Ultrafast, Nanometric Spatiotemporal Mapping for Measurement of Transport Properties of Thin Film Semiconductors

Xianfan Xu[1, S, C]

[1]*Purdue University, West Lafayette, IN, U.S.A.*
xxu@purdue.edu

Transport properties of materials are characteristically the cumulative effect from all carriers. Of critical importance is the ability to experimentally differentiate the contribution of each energy carrier, such as electrons and phonons, to the total transport properties of a material. Since the dynamics of each energy carrier are fundamentally different but coupled at an ultrafast time scale, ultrafast pump-probe studies with sub picosecond resolution serve as an indispensable tool for probing the transport dynamics. The effective temperature of electrons rises far above the initial conditions after the excitation by a pump pulse due to the inherently low heat capacity of electrons. The temperature difference between the electron and phonon subsystems then drives the exchange of thermal energy between electrons and phonons. In a typical ultrafast pump-probe experiment, the pump and probe pulses are aligned such that they overlap on the surface of the material of interest. The temporal information obtained is then matched to an output from a Two-Temperature Model, which has been successfully shown to describe the exchange of thermal energy between these two subsystems. However, little information of the diffusive process of transport is captured. In this work, we developed and utilized an experimental apparatus that allows for simultaneous high spatial and high temporal resolution measurements, with a 10 nm spatial resolution and a sub-picosecond temporal resolution. This apparatus is used to map the spatiotemporal response of electrons under an ultrafast pulse excitation, which is then compared with an optical response model which takes the transport processes into consideration. It is shown that the transport processes of the electron subsystem can be differentiated from those of the phonon subsystem. The measurement results allow us to extract electron transport processes as well as the electron-phonon coupling strength in a number of materials including intrinsic, lightly doped, and heavily doped semiconductors.