L.3 Carrier dynamics in surface quantum wells

GaAsP/AlGaAs quantum wells are utilized in diode lasers, detectors and modulators. We have probed the room temperature carrier dynamics in GaAsP/AlGaAs single quantum wells by transient reflectivity measurements. The quantum wells were grown by SLS, RRCAT. A single, 13 nm $GaAs_{0.9}P_{0.1}$ well was grown with a capping layer of $Al_{0.7}Ga_{0.3}As$ (Fig.L.3.1). For sample A this layer thickness (t) is 50 nm whereas for the sample B it is reduced to 5 nm. The ee1-hh1 transition for the quantum well is at 1.58 eV. Surface photo voltage (SPV) measurements of the two samples show significant difference in the energy range 1.53-1.58 eV, which comes from the different contribution of surface states in the two samples. The laser wavelength was set to 1.56 eV, which is slightly below the quantum well ee1-hh1 transition. Pump-probe reflectivity measurements were done by splitting the output of a 100fs, 82 MHz Ti: Saphhire laser into a strong pump and a weak probe and impinging them on the sample with a variable delay between them. The photo-induced carriers generated by the pump pulse cause a change of absorption due to effects like band filling, band gap renormalization, screening and free-carrier absorption. The change in absorption causes a change of refractive index which gives rise to reflectivity change. The magnitude, sign and the decay of this transient reflectivity change depend on the relative contribution of the above processes. This, in turn, depends on various factors like the material properties including transport, lattice temperature, excitation and detection wavelengths and the excitation power.

The reflectivity dynamics for the two quantum well samples is shown in Fig.L.3.2. For sample A the reflectivity change was positive. There is a fast decay (~0.5 ps) followed by a slower rise which lasts which lasts for more than 50 ps. For sample B, on the other hand, the reflectivity change is negative though it also shows a fast and a slow component. As the wavelength is just below the quantum well ee1-hh1 transition but above the GaAs band gap, we expect the AlGaAs/GaAs interface will also contribute to the signal along with the quantum well states, GaAsP/AlGaAs interface states and surface states. Therefore measurements were also done on GaAs as well as an AlGaAs film deposited on GaAs. GaAs showed a positive reflectivity change (Fig.L.3.3a), which decayed exponentially with a time constant varying between 1-2 ps, depending on the pump energy. This matches with earlier reports. The AlGaAs/GaAs thin film, however, showed a slow rise (1-2 ps) followed by a much slower decay (Fig.L.3.3b). For semiconductors, carrier cooling and carrier decay govern the transient reflectivity behaviour. Carrier cooling can lead to a reflectivity rise time much slower than the excitation pulse width. The sign of the reflectivity change at a given excitation wavelength and pump energy is governed mainly by the relative contributions from band filling, band gap renormalization and free carrier absorption. The interface also plays a significant role in heterojunctions. For example, the AlGaAs/GaAs heterojunction has been shown to possess a high mobility two-dimensional electron gas and therefore a transient reflectivity dynamics very different from bulk GaAs. From these observations it is apparent that in our quantum well samples all the interfaces need to be considered along with the quantum well states to explain the carrier dynamics in these quantum wells. Theoretical analysis and further work is in progress.

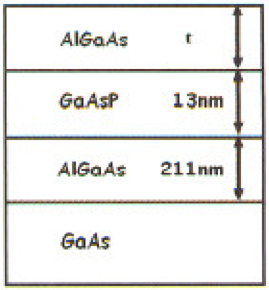

Fig.L.3.1: The quantum well structure. The thickness, t, is 50 nm (sample A) or 5 nm (sample B).

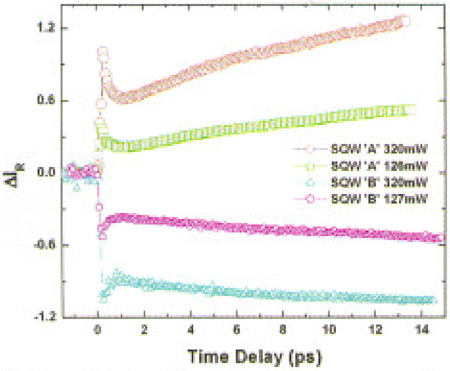

Fig.L.3.2: Transient reflectivity changes as a function of delay between the pump and probe pulses.

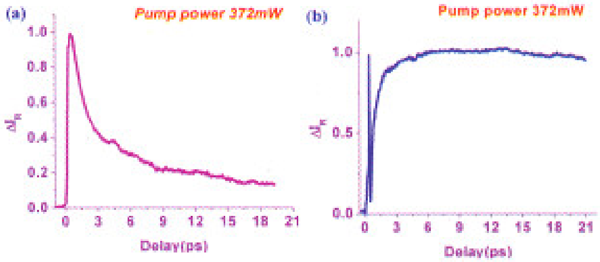

Fig.L.3.3: Transient reflectivity for a) GaAs and b) AlGaAs/GaAs.

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