Thermal reffusivity: Uncovering Relation between Energy Carrier Scattering and Structure

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Electrical resistivity of metals and its variation against temperature directly reflects the electron scattering behavior by phonons and defects and is dependent on the phonon structure. On the other hand, the thermal resistivity concept in heat conduction cannot be used directly to capture the counterpart phonon behavior. This talk will introduce a new concept: thermal reffusivity. It will cover studies we have conducted for various metallic, polymer, and semiconductor materials from micron down to nanoscales from room temperature down to 10 K. Direct measurement of thermal reffusivity is made possible using the transient electro-thermal (TET) technique, which was first developed in our lab to provide one of the most reliable measurements of thermal transport properties of micro/nanosize materials. The variation of the thermal reffusivity against temperature, in comparison with that of bulk counterpart, directly uncovers the contribution of defects on phonon scattering. Also the Debye temperature of materials can be directly determined from the thermal reffusivity-temperature curve, similar to the electrical resistivity-temperature curve. The 0 K-limit of the thermal reffusivity, termed residual thermal reffusivity, is directly used to determine the structure domain size uncovered by low-momentum phonon scattering. This size is very close to that determined by x-ray diffraction. The residual thermal reffusivity could be used to characterize structure domain sizes that are extremely difficult to probe using beam scattering techniques (e.g. amorphous materials, nm-thick materials). Materials including metals, dielectrics, and organic and bio-materials have been studied to uncover their structure domain size. The thermal reffusivity sheds new light on the structure effect on energy transport and provides great potential to look into material's structure from the energy transport respect.