

Band filling and relaxation effects in the transient dielectric function of Ge

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This study investigates the transient dielectric function (DF) of Germanium at very high charge carrier 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 at different electron temperatures, we analyze the impact that the photo-induced phenomena, such as band-filling and many-body effects, have on the material's optical properties.

Measurements were conducted on Ge from -10 ps to 1 ns delay time with a minimum step size of 50 fs, reaching densities on the order of 10^{20} cm^{-3} .^[1,2] Since the critical points (CPs) E_1 and $E_1 + \Delta_1$ lie inside our probing energy range (1.8 to 3 eV), the primary focus 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.^[3] We also simulated the Fermi energies and electron temperatures governing the measurements using Fermi-Dirac statistics. Given the short timescales of the relaxation of the carriers, this analysis focuses exclusively on the first few picoseconds after excitation.

The aim of this work is to enhance our understanding of Ge's optical behavior under intense laser excitation. These findings provide qualitative insight into the mechanisms governing carrier relaxation in Ge and probe the nonequilibrium dynamics in semiconductors. Moreover, we seek to translate these results to describe other materials of interest, such as GeSn alloys.

This work was supported by the Air Force Office of Scientific Research under award number FA9453-23-2-0001. The authors acknowledge the use of the ELI Beamlines Facility, Extreme Light Infrastructure ERIC, Dolni Brezany, Czech Republic.

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