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Thermoelectric Studies of Graphene Antidot Lattices and Comparable Nanoporous Thin Films

Qing Hao

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Bio: Qing Hao is an Associate Professor in Aerospace and Mechanical Engineering at the University of Arizona. He received his B.E. degree in Thermal Engineering from Tsinghua University, China, in 2001. He then obtained his M.S. degree from the University of Texas at Austin in 2004, and his Ph.D. degree from the Massachusetts Institute of Technology (MIT) in 2010, both in Mechanical Engineering. After his PhD, he spent a year as a postdoctoral research associate at MIT, primarily working on novel Na-ion batteries. He joined the University of Arizona in Aug. 2011. His current research efforts include high-power electronics, thermal insulation materials, thermoelectrics, measurements and engineering applications of graphene and other two-dimensional materials. He received the 2008 R&D 100 Award as a team member for thermoelectrics research, 2015 AFOSR YIP Award for graphene studies, and 2017 NSF CAREER Award for thermal studies of grain boundaries.

Abstract: The transport properties of two-dimensional (2D) materials can be dramatically changed by introducing nano- to atomic-scale porous patterns, such as regularly spaced pores (antidots). For gapless graphene, such so-called graphene antidot lattices (GALs) can open a geometry-dependent band gap to benefit the applications of graphene in field effect transistors, optoelectronic devices, and thermoelectrics. Despite many studies, the electron and phonon transport processes in such a periodic porous structure are still not fully understood, which hinders the future development of these metamaterials.

In this work, systematic studies have been carried out on GALs with a hexagonal or square array of antidots[1]. As a new attempt, the maximum and minimum Seebeck coefficients under an applied gate voltage are used to infer the dominant scattering mechanism of charge carriers. It is found that the dominant electron scattering mechanism is associated with the pore-edge-trapped charges. To better understand the electrical properties of a GAL or general nanoporous thin films, analytical modeling[2] and electron Monte Carlo simulations are carried out and compared. The focus is on the treatment of the pore-edge potential field due to trapped charges. For phonon transport, thermal measurements on comparable periodic nanoporous Si films[3] and $In_{0.1}Ga_{0.9}N$ films[4] can be fully explained assuming diffusive pore-edge phonon scattering for patterns with ~100 nm pitches.

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