Thermal Conductivities of Crystalline Organic Semiconductors

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As applications for organic semiconductors grow, it is becoming increasingly important to know their thermal conductivities, k. For example, for sub-micron electronic devices, values of $k > k_0 \sim 5 \text{ mW/cm/K}$ are needed, while values $k < k_0$ are required for desired thermoelectric applications. Whereas it is not surprising that semiconducting polymers typically have room temperature thermal conductivities below $k_0$, many molecular organic crystals also have values of $k$ below this value. We have started measurements of both the in-plane and interplane thermal diffusivities of layered crystalline organic semiconductors using frequency-dependent and position-dependent ac-calorimetry; the thermal conductivities are then determined from the specific heats measured with differential scanning calorimetry. For rubrene, which has $k < k_0$, the interplane thermal conductivity is several times smaller than the in-plane value, although its temperature dependence indicates that the phonon mean-free path is at least a few layers. On the other hand, the in-plane thermal conductivity of TIPS-pentacene, is several times greater than $k_0$, similar to that of the quasi-one dimensional organic metal TTF-TCNQ. Remarkably, its interlayer thermal conductivity is several times larger than its in-plane value, perhaps due to interactions between the large (triisopropylsilyl)ethyl side groups on the pentacene backbone.

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