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Obtaining Spectral Characteristics of Semiconductors of AIIBVI Type Alloyed with Iron Ions using Direct Matrix Method

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Abstract. The spectral regularities of the energy structure of Fe^{2+} ions in semiconductor materials have been studied through the example of ZnS. A comparison has been carried out of the absorption bands wavelengths values obtained experimentally and estimated using the direct matrix synthesis method. The possibilities of creating tunable semiconductor laser on such materials in the range of 1.5–3 microns have been presented.

Keywords: semiconductor lasers, iron group ions, energy structure, transition intensities.

I. INTRODUCTION

Ever growing amounts of information transmitted by fiber-optic communication lines necessitate the enhancement of the frequency range of the transmitting emission. Studies of domestic and foreign authors [1-6] show that the search for emission sources in the spectral range of 1.3–3 microns, especially with frequencies different from those already used in existing devices, is of great practical importance.

Semiconductor lasers are the most optimal source of emission [1], which are characterized by a large range of generated power in continuous and pulsed operation and high speed with pulse modulation, and their emission frequency can be tuned within the luminescence range [2]. Compared to other types of lasers, they have the highest efficiency, as well as smaller weight and dimensions.

AIIBVI semiconductors alloyed with Co2+, Fe2+, Ni2+ ions are of great interest. The ions of this group have wide bands of absorption and emission spectra, which is of interest for tunable mid-infrared lasers [3]. The studies conducted in this field are mostly experimental and are devoted to a single ion in a single semiconductor [4,5] or a single ion in a small array of semiconductors [6, 7].

Some studies are devoted to individual types of semiconductors [8, 9] obtained using the diffuse method [10], as well as to repetitively pulsed lasers [11, 12].

The general theory of the ligand structure of the environment of iron group ions has been developed in the studies [13-18]. However, methods for calculating the amplitude-spectral characteristics of the luminescence of iron group ions in semiconductors, taking into account all possible interactions of fields in the ion and interactions of the ion with the ligand environment fields of different symmetry, have not been created, which entails significant difficulties in creating semiconductor lasers.

The objective of the study is to estimate the parameters of the array of luminescence ranges in Fe2+ ions introduced into AIIBVI semiconductors in the wavelength range of (1.5 - 3) microns and to compare the estimation outcomes with the outcomes of experimental studies by other authors [15].

II. METHODOLOGY

From the experimental data (Fig. 1), it can be seen that the Fe2+ ions in ZnO show the largest number of transitions (five) with a wavelength in the target area of 1.3 - 3 microns, in CdO and ZnS – three transitions each [15]. It has been established that Fe2+ ions in ZnSe have one transition located within the studied range and two transitions in direct proximity to the limit of the target area, while ions in CdSe, CdTe, and ZnTe do not have any transitions with a wavelength in the target area.

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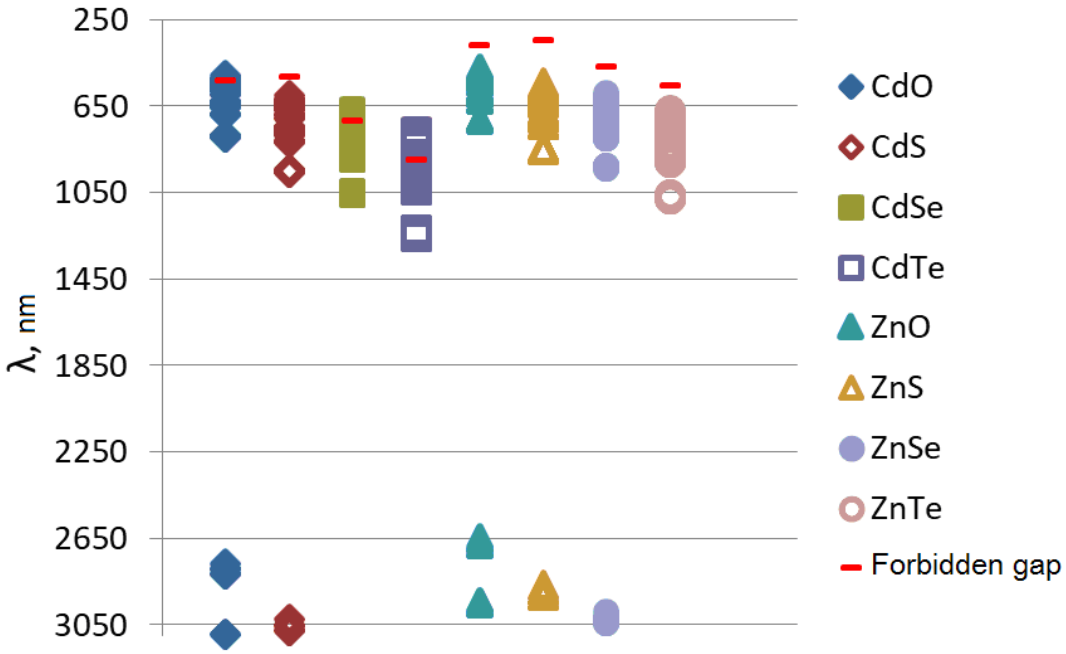

Fig. 1. Wavelengths of transitions of Fe^{2+} ions in the array of $A^{II}B^{VI}$ semiconductors

III. RESULTS AND DISCUSSION

Iron ions in $A^{II}B^{VI}$ semiconductors also have fewer transitions within the fiber transparency window of the corresponding semiconductors. Thus, Fe^{2+} ions in CdS, as well as in all zinc compounds (ZnO, ZnS, ZnSe, ZnTe) do not have transitions outside the forbidden gap. The Fe^{2+} + ions have three transitions in CdO, nine in CdSe, and ten in CdTe.

Iron compounds have a total of 14 transitions in compounds with studied semiconductors, 12 of them have a relatively high oscillator strength to be used as laser materials.

Table 1. The position of the absorption bands obtained by the theoretical and experimental method (nm.)

Fe^{2+} ion in ZnS	
experiment	theory
2800	2891, 2915
3700	3536, 3239

The difference between the absorption limits obtained by theoretical and experimental method ranges from 50-100 nm, which roughly corresponds to the error of the data obtained experimentally.

Compared with materials alloyed with cobalt and nickel, iron-alloyed semiconductors have much fewer luminescence bands in the fiber transparency window of optical fibers 1.5-3 μm. Only ZnO, ZnS and CdO alloyed with Fe^{2+} have bands on the edge of the fiber transparency window of 2500-3000 nm. The luminescence bands of other materials have too long wavelength to fall within the window.

IV. CONCLUSION

Using the new method of direct matrix analysis, the wavelengths of the absorption bands of Fe^{2+} ions in ZnS have been determined. The obtained estimated values of the spectral ranges of luminescence coincide with the values obtained in previously performed experimental studies, which confirms the correctness of the chosen method of estimation.

The results obtained make it possible to purposefully choose from the entire estimated array of transitions in $A^{II}B^{VI}$ materials alloyed with Fe^{2+}, most suitable for creating IR lasers with the required values of the wavelength and spectral characteristics of the emissions tunable within a wide range of wavelengths.

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