figure 7. Hardness comparison results using ASTM D2240 as well as the Durometer Shore 00. Higher hardness is desirable for a lower compressibility.



Sample Type	20 minutes	45 minutes
Rolled 2mm	354.1 C	390.4 C
Mold 2mm	365.2 C	391.9 C
Sample 2mm	382.1 C	410.9 C
Composite + silicone foam x2	205.3 C	234.1 C

Figure 8. Hot-side Cold-side test results. The results help determine which fabrication method returned the best performance. From there we are able to examine the samples properties to determine what properties most effectively slow down heat transfer.

During our research, we observed a consistent relationship between density and various properties of the silicone foam. Specifically, thermal conductivity increased with density, as shown in **Figures 4 & 5**. Similarly, hardness and density exhibited a direct relationship, as demonstrated in **Figures 7 & 5**. However, compression behaved differently, displaying an inverse relationship with density, as illustrated in **Figures 5 & 6**.

These findings indicate that by controlling the density, we can effectively tune the foam's properties. We discovered that greater constraint during fabrication resulted in higher-density foam. This explains why the Mold Method produced denser samples compared to the Rolled Method.

When testing different samples using the Hot-side Cold-side Machine, the results were unexpected. Typically, a material with the same dimensions and higher thermal conductivity would transfer heat more efficiently. However, the results shown in **Figure 8** do not reflect this trend. Instead, samples with higher thermal conductivity performed better than those with lower thermal conductivity due to differences in compressibility. More compressible samples exhibited poorer thermal performance, suggesting that mechanical properties significantly influence heat transfer behavior.

Conclusions

Overall, silicone foam still needs further development to achieve the requirements needed to be a viable thermal barrier solution. Further tests, such as high temperature thermal conductivity, Torch and Grit, and adhesion testing will inform decisions for how to optimize the foam to achieve a cost effective thermal barrier solution.

Acknowledgements

This research was funded by, and performed at, the Ford Research and Innovation center in Dearborn, MI. Special thanks to Patrick Blanchard, Jaewon Yoon & Jeffrey Dahl for their valuable guidance, support, and collaboration.