Nano Thermal Materials for Power Electronics

Kenneth E. Goodson

Mechanical Engineering Department, Stanford University 94305

The heat generated by semiconductor devices is a problem for a variety of power electronics and systems ranging from radar and satellites to hybrid and electric vehicle converters. “Extreme” is a unifying theme, from nanometer features and 10+ kW chips to severe materials heterogeneity. This talk summarizes these challenges and our research progress on advanced thermal conduction materials, nanoscale heat conduction physics, as well as two phase microfluidic heat exchangers and transport phenomena.

One area of activity targets the heat-flux limits of pumped and capillary-driven microfluidic cooling. We have focused on template-fabricated copper inverse opals to facilitate simultaneous heat conduction and fluid transport and, in our most exploratory design, the inverse opals are conformally coated into laser-etched diamond microchannels [1-3]. We continue our efforts on solid-state and liquid-vapor based thermal switches, which enable power management and routing as part of power circuitry. Our past work in this area included chalcogenide films with a switching ratio near 4:1 in thermal resistance [4]. Recently we demonstrated higher thermal resistance ratios using reversible Li intercalation in 10 nm MoS_2 films by means of in-situ scanning time-domain thermoreflectance [5].

This presentation will highlight collaborations with the Silicon Valley semiconductor industry, US defense companies and, more recently, the NSF center on power electronics (POETS) and related collaborations with faculty primarily at The University of Illinois at Urbana-Champaign.

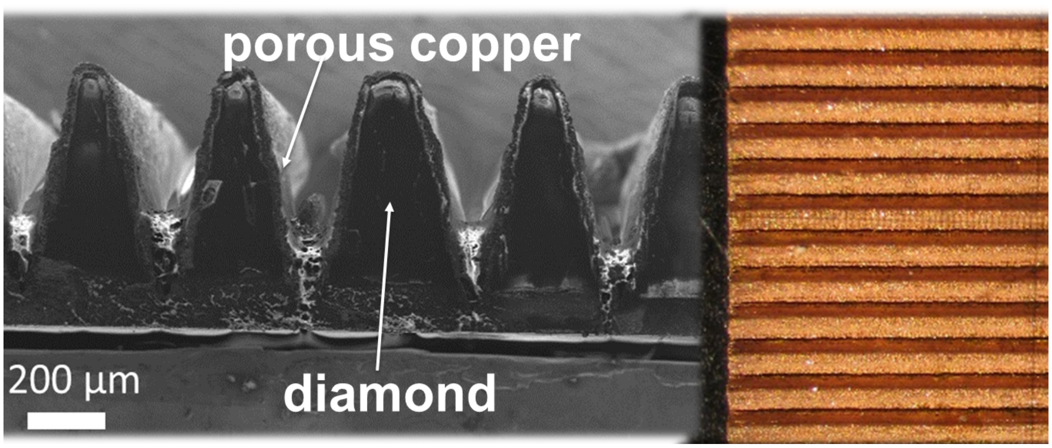

Fig. 1: Template-fabricated copper inverse opals conformally fabricated in diamond microchannels [3]

[1] M. Barako et al., “Quasi-ballistic Electronic Thermal Conduction in Metal Inverse Opals,” *Nano Letters* **16**, 2754-2761 (2015).
[2] J. Palko et al., "Approaching the Limits of Two-Phase Boiling Heat Transfer: High Heat Flux and Low Superheat," *Appl. Phys. Lett.* **107**, 253903
[3] J. Palko et al, submitted and under review.
[4] J. Lee et al., "Phonon and Electron Transport through $Ge_2Sb_2Te_5$ Films and Interfaces Bounded by Metals," *Appl. Phys. Lett.* **102**, 191911
[5] A. Sood et al., in preparation.