Excited acceptor-like states of the exciton bound on a single nitrogen atom in gallium phosphide

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Transitions to the $2S$ and $3S$ excited states of an exciton bound on a single nitrogen atom have been observed experimentally in the differential absorption spectra. It is shown that the nitrogen in GaP is an isoelectronic acceptor.

Nitrogen, which replaces phosphorus in the GaP lattice, is a typical isoelectronic trap which can bind the excitons and substantially increase the luminescence efficiency of this material. It has been suggested that nitrogen should behave as an isoelectronic acceptor, although the excited acceptor-like states have been observed experimentally in luminescence excitation spectra only in the case of excitons bound on deep NN_i pairs.[1] The mechanism for the formation of a bound exciton on a single N center has not been substantiated.

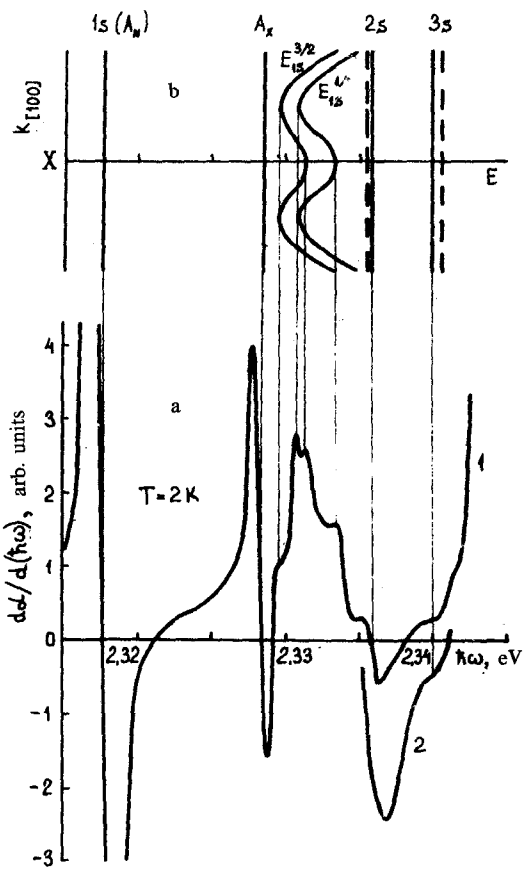

FIG. 1. Differential absorption spectra (a) and a diagram of the energy states (b) of GaP(N). The experimental curves correspond to the samples with two nitrogen concentrations N: 1—3×10^{16} cm^{-3}, 2—6×10^{18} cm^{-3}. The fine solid lines correlate the structural features of the absorption spectrum (a) with the structural features of the energy spectrum (b). In the energy diagram, the dashed lines represent the calculated values of the energy of the exciton and the solid lines denote the experimental values of the energy of the exciton which is bound on a single nitrogen atom. The curves of $E_{1S}^{3/2}$ and $E_{1S}^{1/2}$ represent the dispersion law governing the free exciton, with allowance for the "double-humped" structure of the X_1 minimum in the conduction band of GaP.

In a detailed study of the intrinsic-absorption edge of nitrogen-doped epitaxial layers of gallium phosphide at $T = 2$ K, we have detected two weak oscillations at energies of 2.3358 and 2.340 eV, as shown in Fig. 1a. The intensity of these oscillations is proportional to the concentration of the optically active nitrogen and the energy state coincides closely with the $2S$ and $3S$ excited acceptor-like states which were calculated for the case of the spatial distribution of the electronic charge density near the N site.[2]

The energy diagram in Fig. 1b shows the calculated and experimental positions of the levels of an exciton bound on a single nitrogen atom in GaP. Also shown in this figure are the data on $E_{1S}^{3/2}$ and $E_{1S}^{1/2}$—the ground state of the free exciton, whose position was determined from the phononless component of the intrinsic absorption.[3]

The mechanisms for the formation of excitons bound on a single nitrogen atom and on NN_i pairs are thus identical, and the arguments advanced previously that they may be different mechanisms cannot be seriously justified.

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