Experimental Investigation of 3D-Printed Polymer Lattice Composite Thermal Interface Materials for Semiconductor Packages

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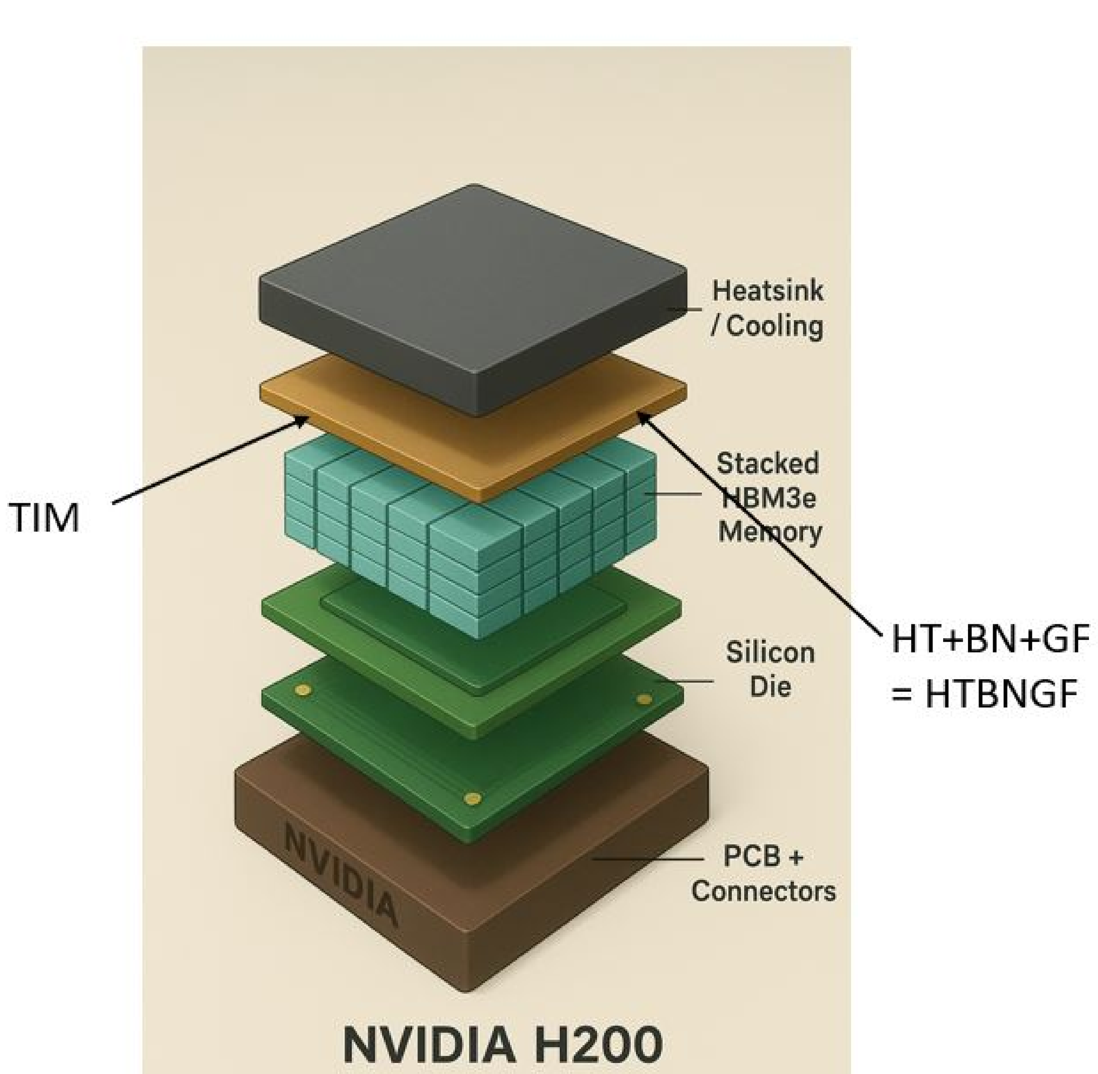
Abstract

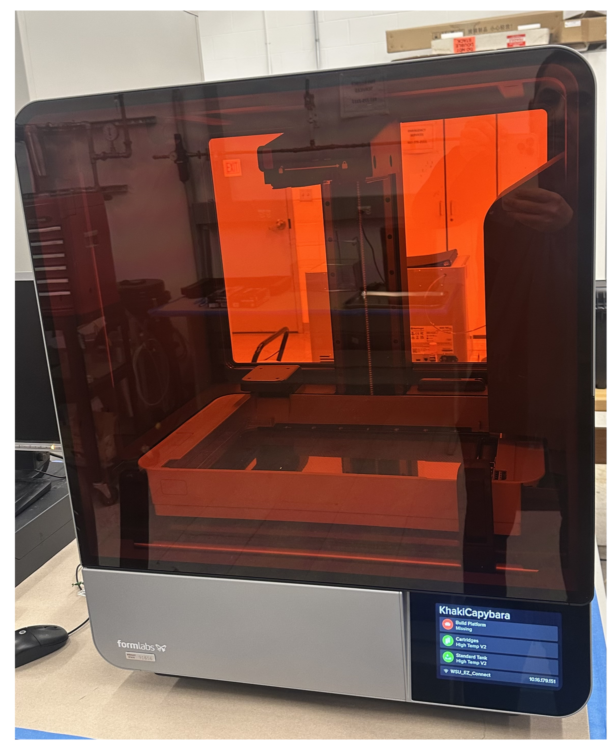
Additive manufacturing enables precise control over the geometry of polymer lattice-based thermal interface materials (P-TIMs) to optimize heat transfer. This study experimentally investigates the thermal and mechanical performance of 3D-printed polymer lattice TIMs with different architectural configurations and composite compositions. A baseline lattice structure was modified by adding vertical struts in uniform, alternating, and gradient arrangements to create multiple P-TIM designs. Both open- and closed-cell configurations, based on Ashby and Gibsonâs principles, were considered to evaluate the effect of unit-cell topology on thermal performance. High-temperature photo-curable resin was loaded with boron nitride (BN) microparticles and glass microfibers at different weight percentages, and the composite materials were 3D-printed using high-resolution stereolithography (SLA). The printed lattices were post-cured and infiltrated with thermally conductive polymer composites. Thermal conductivity and thermal contact resistance were measured under controlled compressive loading, while mechanical compliance was evaluated to assess stability under operational pressures. Results show that both filler composition and lattice configuration strongly influence through plane heat transfer and thermal resistance. Lattices with optimized vertical thermal pathways and appropriate open/closed-cell design achieved the best thermal performance while maintaining mechanical stability. This work establishes that geometry- and composition-modified, additively manufactured P-TIMs provide a clean, reusable, and high-performance solution for chip to heat sink thermal management in advanced electronic cooling applications.

Thermal Interface Material



Structural Design of NVIDIA H200 Chips Technology

3D Printed Technology

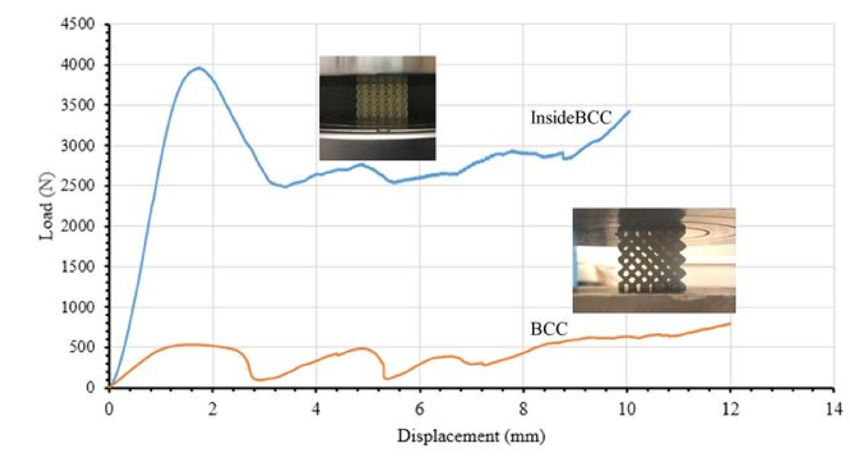


Vat photopolymerization (VP) 3D-4L Printed Technology

Raw Materials

Polymer (Resin High Temp)/Boron Nitride+Glass Fiber Composites

BCC and InsideBCC

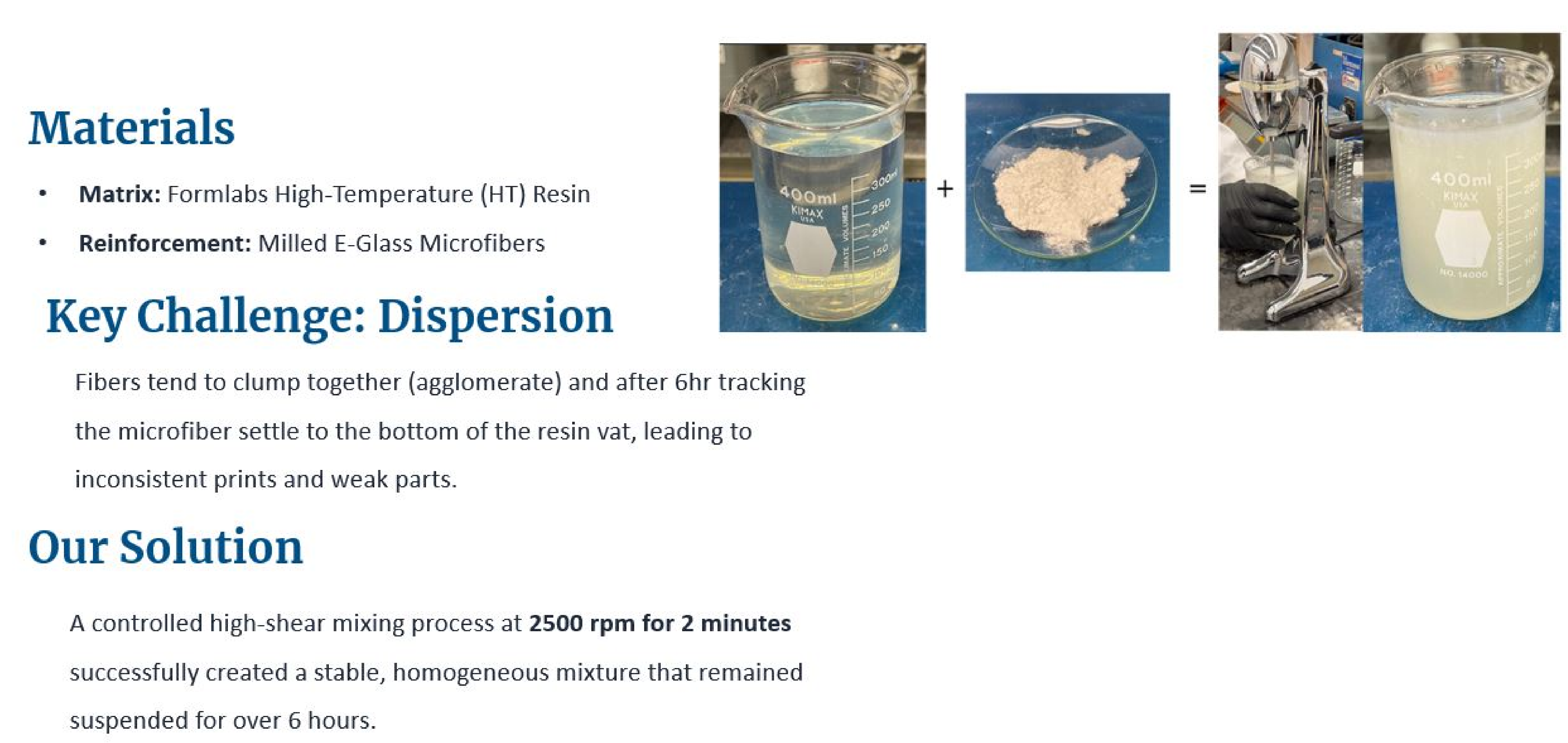


Comparison of load - displacement curves for BCC and InsideBCC configurations

Experimental Workflow

Schematic workflow of composite fabrication, post-treatment, and mechanical characterization

Materials and Key Challenge



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