

LUMINESCENCE SPECTRA OF ZnSe:Fe CRYSTAL AT LOW TEMPERATURES

E.A. EMINOVA¹, M.A. MUSAEV¹, J.I. HUSEYNOV², R.B. ASLANOV³,
S.G. ASADULLAYEVA^{4, 1}, I.I. ABBASOV¹

¹Azerbaijan State Oil and Industry University, Baku, Azerbaijan

²Azerbaijan State Pedagogical University, Baku, Azerbaijan

³Institute of Biophysics, Ministry of Science and Education, Baku, Azerbaijan

⁴Institute of Physics, Ministry of Science and Education, Baku, Azerbaijan

ibrahimabbasov179@gmail.com, eminovaaee@gmail.com

A broad luminescence spectrum of a ZnSe:Fe crystal is presented, covering a wavelength range of 350–800 nm at temperatures of 18–230 K. Luminescence of the sample was excited using a continuous-wave helium-cadmium laser with a wavelength of $\lambda_{ex} = 325$ nm (He–Cd laser). The obtained broad luminescence spectra at 18 K and 140 K were decomposed into Gaussian components, after which the results were subjected to detailed analysis.

Keywords: ZnSe polycrystalline CVD chemical vapor deposition), iron impurities, ZnSe:Fe crystals, high isostatic pressure (HIP), decomposition of luminescence spectra into Gaussian components.

DOI:10.70784/azip.1.2025421

INTRODUCTION

Recently, there has been increased interest in studying the influence of transition metals, including Fe^{2+} ions, on the electronic structure of zinc chalcogenides [1- 14]. Interest in this impurity was mainly due to its ability to reduce the efficiency of luminescence in the visible spectrum and expand the possibilities of using these materials as working media for IR lasers with a wide tuning range, as well as expand the possibilities of operation at room temperature (at $T = 300$ K) due to the formation of deep energy levels [4,5,6,8]. Transition elements, iron in particular, are centers that quench luminescence in the visible spectrum. Therefore, the study of the influence of iron ions on the optical properties of ZnSe in the visible spectrum is limited. At the same time, the calculation of the energy states of impurity iron ions in ZnSe indicates the possibility of radiative transitions with an energy close to the band gap of semiconductors [15]. Therefore, the study of the optical properties of ZnSe:Fe crystals in the visible spectrum is currently very relevant. In particular the study of luminescence associated with impurity defects in ZnSe:Fe at low

temperatures is very important. In the present work, we analyze the PL spectra of ZnSe:Fe in a wide temperature range 18 - 230K.

EXPERIMENTS AND RESULTS

ZnSe:Fe sample was obtained using chemical vapor deposition (CVD) doped with iron. Fe^+ film was deposited on both sides of the ZnSe samples obtained by CVD using electron beam evaporation, followed by diffusion doping using the HIP (hot isostatic pressure) method [8,11,12].

The obtained broad spectra at temperatures of 18K, 50K, 90K, 140K and 230K are shown in Figure 1. The spectra are excited using a He–Cd laser with the wavelength $\lambda_{ex}=325$ nm (so that the energy of exciting photon is larger than the bandgap, $h\nu_{ex} > E_g$).

Decomposition of broad luminescence spectra into Gaussian components (Fig.2,3) provides a complete analysis of the structure for each component of the luminescence centers. It is assumed that the differences in the integrated spectra arise only due to a change in the relative contribution of the intensities of the individual components of the luminescence centers.

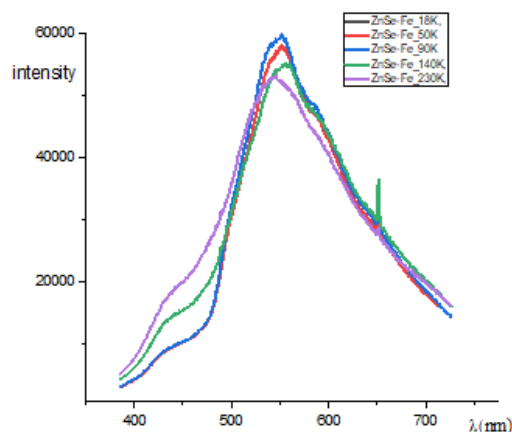


Fig. 1. Luminescence spectra of ZnSe:Fe at temperatures of 18K, 50K, 90K, 140K and 230K ($\lambda_{ex} = 325$ nm).

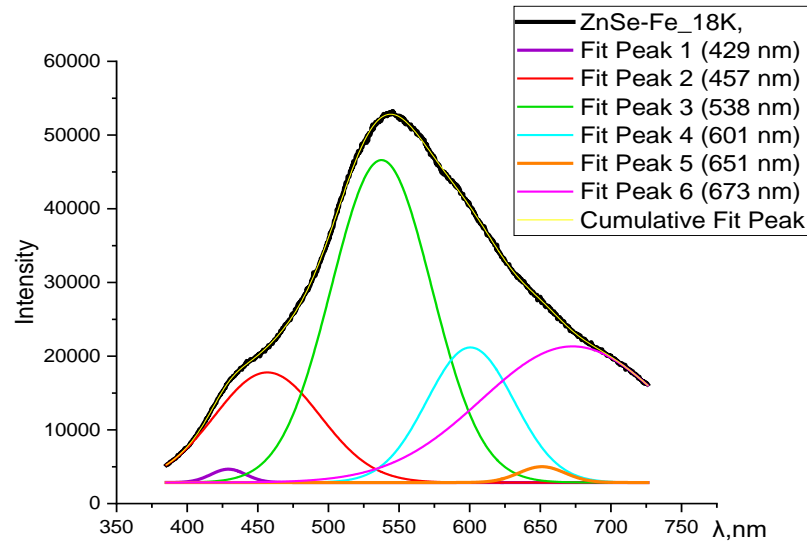


Fig. 2. Decomposition of luminescence spectra of ZnSe:Fe into Gaussian components at temperatures of 18K.

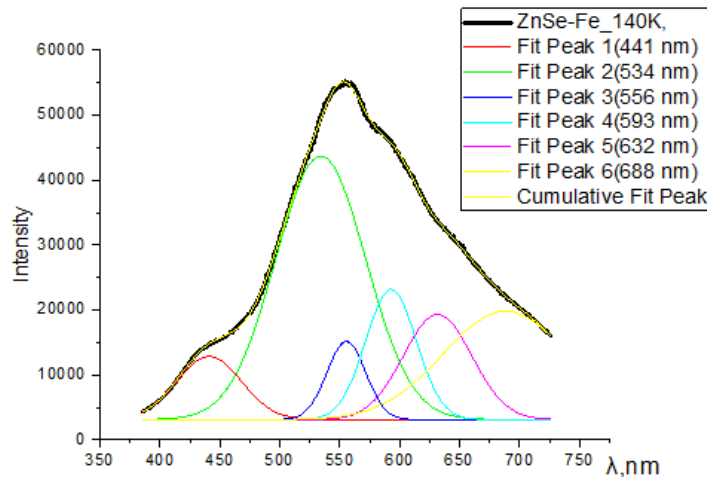


Fig. 3. Decomposition of luminescence spectra of ZnSe:Fe into Gaussian components at temperatures of 140 K.

DISCUSSION OF RESULTS

Separating the luminescence spectrum (Fig. 1) at 18 K into Gaussian components (Fig. 2) reveals that this spectrum consists of maxima at 429, 457, 538, 601, 651, and 673 nm. The band at 429 nm is associated with emission from excitons localized at neutral zinc vacancies, while the band at 457 nm is associated with interband emission. The green band at 538 nm and the remaining red bands are associated with oxygen and copper impurities. When the temperature increases from 18 K to 140 K, the maxima in the luminescence spectra shift to the long-wavelength side. Dividing the luminescence spectrum (Fig. 1) at 140 K into Gaussian components (Fig. 3) shows that this spectrum consists of six maxima and the band of maxima is distributed as follows: 441, 534, 556, 593, 632 and 688 nm. The shift of the exciton maximum is 12 nm, which is consistent with the temperature-dependent change in the band gap with increasing temperature [9-11,16]. With increasing

temperature, interband radiation disappeared (at 457 nm), and this also corresponds to literary data [9,10]. This indicates that band-to-band excitation of long-wave luminescence of ZnSe:Fe crystals is ineffective [10]. The main band at 18 K is green, with a maximum at a wavelength of 538 nm, at a temperature of 140 K it is observed at 541 nm, and it is obvious that mixing is insignificant. It is evident that with increasing temperature the proportion of low-energy bands increases, which is typical for intracenter luminescence [11,16]. At room temperature, under the influence of a helium-cadmium laser ($\lambda_{ex} = 325$ nm), luminescence in the visible region of the spectrum is not observed. We suggest that this is due to the concentration decay of luminescence in the ZnSe:Fe sample.

Thus, it can be stated that the effective excitation of intracenter luminescence of ZnSe:Fe crystals is carried out by light from the region of intrinsic absorption of Fe^{+2} ions and in the low temperature range of 18-140K.

- [1] S.S. Balabanov, K.N. Firsov, E.M. Gavrishchuk, V.B. Ikonnikov, I.G. Kononov, S.V. Kurashkin, S.V. Podlesnykh, D.V. Savin, & A.A. Sirotkin. Room-temperature lasing on Fe²⁺: ZnSe with meniscus inner doped layer fabricated by solid-state diffusion bonding. *Laser Phys. Lett.*, 16055004. 2019.
- [2] N.A. Ismayilova, I.I. Abbasov. First principle calculation of electronic, optical and magnetic properties of Zn (Fe) Se compound. *International Journal of Modern Physics B*, 35(28), 2150278, 2021.
- [3] L.L. Kulik, R. Laiho, A.V. Lashkul, E. Lahderanta, D.D. Negeoglo, N.D. Negeoglo, I.V. Radevuci, A.V. Simmel, V.P. Sirkeli, & K.D. Suskevich. Magnetic and luminescent properties of iron-doped ZnSe crystals. *Physica B*, pp. 405, 4330. 2010.
- [4] S.B. Mirov, V.V. Fedorov, D. Martyshkin, I.S. Moskalev, M. Mirov, & S. Vasilyev. Progress in mid-IR lasers based on Cr and Fe-doped II–VI chalcogenides. *IEEE Journal of Selected Topics in Quantum Electronics*, 21(1), pp. 292–310, 2014.
- [5] R.H. Page, K.I. Schaffers, L.D. DeLoach, G.D. Wilke, F.D. Patel, J.B. Tassano, S.A. Payne, W.F. Krupke, K.T. Chen, & A. Burger. Cr²⁺-doped zinc chalcogenides as efficient, widely tunable mid-infrared lasers. *IEEE Journal of Quantum Electronics*, 33(4), pp. 609–619, 1997.
- [6] V.J. Peppers, V. Fedorov, and S.B. Mirov. Mid-IR photoluminescence of Fe²⁺ and Cr²⁺ ions in ZnSe crystal under excitation in charge transfer bands. *Optics Express.*, 23(4), pp. 4406–4414, 2015.
- [7] I.T. Sorokina, E. Sorokin, S.B. Mirov, V.V. Fedorov, V. Badikov, V. Panyutin, & K. Schaffers. Broadly tunable compact continuous-wave Cr²⁺:ZnS laser. *Optics Lett.*, 27, pp. 1040, 2002.
- [8] E.M. Gavrishchuk, V.B. Ikonnikov, S.Yu. Kazantsev, I.G. Kononov, S.A. Rodin, D.V. Savin, N.A. Timofeeva, K.N. Firsov. *Quantum Electronics*, 45 (9), pp. 823, 2015.
- [9] V.V. Ushakov, D.F. Aminev, V.S. Krivobok, Intracenter radiative transitions at impurity iron centers in zinc selenide. *Fizika i Tekhnika Poluprovodnikov*, 55(4), 304–307 (2021)
- [10] Yu.F. Vaksman, Yu.A. Nitsuk, V.V. Yatsun, A.S. Nasibov, P.V. Shapkin. Influence of iron impurity to luminescence and photoconductivity of ZnSe crystals in the visible spectral region. *Fizika i Tekhnika Poluprovodnikov*, 45(9), pp. 1171–1174, (2011)
- [11] A.A. Gladilin, N.N. Il'ichev, V.P. Kalinushkin, M.I. Studenikin, O.V. Uvarov, V.A. Chapnin, V.V. Tumorin, G.G. Novikov. Study of the Effect of Doping with Iron on the Luminescence of Zinc-Selenide Single Crystals. *Semiconductors*. 53: pp. 1-8, 2019.
- [12] I.I. Abbasov, M.A. Musayev, C.I. Huseynov, Q.Y. Eyyubov, N.N. Hasimova, A.J. Mammadova, Y.I. Aliyev, N.A. Qasumov, R.Sh. Rahimov. A study of impurity defect photoluminescence in ZnSe:Cr AND ZnSe:Fe in the near infrared at room temperature. *Advanced Physical Research Vol.5, № 3*, pp.192-199, 2023.
- [13] I.I. Abbasov. Study of impurities-defective luminescence in ZnSe:Cr and ZnSe:Fe in the red and near infrared range. *AJP Fizika*, 28(4), pp. 3-6, 2022.
- [14] M.A. Musayev, I.I. Abbasov, E.A. Eminova. Study of the dependence of the radiation intensity in the near infrared range of znse:fe on the power of the exciting source *ajp fizika volume XXX № 4, section: E pp.30-32*, 2024.
- [15] A. Zunger. Electronic Structure of 3d Transition-Atom Impurities in Semiconductors *Sol. St. Phys.*, 39, 276, 1986.
- [16] D.D. Nedeoglo and A.V. Simashkevich. Electric and luminescent properties of zinc selenide. Kishinyov: Shtiintsa 1984.

Received: 17.11.2025