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ELECTRON SPIN RESONANCE STUDIES OF Te DOPED AlGaAs EPILAYERS*

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Results of electron spin resonance studies of tellurium doped AlGaAs epilayers are presented. We demonstrate a new approach to the studies of shallow donor–deep DX level transformation upon illumination or with an increase in temperature. The processes can be monitored by observing the changes of magnitude of an unidentified ESR signal of AlGaAs.

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1. Introduction

We present the analysis of the ESR signals observed for Te doped AlGaAs grown by liquid phase electroepitaxy (LPEE) on (100) GaAs. This analysis allows us to determine the valley orbit splitting for the Te donor and to monitor the shallow donor–deep DX state transformation upon illumination or annealing.

2. Experimental

The ESR experiments were performed on a conventional spectrometer for two AlGaAs epilayers. The first sample (E37/90) had a 0.42 Al mole fraction, the other (E23/91) — 0.55 Al mole fraction. Both epilayers were uniform in composition, 200 μm thick and were doped with Te to the level of 3×10^{18} cm^{-3}. For such a doping level no freeze out was observed for illuminated samples even at 4 K.

3. Valley orbit splitting

Illumination of the E37/90 sample with white light resulted in the appearance of a weak ESR signal at $g = 1.94$. This signal was observed after the light was turned off and the temperature reduced to about 2 K. A small anisotropy of the ESR signal was observed ($g_{[001]} = 1.948$, $g_{[110]} = 1.943$), which allowed us to determine the valley orbit splitting for Te donor related to the X conduction band

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(CB) in AlGaAs. It was shown previously that anisotropy of the ESR signal of a group-VI donor is due to the heteroepitaxial strain induced mixing of A_1 and E symmetry donor states [1]. From the ESR signal anisotropy we estimate the energy splitting between the A_1 and E symmetry states for 20 meV. This is in good agreement with the estimations for other group-VI donors [2].

4. Photo-ESR experiments

The bistability is a well-known property of AlGaAs–GaAs heterostructures [3]. Carriers photoexcited from deep DX centers may be trapped by shallow, hydrogen-like donor states. No freeze out is observed for samples with higher donor concentration, which explains the persistence of photoexcited electrons in our samples. As soon as free carriers appear after DX photoionization there is a strong increase in the absorption of microwave power and thus decrease in the intensity of any ESR signal observed in the experiment, owing to the so-called skin effect [4]. This fact is used in the ESR studies performed for sample E23/91. In Fig. 1 we show the isotropic ESR signal observed in the experiment. This signal with g-factor similar to that of shallow donor (1.94) is of unknown origin and comes from the AlGaAs epilayer as confirmed by additional measurements performed for a sample with the GaAs substrate removed.

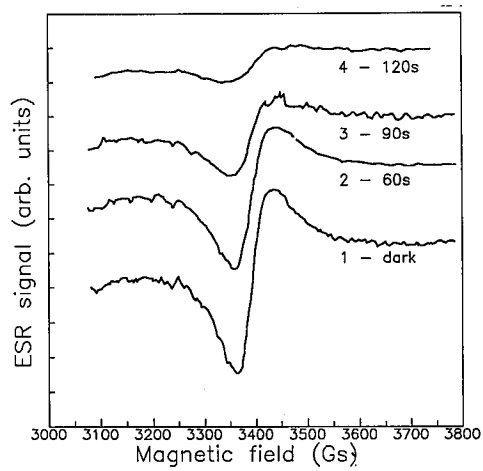

Fig. 1. The ESR signal of unidentified center in AlGaAs measured at 4 K before (1) and after (2–4) DX center ionization illumination. The illumination times are specified.

The DX center ionization and the thermal annealing were measured in the following way. All measurements were taken at 4 K after the light was turned off (Fig. 1) or, in the case of kinetics studies, under weak illumination. In the case of thermal annealing the temperature of the sample was first increased, then the sample was cooled down to 4 K and the ESR signal was measured. The influence of the illumination and its duration (Fig. 1), light intensity, and of the annealing temperature was determined from the change of the ESR signal intensity. An

exactly two-exponential decrease in the ESR signal was observed under the illumination. A two-exponential kinetics of the ionization of the DX centers was observed recently by Dobaczewski and Kaczor and was related to the presence of the intermediate DX^0 state [5–7] in the ionization transition. We have observed that the contribution of the fast component to signal kinetics increases linearly with an increase in the illumination intensity and for large intensities of illumination a one-exponential kinetics is observed.

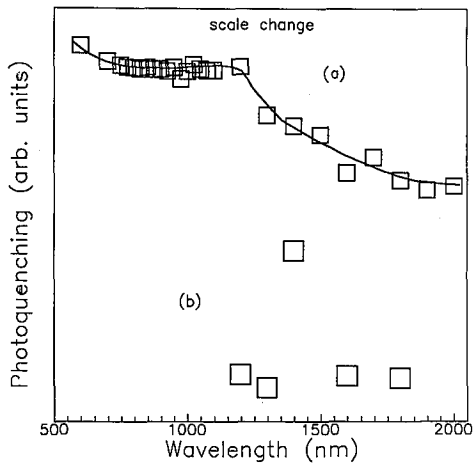

Fig. 2. The spectral dependence of the ESR signal photoquenching measured as a resulting change of the signal intensity after illumination at 4 K. In (b) the spectral dependence of the slow component of the signal kinetics is shown. For 1400 nm illumination the contribution of the slow component reaches 50% of the total signal response to the light.

In Fig. 2 we show the spectral dependence of the DX photoionization as measured in our ESR experiment via the decrease in the ESR signal intensity. We notice that the decrease in the ESR signal intensity after the illumination was persistent at low temperature and an asymmetrical ESR signal expected for conducting sample was observed. In Fig. 2b we show also the spectral dependence of the contribution of the slow component to the photoquenching kinetics. We indicate here that this dependence differs from that reported in Refs. [5–7].

The ESR signal recovers its original amplitude after annealing to temperatures higher than 90 K. Such behavior is a well-known property of the DX center and was observed previously in several cases.

5. Discussion

The lack of freeze out enabled the indirect observation of DX ionization by the ESR method. We report here the experimental data for the DX center ionization process. The first results obtained confirm the two-exponential character of the kinetics of DX ionization. We indicate, however, that by an increase in the light

intensity we could easily regulate the contributions of slow and fast components of the kinetics so that a purely one-exponential dependence could be obtained for an increased light intensity. It needs further investigation in order to conclude if all these properties can be accounted for the recent two-step ionization model [5–7].

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