

ULTRAFAST DYNAMICS OF CARRIERS IN GERMANIUM PROBED BY BROADBAND FEMTOSECOND SPECTROSCOPIC ELLIPSOMETRY

This dissertation aims to investigate the transient dielectric function (DF) of Germanium at very high electron-hole pair densities using time-resolved spectroscopic ellipsometry. By employing a pump-probe technique, we explore the evolution of the critical points near the L-valley on a femtosecond time scale. Through modeling the DF of the material under different carrier temperatures, we analyze the impact that the photo-induced phenomena, such as phase-filling and many-body effects, have on the material's optical properties.

Pump-probe ellipsometry measurements were conducted on Ge from -10 ps to 1 ns delay time with a minimum step size of 50 fs. The pump pulse was energetic enough to achieve carrier densities on the order of 10^{20} cm^{-3} . The evolution of the DF over delay time is dictated by the ultrafast dynamics of the photo-excited carriers. Since the critical points (CPs) E_1 and $E_1 + \Delta_1$ lie inside the energy range of our probe (1.8 to 3 eV), the primary focus of our model is to describe these features as a function of delay times. Given the two-dimensional character of these CPs, the absorption of Ge is significantly enhanced by excitonic effects. Furthermore, at high carrier densities, intervalley scattering and band saturation will play a significant role in the optical response of the material. To address these effects, we combined band-filling effects with a 2D excitonic line shape to model the DF. We also simulated the Fermi energies and carrier temperatures governing the measurements using Fermi-Dirac statistics. The relaxation of photoexcited carriers occurs in very short timescales. As a result, this analysis focuses exclusively on the first few picoseconds after excitation, which is the temporal regime where carrier dynamics were modeled and simulated.

Our aim is to enhance our understanding of Ge's optical behavior under intense laser excitation. These findings provide quantitative insight into the timescales and mechanisms governing carrier relaxation in Ge and demonstrate the utility of femtosecond ellipsometry as a sensitive probe of nonequilibrium semiconductor dynamics. Moreover, we seek to translate these results to describe other materials of interest, providing new insights into the ultrafast dynamics of carriers and their influence on the optical properties of diverse materials. The results have implications for the design of high-speed optoelectronic devices and contribute to the broader understanding of ultrafast processes in indirect bandgap semiconductors.