LT-GaAs carrier lifetime evaluation using THz and optical probe techniques at different carrier injection levels

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1. Introduction

A typical photoconductive antenna (PCA)-based terahertz time-domain spectroscopy (THz-TDS) system has a mode-locked Ti: sapphire laser with a 100-MHz repetition rate as the pulsed excitation source. When an average probe beam power of 10 mW is focused to a 10-μm diameter on a semiconductor substrate, it yields an estimated fluence of around 130 μJ/cm^2 impinging on the spot. The temporal resolution of the system highly depends on the speed of the PCA material. In this study, we evaluate the response of a low temperature-grown gallium arsenide, "LT-GaAs", (grown at 210°C) layer at different carrier injection levels. LT-GaAs has been highly favored as a photoconductive material for THz applications due to its high carrier mobility, high dark resistivity and short carrier lifetimes [1].

Carrier lifetime measurements were carried out using an optical pump-terahertz probe (OPTP) [1-2] spectrometer and a double optical pump terahertz time domain emission spectrometer (DOP THz-TDES) [3]. In both systems, the sample was optically excited at 800 nm.

2. Results and Discussion

Using OPTP, the change in transmission ($-\Delta T/T_{max}$) of a THz pulse through the sample excited at carrier injection levels > 145 μJ/cm^2 was measured relative to the arrival of an optical pulse excitation. The decay of the transmission is regarded as the carrier lifetime. Using DOP THz-TDES, the sample was excited at a carrier injection level of 12 μJ/cm^2, and the measured THz emission reflects the carrier lifetime.

The decay curves for both techniques can be fitted using double exponential decay functions. Fast initial decays were observed, often attributed to the carrier trapping in the disordered LT-GaAs material; followed by longer decays often attributed to usual radiative and non-radiative recombination processes [1]. At high carrier injection (Fig.1), the fast lifetimes were estimated to be 0.93, 0.75, and 1.33 ps for fluences of 145, 217, and 290 μJ/cm^2, followed by longer decays of 86, 38, and 136 ps, respectively. At low carrier injection (Fig.2), the fast lifetime was estimated to be 0.30 ps followed by a 2.10-ps decay.

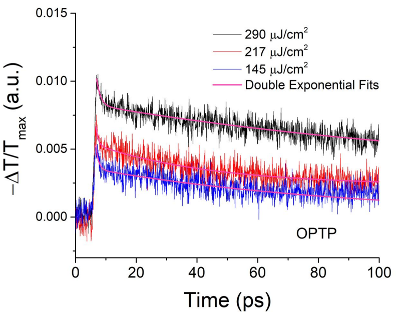

Fig. 1. Carrier lifetime evaluation through OPTP technique at high carrier injection levels

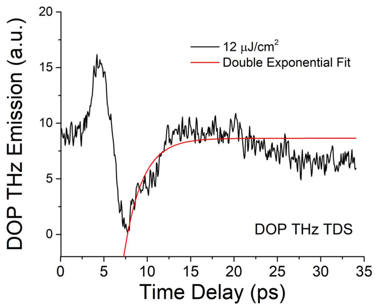

Fig. 2. Carrier lifetime evaluation through DOP THz-TDES at low carrier injection

3. Conclusion

Using OPTP and DOP THz-TDES, carrier lifetimes were evaluated for a LT-GaAs layer. The fast carrier trapping rate was observed to be dependent on the carrier injection level. At low carrier injection, even the longer recombination rate was observed to have a lifetime comparable to the carrier trapping rate.

References

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