Materials Science & Engineering Seminar Series

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How Heat is Transported in Organic-Inorganic Hybrid Materials Including Superatom Crystals and Many Others

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ABSTRACT: Organic-inorganic hybrid materials hold promise for a wide range of solid-state energy, electronic, and even robotic applications due to their unparalleled tunability and their potential scalability. Operating temperature impacts the performance of these applications and understanding the thermal transport properties of hybrid materials is therefore key to their practical technological adoption. I will begin with an introduction to nanoscale heat carriers, and then I will discuss the unique thermal transport properties in a range of novel hybrid materials including organic-inorganic perovskites (OIPs; e.g. $MAPbI_3$), superatom crystals (SACs; e.g. $[Co_6E_8(PEt_3)_6][C_{60}]_2$), nanocrystal arrays (NCAs), and elastomer liquid-metal composites (ELMCs). OIPs and SACs are made from molecular building blocks less than 1 nm in size that are too small to possess an inherent thermal conductivity, but interact cooperatively to create a complex vibrational landscape that carries heat. We find that dynamic disorder (rotations) of cations in OIPs (e.g. MA) and C_{60} molecules in SACs increases phonon scattering and reduces the thermal conductivity of these materials. In contrast, heat transfer in nanocrystal arrays is moderated by the interface between ~10 nm diameter inorganic bricks and the organic ligand mortar. I will show that surface chemistry at this extensive interface, which amounts to the areal footprint of Rhode Island within 1 m^3 of NCA, controls its observable thermal conductivity. Finally, ELMCs made by incorporating liquid metal microdroplets into a soft elastomer, have anisotropic thermal conductivity controlled by directional elongation of the droplets. This results in record setting thermal conductivity per unit elastic modulus, ideal for thermal management in stretchable electronics and soft robotics.

BIOGRAPHY: Jon recieved his Ph.D in Mechanical Engineering at the University of California, Berkeley under the co-advisory of Professors Arun Majumdar (ME, MSE) and Rachel Segalman (ChemE). He investigated thermoelectricity in single molecule junctions, in an effort to learn more about electronic transport in molecular electronics and organic-inorganic hybrid materials. Jon received his B.S. in Mechanical Engineering at the University of Michigan, Ann Arbor in 2000 and an S.M. in Nuclear Engineering (2003) from MIT, where he studied transport at the macroscopic reactor scale under the advisory of Professor Neil Todreas. Since his arrival at Carnegie Mellon in 2009, Jon has received the AFOSR Young Investigator Award (2011), ARO Young Investigator Award (2014), ACS PRF Doctoral New Investigator Award (2011), NSF CAREER Award (2012), ASME Bergles-Rohsenhow Young Investigator Award in Heat Transfer (2014), and the Carnegie Mellon College of Engineering Outstanding Research Award (2016).

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