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FIRST TSC AND DLTS MEASUREMENTS OF LOW TEMPERATURE GaAs

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The first thermally stimulated current (TSC) and deep level transient spectroscopy (DLTS) studies performed on GaAs grown by molecular beam epitaxy (MBE) at low substrate temperatures (LT GaAs) are reported. TSC experiments, conducted on as grown and 400–580°C annealed layers showed domination of arsenic antisite (EL2-like) defect and supported its key role in hopping conductivity. DLTS studies, performed on Si doped and annealed at 800°C layers revealed substantially lower concentration of EL2-like defect and an electron trap of activation energy $\Delta E = 0.38$ eV was found.

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The growth of GaAs by molecular beam epitaxy (MBE) at low (190–250°C) substrate temperatures (further referred to as LT GaAs layers) started three years ago. Since then LT GaAs layers have gained a big interest because of their technological importance as buffer layers for GaAs integrated circuits. It has been shown that LT GaAs is As rich with about 1% more As than Ga [1]. Such an off-stoichiometry should cause high concentration of defects. Up to now, arsenic antisite has been the only identified defect [2]. The aim of this work were studies of deep defects in LT GaAs layers using thermally stimulated current (TSC) and deep level transient spectroscopy (DLTS) techniques.

MBE GaAs layers grown at temperature 190°C were studied. As grown and slightly annealed (400–580°C) samples had high concentration of arsenic antisite (EL2-like) defect. As calculated from optical absorption spectrum using Martin's calibration curve [3], in as grown samples there was 1×10^{20} cm^{-3} of arsenic antisite defect while in annealed samples its concentration was about five times lower. As they had resistivity greater than 10^2 Ωcm they were suitable for TSC measurements.

The results of equilibrium current and TSC are shown in Fig. 1. The equilib-

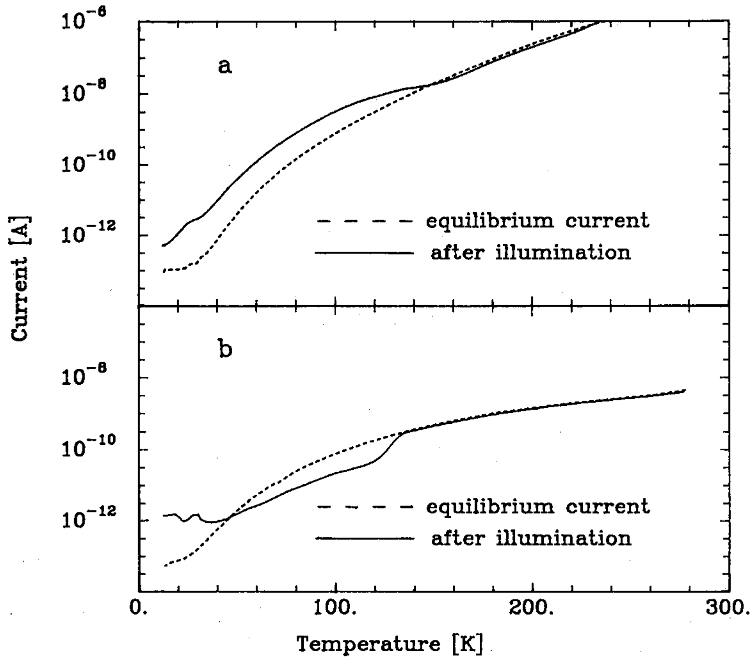

Fig. 1. The temperature dependence of the equilibrium current and TSC for as grown LT GaAs (a) and annealed at 450°C (b).

rium current was due to the hopping conductivity between arsenic antisite defects [4, 5]. Since the Fermi level in LT GaAs was slightly above the midgap energy, TSC should detect traps in the upper half of the energy gap. However, as it is seen from Fig. 1, the shape of the thermally stimulated conductivity versus temperature was smooth showing that there were no traps with significant concentration. Only two relatively small peaks at 30 K and 230 K were observed. The peak at 30 K was present in as grown material and remained of the similar intensity in the annealed samples. The peak at 230 K was observable only in the sample annealed at 580°C (in the as grown layers as well as annealed up to 580°C equilibrium conductivity at 230°C was too high).

The significant difference between TSC and equilibrium conductivity in the temperature range below 130 K for all investigated layers was observed. It was found that in as grown samples TSC signal was higher than the equilibrium current, whereas in all annealed samples TSC fell to the value of about 30 times lower than the equilibrium current. It has been shown recently that in the temperature range below 130 K, some of arsenic antisite defects in LT GaAs are in the metastable configuration after light illumination [6]. Therefore the difference between TSC and the equilibrium current below 130 K was obviously due to the arsenic antisite defect transformation. It needs further studies in order to understand such a difference.

The LT MBE GaAs doped during growth process with Si (2×10^{17} cm^{-3}) was used for DLTS measurements. The samples with Si_3N_4 protective cap (0.2 μm) were annealed at temperatures between 550°C and 800°C. The layers annealed at the temperature lower than 800°C were highly resistive. On the other hand it was found that annealing of Si doped LT GaAs starting from 800°C produced *n*-type layers suitable for DLTS studies. The investigated structure consisted of two MIS structures.

The obtained DLTS spectrum is presented in Fig. 2. Two peaks were de-

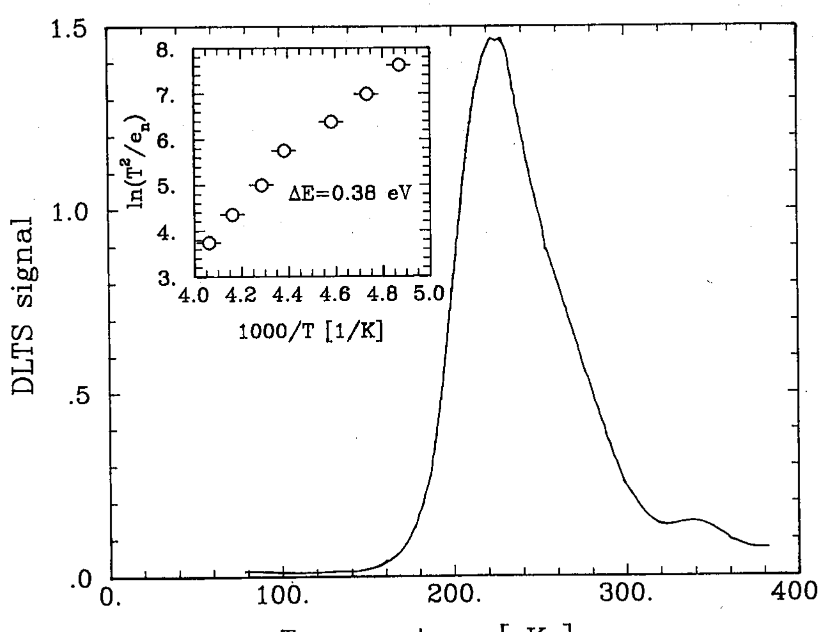

Fig. 2. DLTS spectrum of Si-doped LT GaAs annealed at 800°C (emission rate window 320 s^{-1}). The Arrhenius plot for the dominant trap is presented in the insert.

tected. The Arrhenius plot for the dominant trap of the activation energy $\Delta E =$ 0.38 eV and the electron capture cross section $\sigma_\infty = 1.0 \times 10^{-14}$ cm^2 is presented in insert of Fig. 2. It is probably the same defect as the trap observed in MBE GaAs grown at 300°C [7]. No signal due to the EL2 defect was observed.

At the growth temperature of LT GaAs layers it is difficult for atoms to reach equilibrium positions since they do not have enough thermal energy for migration. Therefore, one can expect high concentration of defects in LT GaAs. From this point of view it is astonishing that except for the arsenic antisite, there were so small number of defects.

In summary, the absolute domination of the arsenic antisite defect in as grown LT GaAs layers as well as annealed up to 580°C was proved. The layers annealed at 800°C showed the supremacy of 0.38 eV electron trap.

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