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Near Bandedge Optical Absorption Processes in Semi Insulating and N-Type GaAs

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Abstract

Near bandedge optical absorption processes in semi-insulating (SI) GaAs and Te-doped n-type GaAs crystals were investigated in the temperature range 10–300 K. We observed absorption peaks whose maximum energies E_m, ranging from 1.498 to 1.485 eV decrease as the temperature increases from 10 K to 100 K. The peaks for both SI and n-type GaAs disappeared above 100 K. Extrapolating the graphs of E_g-E_m versus temperature, we observed that near bandedge absorption is overlapped by the conduction band at about 220 K and 260 K for n-type and SI samples, respectively. Furthermore, we demonstrated that the absorption in the region of near bandedge can be photo-quenched using further irradiation after EL2 photo-quenching at higher temperatures. Comparison of the absorption measurements with the spectral photo-current measurements, we conclude that Reverse Contrast (RC) centres that cause such absorption at energies close to the bandedge have no intra-centre transition.

Key Words: GaAs, near bandedge absorption, reverse-contrast

1. Introduction

A perfect crystal structure has no intra-bandgap absorption. However, in practice it is impossible to produce a perfect crystal structure. The intra-bandgap absorption is due to defect levels. Characterisation of deep defect levels in GaAs substrates as well as in the other semiconductors was generally advanced by the development of Deep Level Transient Spectroscopy (DLTS) by Lang [1]. Martin et al. reviewed and tabulated the deep electron traps in bulk and epitaxial GaAs crystals observed by the various capacitance transient studies [2]. They labelled electron traps as EL1-EL16. Of these deep level electron traps EL2, EL3, EL5and EL6 seemed to play the most important roles in the recombination mechanisms found in bulk and Vapour Phase Epitaxy (VPE) grown crystals. This is because of their high electron capture cross-sections, on the order of 10^{-13} cm^2, and their high concentrations. This is especially true of the electron trap EL2 with concentrations as high as 5-20x10^{15} cm^{-3}. Electron Paramagnetic Resonance (EPR) measurements have shown that EL2 defects are tetrahedral, isolated As anti-site defects, or complexes containing them [3,4]. A recent review on the identification of EL2 has been given by Baraff [5].

One of the most important properties of the EL2 defect is its photo-quenchability to an inactive metastable state. It has been shown that the optical and electrical properties can be reversibly rendered inactive or bleached (photo-quenched) under illumination of white light at sample temperature below 120K [6].

The EL2 defect absorbs infrared light in the wavelength range from 1.5 μm to bandedge at 0.85 μm at sample temperature of 300 K. The longer wave section of absorption spectrum is due to EL2 absorption, its magnitude correlating with EL2^0. The absorption at the near bandgap energy has been proposed to be due to a defect called Reverse-Contrast (RC) centres. This is so-called because it spatially anti-correlates with EL2 absorption in as-grown samples. The near bandedge absorption spectrum extends only to about 50 meV below the band gap energy at 4K. This extension into the bandgap reduces as the sample temperature is increased and becomes zero as the RC level is overlapped by the conduction band.

Photo-quenching experiments at near bandedge absorption region demonstrated that the RC absorption can be reversibly destroyed by illuminating the cooled sample with a suitable light source [7].

It was thought that photo-quenching of the absorption is peculiar to the EL2 defect and that the RC absorption might be due in some way related to the EL2. It was successfully demonstrated by Tüzemen and Brozel [8] that RC absorption can be observed and photo quenched separately from EL2 centres. The wavelength dependence of the photo-quenching efficiency of RC absorption is also quite different to that of EL2.

2. Experimetal

In this work, semi-insulating and Te doped n-type GaAs samples grown by Liquid Encapsulated Czochralski (LEC) technique were used. The samples were cleaned and polished on both surfaces. In order to perform absorption experiments, the samples were placed on the cold finger of a closed cycled helium cryostat and cooled to 10 K. Absorption spectra of the samples as a function of temperature were recorded using IR sensitive spectrometer with a wavelength resolution better than 2nm. Ohmic contacts for the photo-current measurements were made by indium evaporation in a vacuum of 10^{-5} torr. Indium dot contacts located on the corners of SI GaAs sample were sintered at 400 ^{o}C for 3 minutes under nitrogen gas flow. The light was incident on the front of the sample, at appropriate wavelength. Photo-current and absorption measurements were made on the area between the two point contacts of the sample.

A closed cycled helium cryostat and Perkin Elmer UV/VIS 2S spectrometer were used for Reverse Contrast (RC) and EL2 photo-quenching measurements. Both of these defect levels were photo-quenched, separately from each other.

3. Result and Discussion

A typical absorption spectra of a semi-insulating GaAs sample is shown in Figure 1 at sample temperature 15 K, which is identical for n-type sample. We calculated EL2 and RC concentrations by using, respectively, Martin's [6] and Tüzemen's [9] calibrations which are shown in Table 1. The shorter wavelength section of the absorption spectrum is due to RC absorption extending from 1.494 eV to 1.503 eV. It has been earlier proposed that As-vacancy type defects ionising to its negative charge state cause such absorption [9].

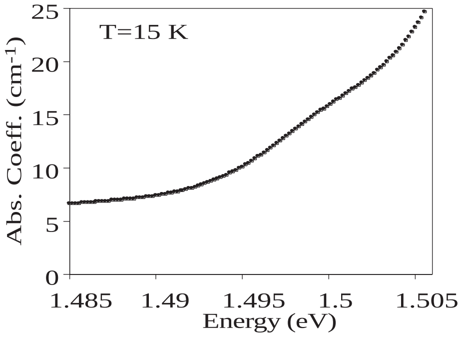

Figure1. Optical absorption spectra of SI GaAs

Table 1. Calculated values for RC and EL2 concentrations.

Samples	**[EL2] (cm^{-3})**	**[RC] (cm^{-3})**
n-GaAs	1,52x10^{16}	1,04x10^{15}
SI-GaAs	2,65x10^{16}	1,24x10^{15}

Substituting experimentally measured absorbance values into the following equations:

$$T = I_t/I_0 = (1-R)^2 \exp(-\alpha t)\left[1 - R^2 \exp(-2\alpha t)\right]^{-1}$$

$$A = -\log(T)$$

$$T_m = (1-R)/(1+R)$$

α values are calculated. Here, A,T and R represent the absorbance, transmittance and reflectivity, respectively. Furthermore, α is the absorption coefficient, t is the sample thickness and T_m is the maximum transmittance which is obtained in spectral regions where the absorption is nil.

The characteristic peaks whose maximum energies E_m ranging from 1.498eV to 1.485eV is subtracted from the spectra shown in Figure 1. Typical characteristic peaks for n-type and SI samples are shown in Figure 2(a) and (b) at sample temperature of 15K. Such peaks are calculated by means of fitted curves to pairs of experimental data. As the sample temperature is increased the characteristic peak values decrease to 1.485 eV following the bandgap energy as a function of temperature. These peaks cannot be obseved above 100K.

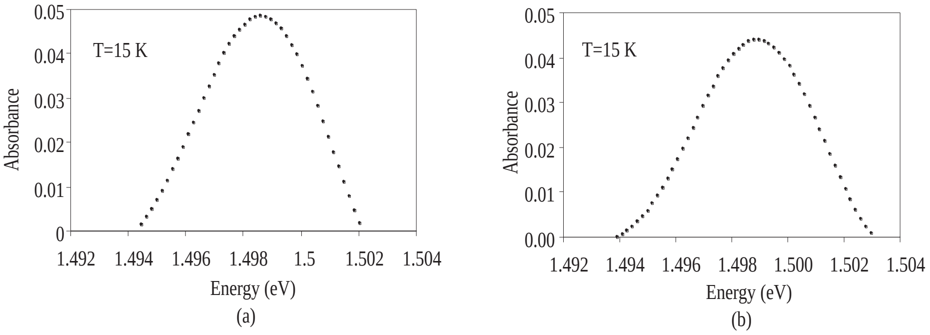

Figure 2. Characteristic peaks subtracted from absorption spectra of (a) n-type GaAs, (b) SI-GaAs

The E_g-E_m versus temperature graphs for n-type and SI GaAs samples are shown in Figure 3. Extrapolating these graphs, we observed that the RC level is overlapped by conduction band at about 220 K in n-type and 260 K in semi-insulating samples. The value of 220 K is in very good agreement with the value observed by Hall measurement [10]. The value for SI material is observed in the present work only.

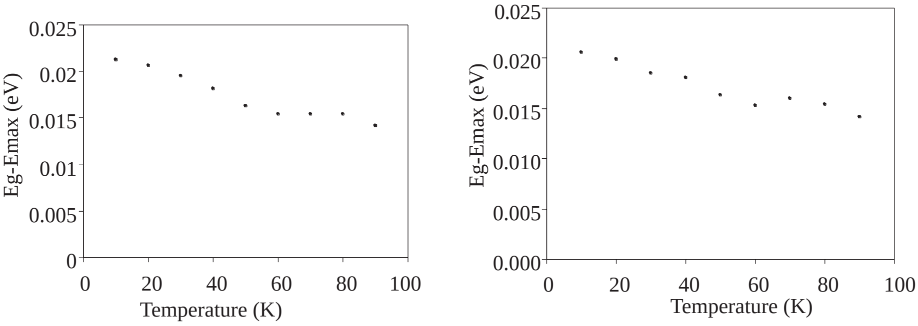

Figure 3. Eg-Emax vs temperature for (a) n-type GaAs and (b) for SI-GaAs

In order to examine whether this characteristic peak is due to intra-centre transition, we performed parallel photo-current and optical absorption measurements. As seen in Figure 4, the absorption data fit quite well with those of photo-current. It follows that RC centres have no intra-centre transition, unlike in the case of EL2, as found previously [11]. Photo-quenching measurements are performed in both semi-insulating and n-type samples. Results are in agreement with the experiments performed earlier [9].

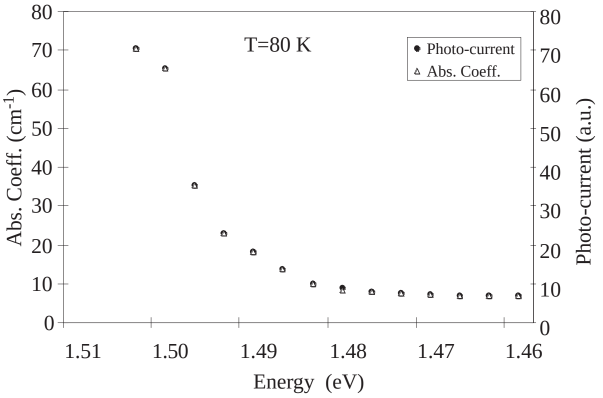

Figure 4. Absorption coefficient and Photo-current vs Energy for SI GaAs

4. Conclusions

RC centres have the characteristic peaks of absorption and such peaks can not be seen above 100 K. Absorption of EL2 and RC centres can be photo-quenched separately. Extrapolating Eg-Em versus temperature graphs, we concluded that near bandedge absorption is overlapped by conduction band at about 220 K for n-type and 260 K for SI-GaAs samples. Parallel optical absorption and photo-current data show that no intra-centre transition is involved in RC absorbtion process.

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