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Nanophononic metamaterial: Thermal conductivity reduction by mechanical vibrations

Thermoelectric materials (TEM) allow heat energy to be converted into electricity and vice-versa. To attain a high conversion performance (*ZT* figure-of-merit), a TEM must have a low thermal conductivity, κ, while simultaneously possess a high power factor, which is proportional to the electrical conductivity, . The challenge, however, is that these two requirements tend to be at odds with each other. In the last decade or so, the overriding philosophy for increasing *ZT* has been to introduce small features, such as inclusions, defects and interfaces, within the internal domain of the TEM that scatter the heat-carrying phonons and subsequently reduce . This strategy, however, still suffers from the above trade-off since scatterers also impede the transfer of electrons. A significant advance in the value of the *ZT*, for a reasonably low-cost material with favorable device integration attributes, promises to spark a revolution in energy conversion across many industries in light of the tremendous economic and environmental benefits.

In this talk, I will present a novel TEM concept that we have developed at CU-Boulder. The new material, which we refer to as a “nanophononic metamaterial”, is based on a uniform semiconducting thin-film, for example of silicon, with a periodic array of *nanopillars* standing on one or both of its free surfaces (i.e., exterior to the thin-film cross-section). The numerous resonance modes of these pillars couple with the underlying atomic-level phonon dispersion of the thin-film and do so across the full range of its spectrum. These couplings, as demonstrated by theoretical calculations, lower the group velocities (at each interaction point in the phonon band structure) and subsequently cause a significant reduction in the overall κ. This represents a new mechanism for the reduction of κ. The key advantage is that the main feature that reduces κ (the pillars) falls outside the main flow path of the electrons, thus causing a minimal negative effect on σ. Hence, with some parameter tuning, the proposed material configuration promises to perform exceedingly well for thermoelectric energy conversion.