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Coupled Lattice Boltzmann Modeling of Transient Thermal Response in Nanoscale Metallic and Multilayered Films

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Abstract

In recent years, with the continuous reduction in size of numerous sensors and devices, especially electronics and data storage, to the nanoscale domain, the conventional approach to the energy transport modeling, through the Fourier law of heat conduction, becomes inaccurate due to its phenomenological formulation for length scales below the carrier's mean free path. Understanding the fundamentals of thermal transport in these miniaturized devices has become very important for the effective functioning and better reliability of these devices. To achieve this objective, we have developed a novel numerical technique: lattice Boltzmann method (LBM), based on Boltzmann transport equation (BTE) for energy carriers, which is computationally advantageous and easy to implement regarding multiphysics phenomena.

We have successfully captured and demonstrated the sub-continuum thermal effects in semiconducting thin single layers. In this project, we will incorporate electrons and phonons coupling into our transport model to accurately simulate thermal behavior of metals in addition to semiconductors. Furthermore, we will extend our model to incorporate multilayered solid, where the different thermal characteristics of the layer and the interface between them substantially increase the system's complexity. This novel numerical tool will be suitable for simulating complex multiscale systems involving multiple energy carriers with orders of magnitude different length and time scale. The industrial applications such as heat assisted magnetic recording (HAMR), silicon-on-insulator (SOI) transistor, and giant magneto-resistive (GMR) heads requires such a novel simulation tool for design.