Characterization of Thermal Transport in One-Dimensional Microstructures using Johnson Noise Electro-Thermal Technique

Jing Liu [S] and Xinwei Wang [C]
Mechanical Engineering, Iowa State University, Ames, Iowa, U.S.A.
xwang3@iastate.edu

This work reports on the development of a Johnson noise Electro-thermal (JET) technique to directly characterize the thermal conductivity of one-dimensional micro/nanoscale materials. In this technique, the to-be-measured micro/nanoscale sample is connected between two electrodes, and is subjected to steady-state Joule heating. The average temperature rise of the sample is evaluated by simultaneously measuring the Johnson noise over it and its electrical resistance. The system's Johnson noise measurement accuracy is evaluated by measuring the Boltzmann constant (k_B). Our measured k_B value (1.375×10^{-23} J/K) agrees very well with the reference value of 1.381×10^{-23} J/K. The temperature measurement accuracy based on Johnson noise is studied against the resistance temperature detector method, and sound agreement (4%) is obtained. The thermal conductivity of a glass fiber with a diameter of 8.82 µm is measured using the JET technique. The measured value: 1.20 W/m·K agrees well with the result using a standard technique in our lab. The JET technique provides a very compelling way to characterize the thermophysical properties of micro/nanoscale materials without calibrating the sample's resistance-temperature coefficient, thereby eliminating the effect of resistance drift/change during measurement and calibration. Since JET technique does not require resistance-temperature correlation, it is also applicable to semi-conductive materials which usually have a non-linear *I-V* relation.