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Contactless thermal conductivity imaging in nanoscale semiconductors

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Pulsed thermoreflectance (PTR) and photothermal deflection spectroscopy (PDS) are powerful and contactless methods to simultaneously determine the thermal diffusivity and thermal conductivity of thin solid films. In PTR, the heat generated in an optically absorbing thin film by a pulsed and monochromatic light beam creates a change of reflectance in the material, which is detected via a lock-in amplifier. In PDS, the heat generated in the thin film diffuses through a transparent photothermal fluid in which the film is embedded and the thermal gradient experienced at the interface between the film and the adjoining fluid can be probed by a laser beam grazing the film surface and periodically deflected away from the surface by modulated changes of refractive indexes at the interface. In both PTR and PDS, the phase and amplitude of the signals are measured using position-sensitive photodetectors. From the two measured parameters, phase and amplitude, the thermal diffusivity and thermal conductivity of the sample can be simultaneously inferred without any needs of contacts on the thin film sample. Consequently, the thermal properties investigated in this way are not dependent on interface effects between the solid and metallic contacts.
We demonstrate that PTS and PDS are also capable of mapping the thermal properties of thin films at the microscopic level and beyond, if PTS and PDS are coupled with a system comprising two optical microscopes, an upright optical microscope, in which pulsed monochromatic light is focussed, and an inverted optical microscope from which the signal is probed and detected.
This setup will be used for imaging the thermal properties of thin films that are composite at the nanoscale and will include collections of graphene flakes on glass and polymer-fullerene blends for organic photovoltaic applications. In case of graphene flakes on glass, different interface thermal resistivities can be observed for different types of edges, armchair and zigzag. The ultimate resolution of our imaging techniques will be discussed as well.

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