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NEW DX-RELATED PHOTOINDUCED ABSORPTION IN AlGaAs:Te

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Absorption measurements on thick AlGaAs:Te layers reveal a new absorption band at *ca.* 0.55 eV. Also the absorption coefficient of the DX-center ground state was measured directly for the first time.

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In the study of DX-centers in AlGaAs one important aspect is missing. It is the direct measurement of the photoionisation cross-section of the DX ground state. Up to now the most of DX-related absorption studies were made in the far infrared region [1]. The only attempt to estimate the DX absorption coefficient was done in the early years of the DX-research by Merz et al. [2]. The technique used there yielded very indirect results. The major reason unabling direct DX-absorption measurements was small thickness of the AlGaAs epitaxial layers.

We report here for the first time direct estimation of the absorption coefficient of the DX ground state as well as new DX-related absorption band in the vicinity of 0.55 eV.

The investigations were done on thick (40–100 μm) and very homogeneous in composition $\text{Al}_x\text{Ga}_{1-x}\text{As}:\text{Te}$ layers grown by liquid phase electroepitaxy. The dopand concentration was 2×10^{18} (for $x = 0.41$) and *ca.* 5×10^{17} (for $x = 0.33$ and $x \approx 0.54$). It seems that no additional impurity (in measurable concentrations) could have been introduced during the growth process (free carrier concentration in nominally undoped sample was in the order of 1×10^{16}).

The experimental work was carried out on BOMEM DA3 Fourier transform IR-spectrometer in the range from 700 up to 11000 cm^{-1} . Examples of the photoinduced absorption spectra obtained as a result of "white" light illumination for temperatures below 80 K are shown in the Fig. 1. The reference for these absorbance spectra was registered in the very beginning of the experiment in the time interval two orders of magnitude smaller compared with the duration of the whole experiment. So it is reasonable to assume that so obtained spectrum is that

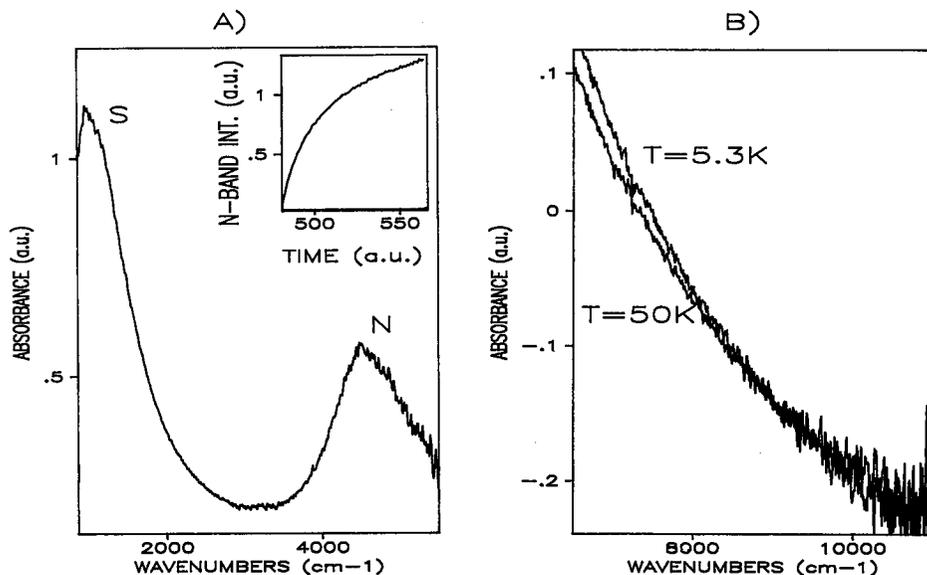


Fig. 1. DX-related infrared spectra. (a) Photoinduced mid-IR spectrum with two bands *S* and *N*. (b) Near-IR spectrum with line shape of the DX-center optical cross section.

of the "unperturbed" sample. The rapid scan technique of BOMEM DA3 enabled us to register the time evolution of the absorbance spectra.

The spectrum shown in Fig. 1a was measured in the mid-IR range (700–5500 cm^{-1}). It reveals two characteristic features: the well known IR absorption band related to the metastable DX shallow donor state [1], labelled as *S*, and a new broad peak, labelled as *N* located in the vicinity of 0.55 eV. Both bands are metastable i.e. once photoinduced they disappear only after heating the sample to 90 K. The maximum of the *N*-band shifts towards higher energies with Al composition.

The time dependence of the *N*-peak intensity was evaluated for $x = 0.41$ sample and for four different temperatures. An example is given on the inset of Fig. 1a. Similar measurements were performed for the *S*-band. The obtained kinetics of band intensity changes are strongly nonexponential but they correlate almost exactly up to very long measurement times (Fig. 2a). Both bands reach saturation at the same time. It was also seen that the correlation curve of Fig. 2a exhibits *no change* with rising temperature (below 80 K). A temperature dependence of the saturation intensity of the *S* and *N* bands was investigated. Also in this case an exact correlation was obtained (Fig. 2b).

The absorbance spectra in the near-IR region (4000–11000 cm^{-1}) show a *fall* of absorption for energies around 1.2 eV accompanied by the appearance and subsequent rise of the *N*-band related absorption.

All experimental facts listed above enables one to draw following conclusions:

1) The appearance of both mid-IR bands follows the photoionisation of the

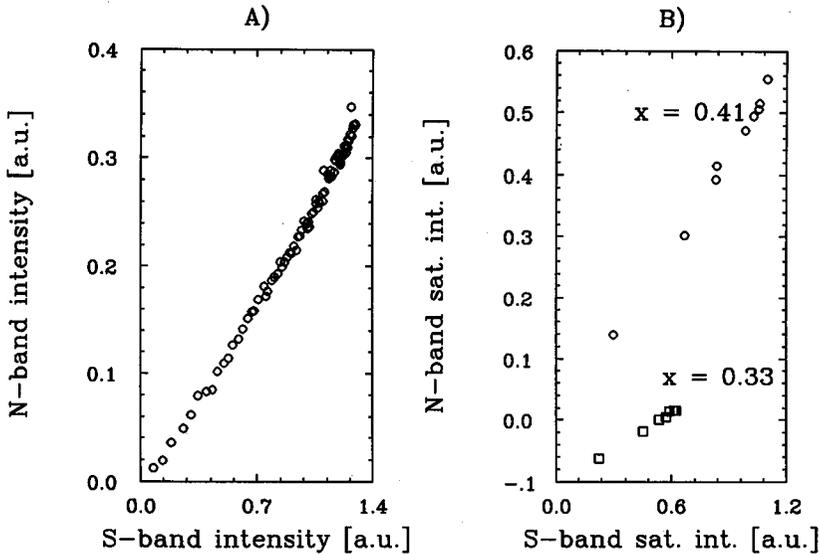


Fig. 2. The correlation curves. (a) N -band intensity vs. S -band intensity (both time dependent). (b) Saturation intensity of the N -band vs. saturation intensity of the N -band (both temperature dependent).

same defect. Otherwise it would be highly improbable that strongly nonexponential kinetics (Fig. 1a, inset) correlate so well.

2) The absence of the temperature dependence of the correlation curves shown in Fig. 2 indicate that the S and N bands should be attributed either to the same defect or to two different defects with no emission and capture barriers between them — thermal emission and capture through such barriers is expected to influence the photopopulation kinetics at higher temperatures. Moreover the correlation in temperature dependences of saturated mid-IR absorption shows that these centers should exhibit the same capture barrier with respect to the source defect mentioned in point (1).

3) The similarity between (a) the near-IR absorbance line shape and the spectral dependence of the DX-center optical cross-section [3] and (b) the correlation between near-IR and mid-IR absorption kinetics allow us to relate both S and N mid-IR bands to the DX center in AlGaAs:Te.

Concluding, if there are two metastable DX-related centers, they should be equally populated after the illumination (quite unlikely for *all* temperatures below 80 K). They would differ only in localization of their ground state wave function which would explain different intensities of the S and N absorption bands. The center corresponding to N -band should become deeper with increasing Al content.

We favor, however, another explanation. We assign both mid-IR bands to two different transitions of the same defect. Most probable candidates would be transitions from the shallow metastable X -bound donor to X_1 (S -band) and X_3

(N -band) conduction band valleys. Similar transitions were observed for p -type III-V compounds valence band defect processes [4]. The shift of the N -band with composition towards higher energies reflects in our opinion the corresponding increase in X_1 - X_3 separation. The later was calculated by Chen and Sher [5].

Acknowledgments

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References

- [1] T.N. Theis, T.N. Morgan, B.D. Parker, S.L. Wright, in *Proc. 15th Int. Conf. Defects Semicond., Budapest 1988, Mater. Sci. Forum* **38-41**, 1073 (1988); J.E. Dmochowski, J.M. Langer, J. Raczynska, W. Jantsch, *Phys. Rev. B* **38**, 3276 (1988).
- [2] J.L. Merz, J.P. van der Ziel, R.A. Logan, *Phys. Rev. B* **20**, 654 (1979).
- [3] D.V. Lang, R.A. Logan, M. Jaros, *Phys. Rev. B* **19**, 1015 (1978).
- [4] O. Madelung, *Physics of III-V Compounds*, Wiley, New York 1964, p. 63.
- [5] A.B. Chen, A. Sher, *Phys. Rev. B* **23**, 5360 (1981).