Large Scale Production and Customization of Thermal Management Devices for Semiconductor Applications using Continuous Liquid Interface Production (CLIP)

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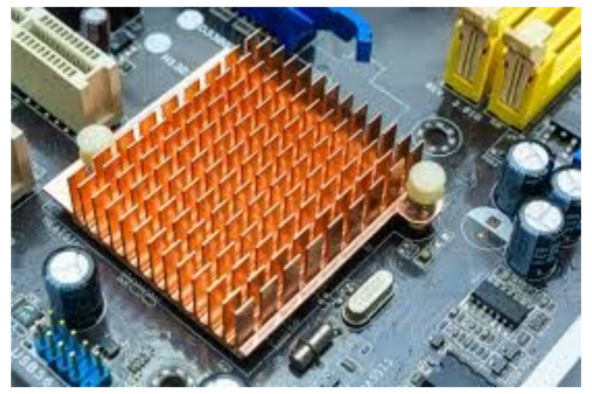
1. Background

As semiconductors shrink and power density increases according to Moore's law, managing the resulting heat has become a critical engineering challenge. While Metal Additive Manufacturing (MAM) offers the ability to print complex, high-conductivity geometries, traditional 3D printing is often too slow and lacks the resolution required for microscale applications. To overcome these barriers, we utilize Continuous Liquid Interface Production (CLIP). This layerless approach allows for the rapid, scalable fabrication of intricate microscale heat sinks with smooth surface finishes. By integrating thermal simulations with experimental validation, this research aims to optimize and mass-produce customized thermal management devices, ensuring peak performance for next-generation electronics.



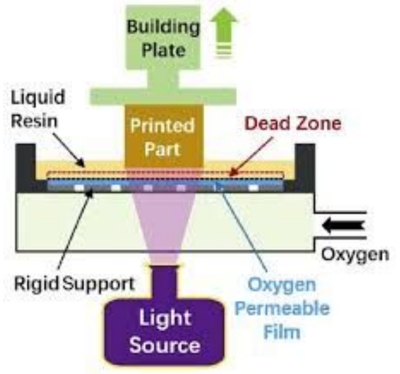


Fig 1: Thermal Management Device on Circuitboard (left), CLIP printing (right)

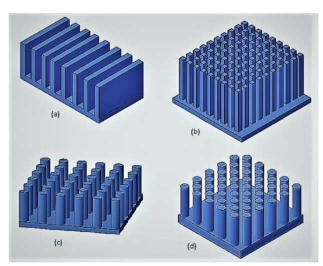
2. Objectives

- Develop geometrically complex heat sink architectures using advanced CAD software, specifically tailored for additive manufacturing constraints
- Systematically identify the optimal printing speeds and grayscale parameters to achieve high-resolution, structurally sound micro-architectures.
- Heat sinks with different design geometries will be place on a simulated framework to predict thermal performance on a circuit board
- Fabricate wide range of heat sinks with different design parameters in a single batch production using layerless metal AM

3. Methodology

1. **Creation of 3D Optimized Heat Sink utilizing CAD**

By replacing traditional manufacturing with CAD-optimized microstructures, our 5mm x 5mm heat sinks deliver cooling performance that far exceeds standard mass-produced solutions.



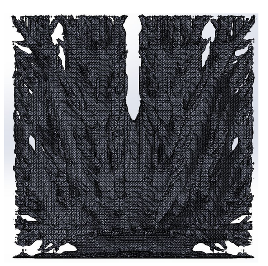
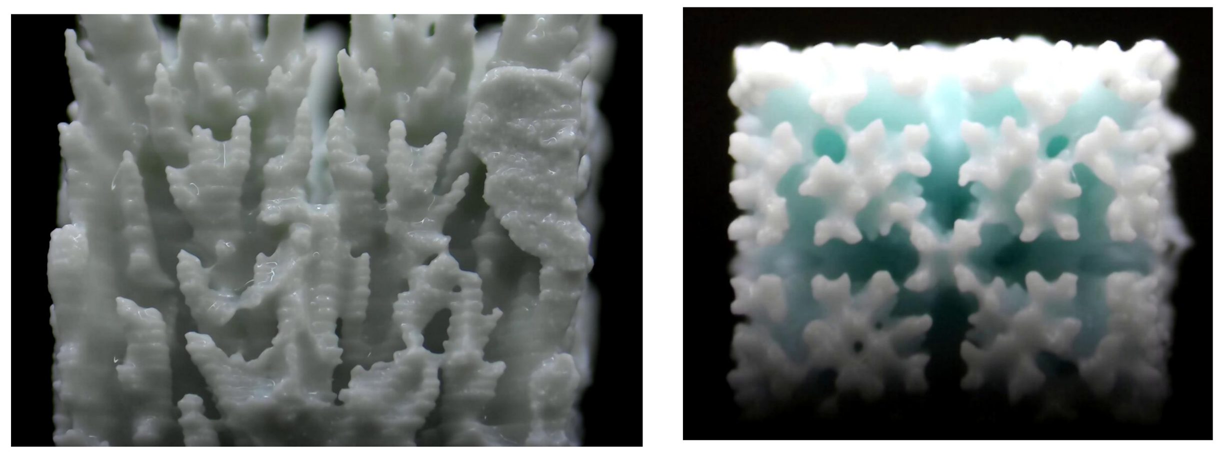
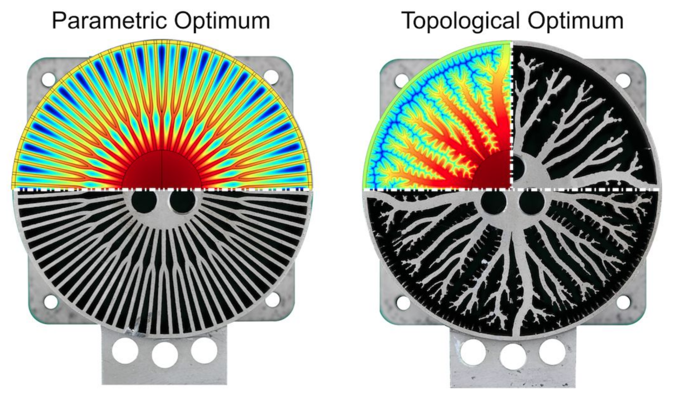


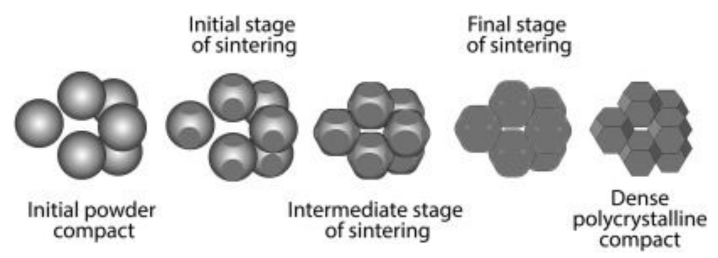
Fig 2: Typical Mass manufactured heat sinks (left), Optimized heat sink (right)

2. Optimized printing parameters like speed and greyscale



3. Postprocessing





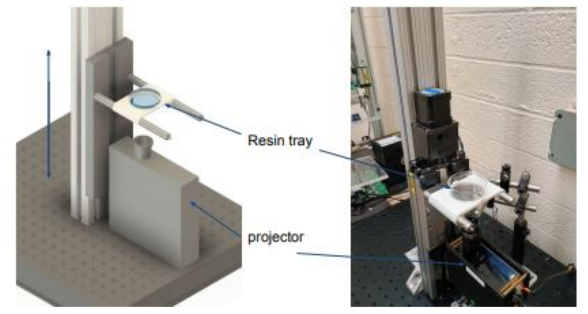


Fig 3: Optimized heat sink (top left), Sintering process (top right), Printing setup (bottom left)

4. Investigation

Equation 2.5.1 $$\dot{Q} = kA\frac{\Delta T}{x}$$

Where:

- $\dot{Q}$ = Heat transferred per unit time (W)
- k = Thermal conductivity of the material (W/m K or W/m °C)
- A = Heat transfer area (m^2)
- ΔT = Temperature difference across the material (K or °C)
- x = Material thickness (m)

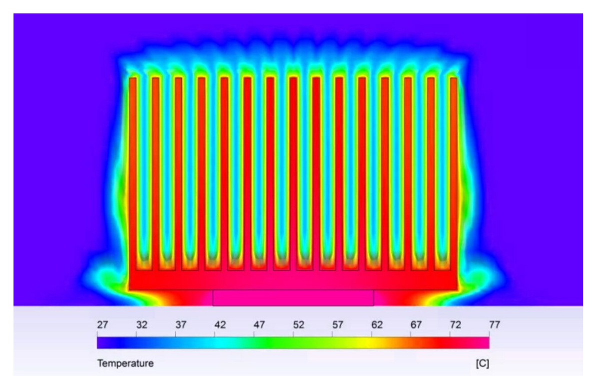
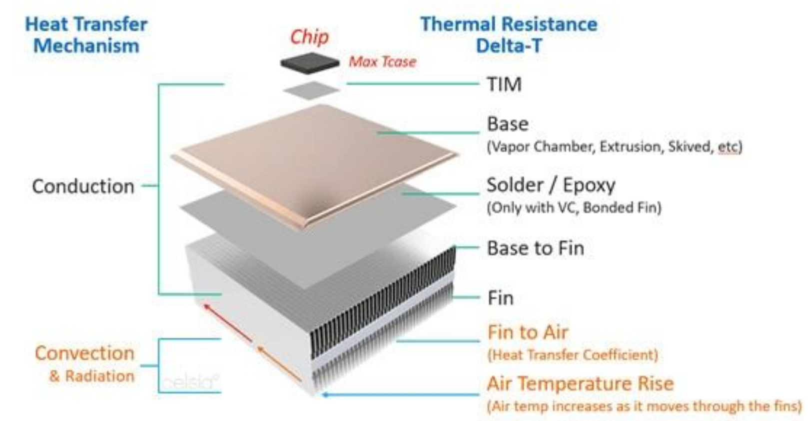


Fig 4: Heat sink comparison calculations (left), thermal image of heat sink (right)

Utilizing heat transfer equations, we are able to compare the different between normal manufactured heat sinks and our heat sinks.

1. More heat transfer at a faster rate
2. Cheaper cost per unit value
3. Less material waste
4. Customization of structures compared to limited shapes due to manufacturing processes



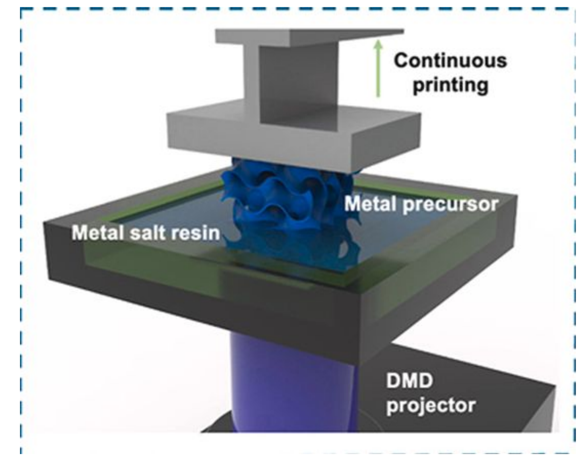


Fig 5: Printing setup (right), test heat transfer of heat sink (left)

5. Future Work

The optimized heat sink should be printed across a wider scale with as many as 50 printing at a time. Future work will utilize a larger projector to print multiple samples at once.

6.Acknowledgements

I'd like to thank Dr. Xiangjia Li for her help as well as Dylan D. Joralmon for his mentorship. I am grateful to FURI for offering this opportunity to me and help me grow.

7. References

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