On the Bergman−Levy Limit to the Thermoelectric Figure of Merit of Composite Materials

Dario Narducci
Department of Materials Science, University of Milano Bicocca, via R. Cozzi 53, 20125 Milano (Italy)

It is a common belief that in composites the thermoelectric figure of merit ZT is never larger than its value in the most efficient of its components. This criterion was demonstrated in 1991 in a classical paper by Bergman and Levy [1] based upon a variational analysis of two-component mixtures. The Bergman−Levy limit may be violated (and has been experimentally verified not to hold) in nanostructured systems, namely wherever interfaces play a significant role on the composite transport properties, but has always been considered an unsurpassable threshold in macroscopic systems. Very recently, however, Yang and coworkers [2] argued that heat fluxes in thermoelectric systems are not necessarily divergence-free, so that the use of Laplace equation made by Bergman and Levy may not be appropriate to compute the effective value of the transport properties of *any* composite. Specifically, Yang et al. showed that in a one-dimensional system ZT may actually exceed its value in both components – although the improvement is small and achievable only under an external bias. In any case and beyond the practical relevance of the reported result, the theoretical criticism to the Bergman−Levy limit appears founded, motivating an investigation of the possibility of designing composites with enhanced thermoelectric efficiency with respect to their components.
In this communication analytical and numerical analyses concerning the thermoelectric properties of two-phase macrostructured composites will be reported. Preliminary results confirmed the claim of Yang and coworkers concerning the violation of the Bergman−Levy limit in one-dimensional systems. An extension of the analysis to periodically layered systems will be presented, allowing for conjectures on the criteria to be followed in order to maximize ZT in such a class of structures.

1 D.J. Bergman and O. Levy, J. Appl. Phys., 70 (1991) 6821.
2 Y. Yang et al., J. Appl. Phys., 111 (2012) 013510