Advanced Thermal Characterization of 3D-Printed Metallic Triply Periodic Minimal Surface structures for Efficient Heat Dissipation

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The increasing power density in modern electronic devices, particularly in automotive traction inverters using Wide Bandgap (WBG) semiconductors such as Silicon Carbide (SiC) Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs), calls for advanced and highly efficient thermal management strategies. These devices offer significant benefits, higher switching speeds, elevated operating temperatures, and improved efficiency, but they also impose stringent thermal requirements. Inadequate heat dissipation can lead to thermal fatigue, reduced reliability, and performance degradation.

This work explores the use of metal Additive Manufacturing (AM) as a key enabler for the design and fabrication of Triply Periodic Minimal Surface (TPMS) structures, integrated into baseplates for SiC MOSFETs. The geometrical complexity and design freedom offered by AM allow the realization of highly efficient, thermally conductive architectures that cannot be achieved through conventional manufacturing methods.

A central focus of this study is the development of advanced thermocalorimetric techniques for a reliable assessment of thermal conductivity, enabling accurate thermal modeling. In parallel, comprehensive thermo-mechanical characterization was carried out to evaluate structural and functional performance under operating conditions, with particular attention to geometrical tolerances which are critical for module mounting and thermal contact.

The design process was supported by topology optimization algorithms and material selection tools, reinforcing the fundamental link between structure, properties, process, and performance. This holistic design approach integrates the constraints and opportunities of the AM process from the outset, ensuring realistic and optimized outcomes.

By combining metal AM, TPMS-based design, experimental validation, and digital engineering tools, this work lays the foundation for the next generation of high-performance baseplates and heat exchangers, tailored for demanding power electronics applications.

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