A Novel Four-Probe Thermal Transport Measurement Method for Nanostructures

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Several experimental techniques reported in the new millennium have enabled the probing of thermal transport in nanoscale and low-dimensional structures. However, the inability of separating the contact thermal resistance has often prevented these techniques from revealing intrinsic size-dependent thermal transport properties. Here we report a novel four-probe measurement method that can obtain both the intrinsic thermal conductance and the contact thermal resistance of individual nanostructures. In this method, the nanostructure sample is transferred across four suspended Pt/SiNx resistance thermometer lines of a microfabricated measurement device. During the measurement, the average temperature rise in the four lines are measured when one of the four lines are electrically heated. By using each of the four lines as the heater lines, a total of sixteen temperature measurements are made. The sixteen temperature measurements can be used to obtain nine thermal resistances in the system. Because the heat flows across the two contacts and the suspended portion of the middle segment of the sample are different and depend on which of the four lines are used in the heater line, the contact thermal resistance and intrinsic sample thermal resistance of the middle segment can be determined. In this work, two samples of patterned Si nanorod with different width have been measured to demonstrate the effectiveness of the method. Because of the ability to obtain both the contact thermal resistance and intrinsic thermal conductance of nanostructure, this new four-probe thermal transport measurement method for nanostructured materials can potentially enable the discovery of a number of unique size-dependent thermal transport phenomena that have or have not been predicted by existing theoretical studies.