4:30pm - 4:45pm
WCC3

Electron trapping time versus annealing temperature in low temperature grown GaAs

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Low-temperature-grown GaAs (LT-GaAs) has been the subject of sustained studies due to its short carrier lifetime and semi-insulating properties [1]. Taking advantage of it short carrier lifetime and the subsequent fast optical responses, ultra-high speed photodetectors operating at 830 nm [2] and other high-speed applications, such as Ti:sapphire laser modelocking [3], have been demonstrated. Previous studies show that the excess arsenic atoms form As antisites (As_{Ga}) with energies close to the center of the bandgap. The As_{Ga} defect is generally found in the neutral charged state $As_{Ga}{}^0$ and in the single positive charged state $As_{Ga}{}^+$. The positively charged $As_{Ga}{}^+$ defects act as electron traps. The native vacancy states (V_{Ga}) are located at a position ~0.34 eV above the valence band and act as hole traps. When studied with a above-bandgap infrared pulse, the optical responses corresponded to both electron and hole trapping times, as well as recombination time, were all observed. For near infrared applications, both electron and hole dynamics will determine the response time of the applications.

However with a below bandgap excitation within the wavelength range of 1200 nm to 1700 nm, covering the telecommunication wavelengths, electrons from the As_{Ga} defect states will be photoexcited into the conduction band Γ valley. Optical responses governed only by the fast electron trapping back to the defects states can thus be expected. A. C. Warren *et al.* have previously demonstrated a 1.3 μm p-i-n photodetector using GaAs:As [4]. P. Grenier and J. F. Witaker [5] have studied LT-GaAs using 1.56 μm pulses from a fiber laser on a sample annealed at 600 °C. In this presentation, we will report on our study of the carrier trapping time versus different annealing temperature, which will be important for LT-GaAs application on high speed telecommunication devices.

The samples investigated are 1-μm-thick MBE-grown LT-GaAs films sandwiched between two AlAs layers with a growing temperature of 220°C. The samples were annealed at 500, 600, or 700°C for comparison. The experiments were first studied by using a femtosecond Cr:forsterite laser modelocked with an InGaAs semiconductor saturable absorber mirror. 90-150 fs pulses were obtained at a wavelength of 1230 nm. The 1-eV photons will excite electrons from the midgap defect states into the conduction band Γ valley and would mimic the responses at longer telecommunication wavelengths. The transient measurements were performed using standard reflection-type pump-probe technique. Inset of figure 1 shows a typical transient response measured by 1230 nm pulses at a LT-GaAs sample annealed at 700 °C. At zero time delay, a positive reflection peak with a width of pump-probe autocorrelation was observed. We believe that this positive peak should be contributed from instantaneous nonlinear refractive index. After zero time delay, a negative reflection change was observed for all traces. Figure 1 shows an enlargement of the trace. A fast relaxation on the order of 560 fs can be obtained though a convolution fit. This negative transient reflection can be attributed to the absorption decrease in the LT-GaAs film due to state filling in the conduction band. The fast relaxation of 560 fs, much faster than the typical electron cooling in GaAs, can thus be attributed to carrier trapping back to the midgap states. With a lower annealing temperature, the relaxation time decreases, indicating faster carrier trapping. Figure 2 shows an enlargement of the measured transient reflection response of a LT-GaAs sample annealed at 500°C. A fast relaxation time on the order of 380 fs can be derived from a convolution fit. Transmission-type pump probe measurements were also performed on these samples. We have observed positive transient absorption saturation behaviors following negative two-photon absorption peaks with the same time constants as what observed in reflection

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measurements. This confirms our assumption that the fast relaxation is contributed from the carrier relaxation of the photo-excited electrons.

Comparison experiments were also performed using femtosecond pulses at 800 nm wavelength from a Kerr-mode-locked Ti:sapphire laser. In this excitation wavelength, both electron and hole will be photo-generated and we are expected to observe time-constants associated with both electron and hole dynamics. Relaxation time constants of 380 fs and 1.3 ps was observed for LT-GaAs samples annealed at 500 and 700°C respectively. The longer time constant observed in the 700°C sample, comparing with 1230 nm data, reflects the extra contribution from hole dynamics. However, it is interesting to notice that for lower annealing temperature, similar time constants were obtained from both above-bandgap and midgap excitation, indicating fast hole capture mechanism.

We will also report our studies on unannealed LT-GaAs samples. The extremely short optical response time observed by using midgap infrared wavelength indicates great potential of LT-GaAs for high-speed telecommunication applications. With a lower annealing temperature, faster response time will be obtained. This work is sponsored by National Science Council of Taiwan, R.O.C. under Grant No. 89-2218-E-002-012.

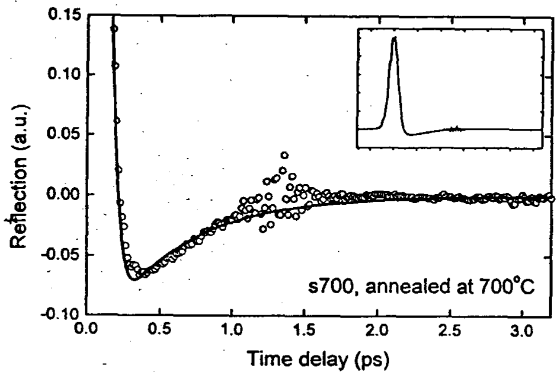

Figure 1. Transient reflection measurement on a LT-GaAs sample annealed at 700°C using femtosecond pulses at a wavelength of 1230 nm.

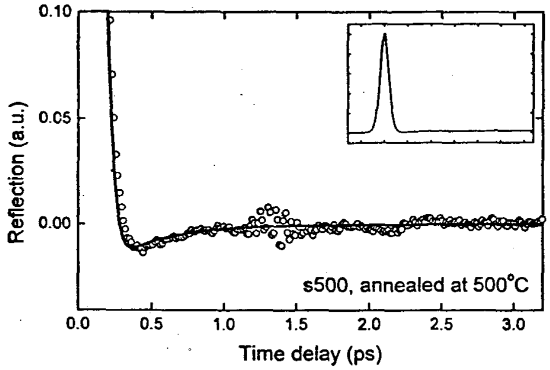

Figure 2. Transient reflection measurement on a LT-GaAs sample annealed at 500°C using femtosecond pulses at a wavelength of 1230 nm.

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