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LIGHT INDUCED ORDERING OF THE EL2 DEFECTS IN THE METASTABLE STATE

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We tried to detect a strain in the crystal induced by the ordering of the EL2 defects in the metastable state by measuring linear dichroism and birefringence. We found that this strain is below the detection limit of our experiments and lower than that induced by 1 MPa of external stress. The observed dependence of orientation of the EL2 defects in the metastable state on the polarization of light used to transform EL2 to the metastable state is consistent with the attribution of the metastability of EL2 to the transformation of the isolated $\mathrm{As_{Ga}}$ to the $\mathrm{V_{Ga}As_i}$ defect and is in conflict with the $\mathrm{As_{Ga}}$–$\mathrm{As_i}$ defect pair model of EL2.

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Recently we have shown experimentally [1] that the transformation of the EL2 defect from the normal to the metastable state is connected with a lowering of the symmetry of the defect from tetrahedral T_d to trigonal C_{3v}. The evidence was based on the study of recovery of optical absorption due to EL2 during heating of the crystal under uniaxial stress. The recovery step of optical absorption splits under [111] stress and no splitting is observed under [100] stress. This indicates that EL2 in the metastable state is orientationally degenerate and has trigonal C_{3v} symmetry. From the relative magnitudes of the steps it was judged that the centers recovering at lower temperature are oriented along the [111] direction of the stress and those recovering at higher temperature are oriented aslant to this direction.

Further evidence for the orientational degeneracy of EL2 in the metastable state is that the relative magnitude of the steps can be altered by excitation of the metastability with polarized light or by excitation under stress (see Fig. 1). Excitation of metastability with light polarized parallel to the [111] direction results in an increased number of centers in the metastable state oriented along this direction, and excitation with light polarized perpendicularly results in a decreased number of centers oriented along the [111] direction (see curves *b* and *c* in Fig. 1). All the centers became oriented aslant the [111] direction of the stress after excitation performed under stress of 500 MPa (see curve *d* in Fig. 1). When the centers were transferred to the metastable state by illumination with unpolarized light, and therefore became oriented both along and aslant to the [111] direction,

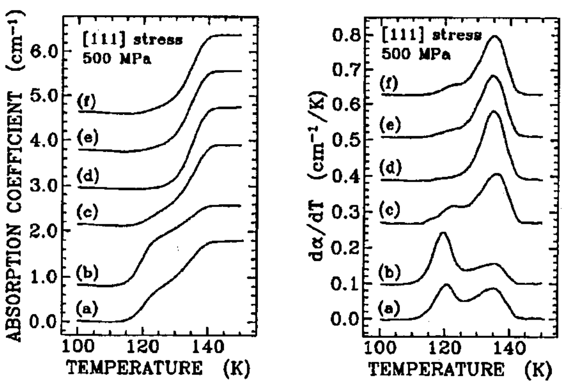

Fig. 1. Thermal recovery of the absorption due to EL2 defect in semi-insulating GaAs under [111] uniaxial stress of 500 MPa (on the left), and first derivatives of these curves with respect to temperature (on the right). Curves *a* show the recovery after excitation of metastability with unpolarized light; curves *b* and *c* were obtained after excitation with light polarized parallel (*b*) and perpendicularly (*c*) to the direction of the stress which was applied after the excitation; curve *d* was recorded after excitation performed under a stress of 500 MPa with unpolarized light. During excitation in cases *a*, *b*, and *c* no stress was applied. Curve *e* was obtained after excitation under [111] stress of 500 MPa followed by excitation with no stress applied. Curve *f* was obtained after excitation as in case *a* followed by that of case *d*.

and the crystal was then illuminated under stress of 500 MPa, the centers finally became all oriented aslant the direction of the stress (see curve *f* in Fig. 1). If the order of these two illuminations is reversed, the centers are also oriented aslant to the [111] direction (see curve *e* in Fig. 1). This is an indication that optical recovery of EL2 is present under [111] stress of 500 MPa, and it is absent when stress is not applied. EL2 in the metastable state can be oriented mostly along the [111] direction by excitation of metastability with light polarized parallel to this direction, and it can be oriented completely aslant to the [111] direction by the excitation under stress of 500 MPa.

We tried to detect a macroscopic strain in the crystal induced by ordering of EL2 in the metastable state by measuring linear dichroism in the region of the edge of fundamental absorption and birefringence at 0.93 eV. To produce a strain in the crystal it is necessary to supply a certain amount of energy. We assume that this energy may be supplied as the result of transformation of EL2 to the metastable state. The estimated energy per EL2 center necessary to produce a strain equivalent to that produced by an external stress of 10 MPa, which should be detected by our experiments, is about 0.2 eV assuming that the strain is distributed homogeneously in the crystal and that concentration of EL2 is equal to 2×10^{16} cm^{-3}. A more realistic assumption is that the strain is present only in a small volume around the defect. In this case a much smaller macroscopic effect will result.

Application of uniaxial stress to the crystal induces strong dichroism in the edge of fundamental absorption due to splitting of the valence band (see curve *a* in Fig. 2). Ordering of the EL2 defects in the metastable state does not produce detectable dichroism as shown by curves *b* and *c* in Fig. 2. We also tried to detect the strain by measuring the birefringence of the crystal at 0.93 eV. This method is about ten times more sensitive than the measurement of dichroism. The birefringence was measured during recovery of EL2 from the metastable state, in which EL2 was ordered by appropriate illumination. Also this method did not allow to detect a strain induced by ordering of EL2 in the metastable state. It is estimated that this strain is lower than that induced by an external stress of 1 MPa.

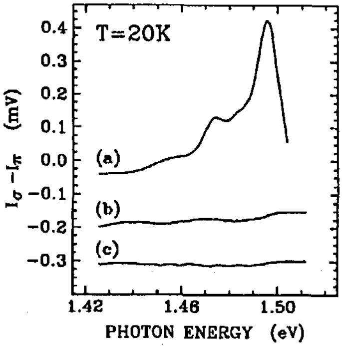

Fig. 2. Spectra of linear dichroism $I_\sigma - I_\pi$ in the region of the onset of fundamental absorption edge of GaAs. Curve *a* was obtained when the sample was under [111] uniaxial stress of 100 MPa and EL2 was in the metastable state. Curve *b* was measured with no stress applied after transformation of EL2 to the metastable state under [111] stress of 500 MPa. Curve *c* was measured with no stress applied after transformation of EL2 to the metastable state with light polarized parallel to the [111] direction with no stress applied.

On the basis of investigations of no-phonon lines in absorption [2, 3] and luminescence [4] under uniaxial stress, EL2 is attributed to an isolated arsenic antisite As_{Ga}. According to the current theoretical model [5] transformation of EL2 to the metastable state is induced by trigonal Jahn–Teller distortion following optical excitation of the defect. The central As atom then breaks one of its four As–As bonds, forming a gallium-vacancy-arsenic-interstitial $V_{Ga}As_i$ defect of C_{3v} symmetry. The direction of the Jahn–Teller distortion is expected to be dependent on the polarization of light exciting EL2, which accounts for the observed dependence of orientation of EL2 in the metastable state on polarization of light inducing the transformation. On the basis of optically detected electron nuclear double resonance experiments [6], EL2 is attributed to distant arsenic-antisite-arsenic-interstitial As_{Ga}–As_i defect pair and it is claimed [7] that As_{Ga} without the interstitial does not have the metastable property. Within this model it is expected that the orientation of EL2 in the metastable state is determined by the orientation of the As_{Ga}–As_i pair and not by the polarization of light inducing the transformation to the metastable state. This is in conflict with the presented experimental results. Concluding, our results support the attribution of metastability of EL2 to the transformation of isolated As_{Ga} to tightly bound $V_{Ga}As_i$ defect.

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