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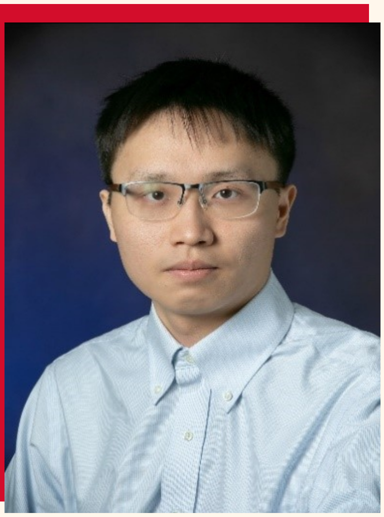
Extreme Thermal Materials and High-Throughput Characterization Tools



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ABSTRACT:

Today's megatrends such as the miniaturization of electronics, the drive towards electrification of vehicles, and the demand for sustainable buildings energy technologies requires new thermal management and storage materials with extreme or dynamically switchable thermal properties. Towards this goal, the understanding of the thermal transport and related properties in materials is crucial for the materials development and requires reliable high-throughput thermal characterizations. In this seminar, I will cover four topics related to extremes of thermal conductivity (Λ), novel thermal characterization technique, and thermal energy applications. First, I will present the establishment of the ultrahigh Λ in BAs and isotope-enhanced BN, with values of 1000 W m-1 K-1 and 1600 W m-1 K-1 respectively, vastly exceeding that of even copper (400 W m-1 K-1). These materials hold potential as next-generation heat spreaders in microelectronics and power electronics beyond cost-inefficient synthetic diamond. Their extraordinarily high values can be understood through modern first-principles theories which carefully consider the interplay of phonons, isotopic disorder, and other defects. Second, I will show a new class of phase change materials (PCM), Ni-Mn-In alloys, for solid-state thermal switches for dynamic thermal management to improve the energy efficiency in various areas, e.g., vehicle engines, fast-charging batteries and building envelopes. These materials exhibit high-contrast (up to ~75%) reversible Λ change near 300 K through a martensitic transition induced electron mobility change, showing higher Λ in the high-temperature phase (opposite to the trend in common PCMs). Third, I will present a first-of-its-kind thermal metrology based on structured illumination and thermal imaging for high-throughput materials characterization. This technique enables efficient paralleled study of multiple samples with the potential to achieve mega-pixel property mapping, which is unattainable with traditional laser techniques. It can also conveniently measure the anisotropic thermal transport properties with tolerance to sample imperfection and roughness.

BIOGRAPHY:

Dr. Qiye Zheng received his B.S. in Physics at Peking University and Ph.D. in Materials Science and Engineering at the University of Illinois at Urbana-Champaign, where his research focused on the thermal transport and structure-properties relationship in novel functional materials for heat dissipation and thermal regulation, advised by Profs. David Cahill and Paul Braun. Dr. Zheng is currently a postdoctoral research fellow in the Energy Technologies Area of the Lawrence Berkeley National Laboratory and the Mechanical Engineering Department at the University of California, Berkeley working with Profs. Ravi Prasher and Chris Dames, where he is developing high-throughput optical thermal metrologies for materials characterization and studying thermal radiation management and energy storage for building applications.