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“EXCITONIC” AND PHOTOIONIZATION ABSORPTION SPECTRA OF IRON IN III-V MATERIALS

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We report optical absorption measurements of Fe-doped GaAs, InP and GaP crystals obtained with the help of different doping techniques. In all these crystals photoionization spectra corresponding to $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}$ transitions with sharp “excitonic” lines were observed. The intensities of these lines are not proportional to the intensities of photoionization absorption bands, i.e. to the concentration of the Fe^{3+} centers. Variation of more than one order of magnitude was observed for different semiconductors and for different crystals of the same material. These results suggest that only some iron centers are responsible for the “excitonic” spectra.

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1. Introduction

The optical properties of iron impurity in InP, GaAs and GaP crystals have been investigated for many years. There are three review articles devoted to this subject [1–3]. Several new papers [4–12] published recently have brought new information about the $\text{Fe}^{3+}(3d^5) \rightarrow \text{Fe}^{2+}(3d^6)$ photoionizing transitions in these materials. Sharp “excitonic” structures of the photoionization bands reveal distances of the $\text{Fe}^{2+}(3d^6)$ intracenter transition zero-phonon lines within 0.1 cm^{-1} accuracy. These spectra were investigated with the help of calorimetric-absorption spectroscopy (CAS) [4, 5], magnetic circular dichroism (MCD) [6, 7], Fourier-transform spectroscopy (FT) [8–11] and conventional absorption spectroscopy (OA) [12].

This paper reports absorption measurements of the $\text{Fe}^{3+}(3d^5) \rightarrow \text{Fe}^{2+}(3d^6)$ transition in GaAs, GaP and InP crystals obtained with the help of different doping techniques.

2. Experimental

We have studied more than 10 different Fe-doped, semi-insulating (SI) liquid encapsulated Czochralski (LEC) InP, GaP and GaAs crystals and Fe-diffused GaAs and GaP crystals. Absorption measurements were performed at about 10 K between 0.8 and 3 μm with the help of a Cary 5 UV-VIS-NIR spectrometer.

3. Results and discussion

In all these crystals, nearly identical photoionization spectra corresponding to the already reported $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5E)$ and $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5T_2)$ transitions were observed, as shown in Fig. 1. The only differences between the spectra in these materials are their energy positions. The first $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5E)$ transition starts at 0.49 eV in GaAs, at 0.78 eV in InP and 0.82 eV in GaP. The second $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5T_2)$ transition starts at 0.87 eV, 1.14 eV and 1.23 eV, respectively.

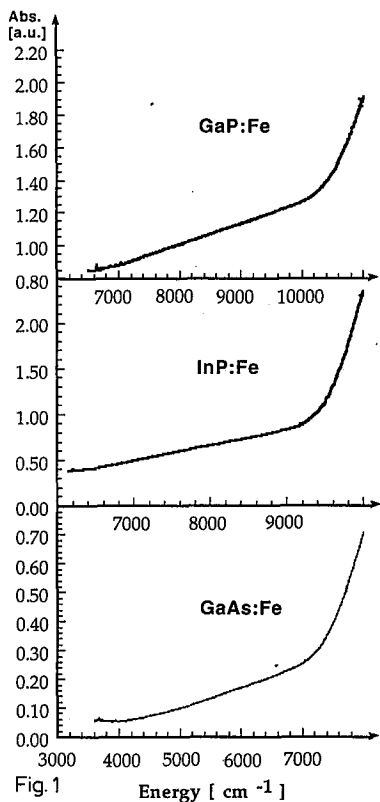


Fig. 1

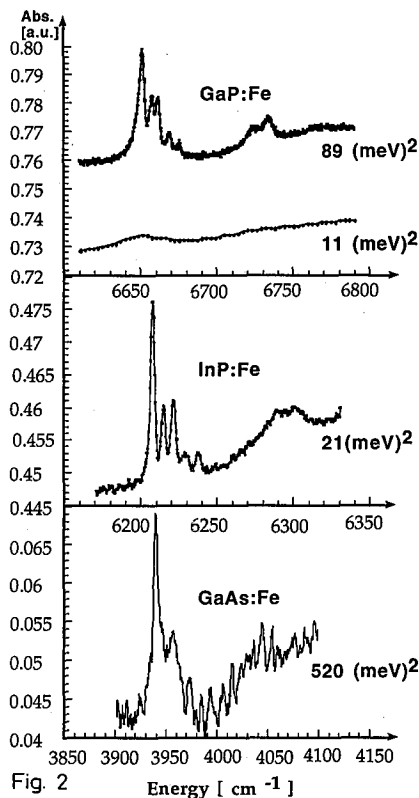


Fig. 2

Fig. 1. Absorption photoionization spectra of the $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5E)$ and $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5T_2)$ transitions in III-V semiconductors obtained at about 10 K.

Fig. 2. Sharp "excitonic" structures (so called a'-e' lines) at the beginning of the $\text{Fe}^{3+} \rightarrow \text{Fe}^{2+}(^5E)$ transitions in III-V semiconductors. The numbers on the right side represent the ratio of their intensity to the slope of the photoionizing transition.

At the beginning of these transitions several authors found a number of sharp "excitonic" lines [4-12]. We observed all the lines previously reported. There are theoretical models available, which try to explain these results as excitons bound to the iron impurity, optical transitions from the valence band to the Fe^{2+} charge state or transitions generating an effective-mass like bound hole. All these

interpretations of the sharp structures assume that their intensity is proportional to the intensity of the photoionization absorption bands, i.e. to the concentration of the Fe^{3+} centers.

To check this assumption, we chose the strongest, first group of lines (Fig. 2), so called a'-e' lines, and calculated the ratio of their intensity to the slope of the first photoionizing transition. We find that this ratio varies very strongly for different semiconductors and even for different crystals of the same material. It is equal to about 500 meV^2 for GaAs crystals, about 20 meV^2 for InP and varies from 10 meV^2 for diffused samples to 90 meV^2 for melt doped GaP crystals.

In our opinion this result suggests that only some iron centers are responsible for the "excitonic" spectra, and that their concentration depends on the doping technique. In this situation the above-mentioned models should be reconsidered.

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