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Project Title.
Cure-in-Place Phase Change Thermal Interface Material for Superior Thermal Management in High-Power Energy Systems

Abstract.

Current challenges in heat dissipation in high-power energy systems have become critical for applications, particularly as extreme weather conditions and time-worn electrical grid infrastructure cause rapid changes in power that result in extreme temperatures and sudden temperature spikes with catastrophic consequences. The key challenge for heat dissipation is the thermal interface material (TIM)—located between heat-generating components and the heatsink—which is a major contributor to thermal resistance. TIMs must exhibit a unique combination of properties including high thermal conductivity, electrical isolation, and low contact resistance, while providing high conformability to maintain contact between heat-generating components and the heatsink. However, good interfacial contact is compromised by significant expansion and contraction under extreme or sudden spikes in temperature. To address this, phase change materials (PCMs)—which absorb and release heat during periods of high and low heat generation, respectively—can be used to regulate temperature in electronic devices; however, PCMs suffer from low thermal conductivity ($k < 0.2$ W/m-K), ultimately limiting their use.

To overcome these limitations, the **research objective of this proposal** is to create a novel soft polymer composite phase change TIM composed of silicone elastomer and a multiphase liquid metal filler embedded with tailorable phase change microspheres. It is hypothesized that the phase change TIM will exhibit both high thermal conductivity ($k > 15$ W/m-K) and high heat storage capacity, enabling passive regulation of device temperature while simultaneously achieving high heat dissipation. Furthermore, embedding the PCM into a liquid metal filler is expected to yield low elastic modulus (<1 MPa) and large max strain (> 300%), overcoming the trade-off between thermal conductivity and stiffness, high density, and component failure typical of traditional rigid metal or ceramic particle fillers. Overall, this research will generate insights critical to thermal management and resilience of high-energy systems, translatable to numerous electronic applications.