EFFECT OF GAMMA IRRADIATION ON CRYSTAL STRUCTURE AND SURFACE MORPHOLOGY OF $Cd_{1-x}Fe_xS$ THIN FILMS

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$Cd_{1-x}Fe_xS$ (x=0.03) solid solutions were synthesized and thin films were obtained on their base by the molecular beam condensation method. The growth properties, crystal structure and surface morphology of thin films as well as effect of γ-irradiation on these properties were studied by XRD, SEM, EDX methods. XRD analysis showed that the orientation of crystal planes changes after γ-irradiation. It was determined that the peak intensity of the (101) plane of $Cd_{1-x}Fe_xS$ solid solutions increased with the radiation dose. Sizes of crystallites increased after γ-irradiation. XRD investigations demonstrate, that thin films grown on glass substrates at substrate temperature T_{sub}=470 K were polycrystalline structures and thin films grown at substrate temperature T_{sub}=670 K were monocrystalline structures.

Keywords: Solid Solution, Semimagnetic Semiconductor, SEM, XRD, EDX, γ-radiation
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1. INTRODUCTION

Cadmium sulfide (CdS) with a bandgap of 2.44 eV is considered to be one of the semiconductor compounds of II-VI group, and useful in solar cell devices, thin film transistors, optoelectronic devices, etc. making interesting material for application purposes [1-6]. Thin films of CdS are more focused in the production of electronic devices, photovoltaic cells and optical detectors. In recent years, some research in the field of magnetic materials has been directed to obtain semiconductors with ferromagnetic properties at room temperature. Semiconductor compounds II-VI group containing Mn, Fe, and Co ions have been extensively studied for their properties as dilute magnetic semiconductors or semimagnetic semiconductors (SMSC) [7,8].

New class materials in which semiconductors are doped with magnetic impurities are II-VI semiconductors. SMSC is critical to the future of electronic science because it combines elements of semiconductors (charge) and magnetism (spin) into a single material known as spintronics [9, 10].

Nowadays, it is impossible to imagine modern electronics without thin films. Since devices are created on the surface of crystals, including all structural changes reflected in the parameters of devices, it is necessary to obtain thin films with perfect crystal structure and clean smooth surface. Meanwhile, one of the urgent problems of modern physics is to obtain radiation-resistant and radiation-sensitive materials with stable physical properties. It should be noted that due to the formation of radiation defects, changes in the physical properties of materials that are most strongly affected by ionizing radiation under certain conditions are observed [11]. For this reason, it is important to study the effect of ionizing radiation on the physical properties of semiconductor materials. These materials have many promising applications in solar cells, optoelectronics, light amplifiers, light-emitting diodes, laser diodes, photoelectrochemical cells, nanosensing, and biomedical imaging [12-14].

$Cd_{1-x}Fe_xS$ thin films are of particular significance in actual application and basic research. Some works have been dedicated to the problem of physical properties of $Cd_{1-x}Fe_xS$ thin films [15,16]. The current paper is about the investigation of the effect of γ-irradiation on the crystal structure and surface morphology of $Cd_{1-x}Fe_xS$ thin films.

2. MATERIAL AND METHOD

Synthesis of $Cd_{1-x}Fe_xS$ solid solutions was obtained, therefore treatment of primary components: cadmium, sulfur, iron. In order to clean electrolytic iron covered with an oxide layer, we etch it in a solution of distilled water and nitric acid (HNO_3) taken in a ratio of 1:1, and then wash it in distilled water. We accurately weigh the primary components on the VLA-200 analytical scale. The following formula is used to calculate the amount of substances:

$$P_{Cd} = P \cdot A_{Cd} \cdot x / (A_{Cd} \cdot x + A_{Fe} \cdot y + A_S \cdot z); \quad (1)$$

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$$P_{Fe} = P \cdot A_{Fe} \cdot y / (A_{Cd} \cdot x + A_{Fe} \cdot y + A_S \cdot z); \quad (2)$$

$$P_S = P \cdot A_S \cdot z / (A_{Cd} \cdot x + A_{Fe} \cdot y + A_S \cdot z) \quad (3)$$

where, P – total weight of charging, P_{Cd} – cadmium weight, P_{Fe} – Fe weight, P_S – sulfur weight, A – atomic weight of element, x,y,z – atomic share of Cd, Fe, S respectively.

It is noteworthy, which filling of drawn components into recycled and thermally treated ampoules is carried out in the same order. After creating a vacuum of $1 \cdot 10^{-4}$ Pa in the ampoules, its mouth is separated from the absorption system by melting and soldering, and then the process of synthesis of the materials to be processed is carried out. The ampoule set down in the horizontal furnace is heated to the melting temperature of the solid solution at 100 degrees/hour, and the temperature increases by 50 degrees after keeping for 3 hours. When the required temperature is obtained, the mixing mechanism is periodically changed for 2 hours. Then the temperature is reduced to T_{fus}. The bulb is kept at this temperature for 24 hours and the entire system is rotated periodically to mix the alloy well. After the synthesized samples undergo a homogeneous thermal treatment at a temperature of 873÷973 K for a week, the substance quantity of 10 g of $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions is calculated using the above formula.

$Cd_{1-x}Fe_xS$ (x=0.03) SMSC thin films of 1.5 μm thickness were deposited on cleaned glass substrates at the rate of υ=18-20 Å/s by molecular beam condensation technique in a vacuum of $(1\div2)10^{-4}$ Pa. All technical details and preparation methodology are reflected in our previous works [17,18].

The rate of condensation is controlled by the temperature of the primary source. We can note that additional S source evaporation was used in order to obtain perfect film surface morphology without using any samples. It can be seen from the XRD studies that $Cd_{1-x}Fe_xS$ thin films develop in glass substrates at T=470 K have a polycrystalline structure, and at the substrate temperature T=670 K they have a monocrystalline structure.

$Cd_{1-x}Fe_xS$ (x =0.03) thin films were irradiated with γ- rays obtained from ^{60}Co source of E=1.17 MeV, E=1.33 MeV energies.

The structure and phase purity of the γ-irradiated films were examined by X-ray diffraction (XRD) at room temperature using a BRUKER XRD D8 ADVANCE. The studies of surface morphology of $Cd_{1-x}Fe_xS$ (x=0.03) thin films were carried out the scan electron microscope (SEM) JEOL/ JSM-6610. According to the Energy Dispersive X-Ray Analysis (EDX) technique, the chemical structure of these films was analyzed using standard energy dispersive analysis.

3. RESULTS AND DISCUSSIONS

On the characteristics of electronic devices are relatively related to the surface morphology of crystals, the study of external effects (temperature, pressure, lighting, radiation, etc.) occupies the significant place in diagnosing their surface. It is clear that radiation technology is more dominant favorable methods for the modification of semiconductor materials. Thus, by irradiating the material, it is possible to control the physical feature of these materials, as well as to predict the properties of devices based on them. In this regard, it is of great interest to study the changes in the surface of the $Cd_{1-x}Fe_xS$ (x=0.03) thin films irradiated by γ-quanta. The results of SEM and XRD studies of $Cd_{1-x}Fe_xS$ (x=0.03) thin films exposed to γ-irradiation (D_γ=10÷100 kGy) are presented in this study.

The X-ray diffraction patterns of $Cd_{1-x}Fe_xS$ (x=0.03) thin films are illustrated in figure 1 that indicates the polycrystalline nature of films. High intensity peaks of sample is given using Debye Scherrer equation. According to the table 1, the XRD measurement reveals that all the sharp diffraction peaks (100), (002), (101), (102), (110), (103), (200), (112), (201) and (202) confirmed face centered cubic structure of $Cd_{1-x}Fe_xS$ with crystal lattice parameter of a=b=4.1002 Å, c=6.6568 Å, γ=120^0. The crystallite size (figure 1,a) of $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions may be estimated from the width of the XRD peak using Debye–Scherrer's formula [19] given by

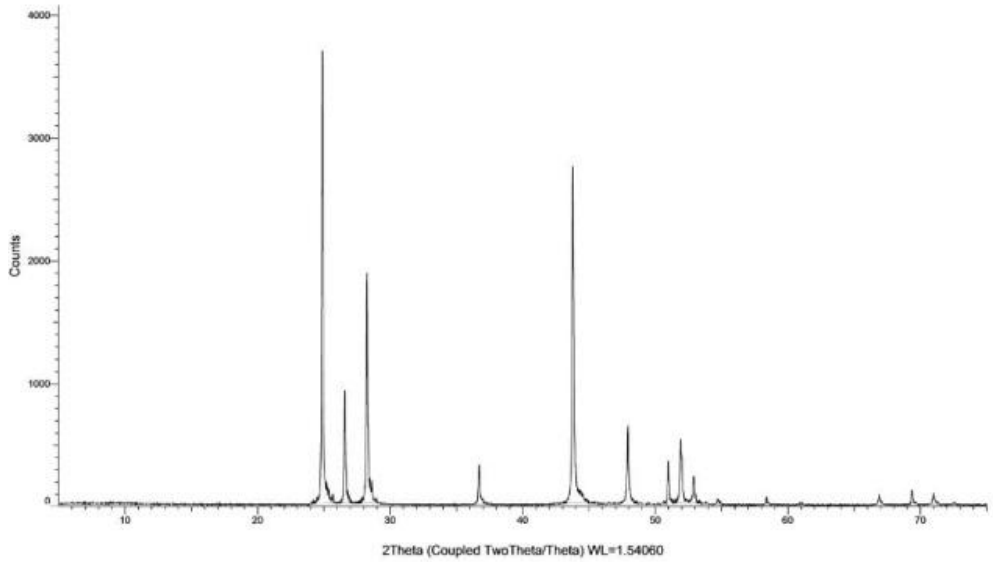
$$D = (0.9\,\lambda)/(\beta \cos\theta) \quad (4)$$

where, D - is crystallite size, β - is full width at half maxima (FWHM) of the peak intensity, θ - is diffraction angle in degrees and λ - is the wavelength of X-ray used (table 1).

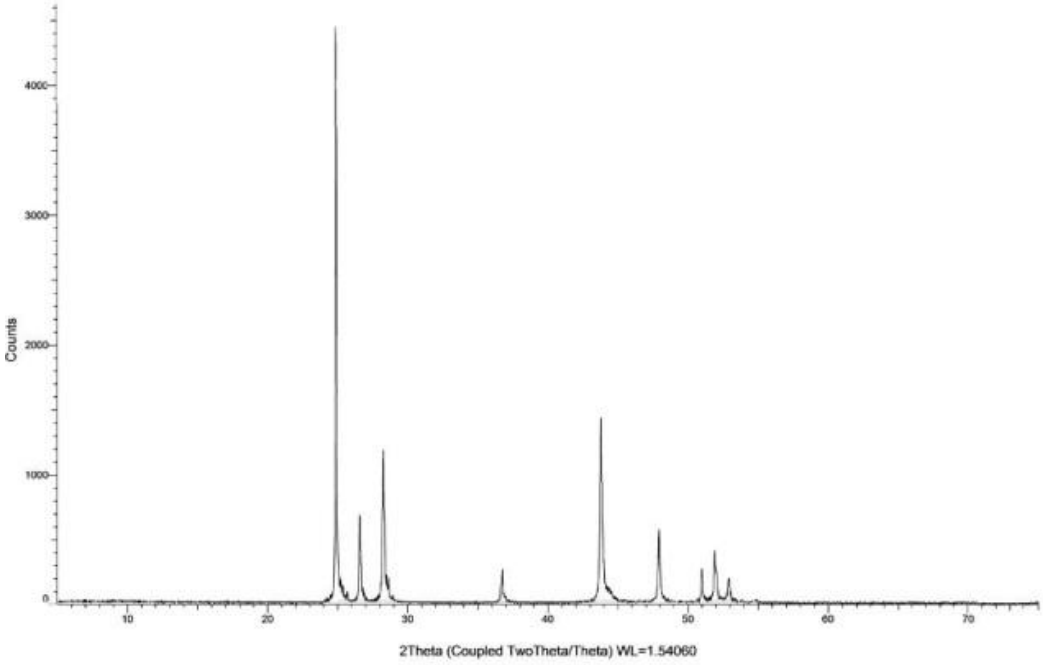
The particle size for $Cd_{1-x}Fe_xS$ (x=0.03) thin films was 15.20 nm.

It was studied effect of γ-irradiation on crystal structure of $Cd_{1-x}Fe_xS$ (x=0.03) thin films. XRD patterns of $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions on glass substrate and irradiated by γ- quanta (E=1.17 MeV, E=1.33 MeV) with different doses (D_γ=10÷100 kGy) are shown in figure1,b. The diffraction pattern of γ - irradiated thin films with different doses D_γ < 100 kGy revealed that the peak intensity of (100) plane of $Cd_{1-x}Fe_xS$ increased with dose.

It can be seen that the number of planes aligned along the (100) direction increased with γ-irradiation. The reason for this is that ^{60}Co γ-rays are high-energy electromagnetic waves. When the radiation dose D_γ=50 kGy÷100 kGy, the surface energy becomes important in the process of crystal growth. During the process, atoms are easily attracted by the high surface energy (100) crystal face and condense there, which can lead to the predominance of the (100) plane [20,21]. XRD analysis confirmed the change in orientation of the planes after γ-irradiation exposure.



a)



b)

Figure 1. X-ray diffraction patterns of $Cd_{1-x}Fe_xS$ (x=0.03) thin films: a) D_γ=0, b) D_γ=100 kGy.

Table 1.
The XRD measurements

№	2θ (deg)	Crystal system (hkl)	FWHM, β (deg)
1	27	100	0.15
2	28.2	002	0.15
3	30	101	0.15
4	38.4	102	0.1
5	45	110	0.25
6	50	103	0.25

7	52.7	200	0.2

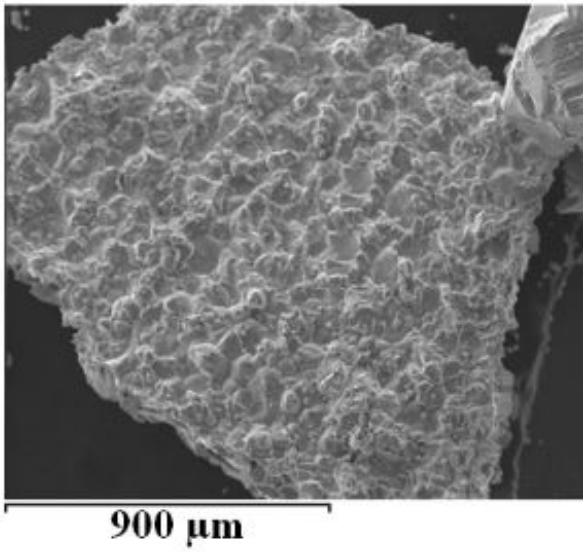


Figure 2. SEM imagines of $Cd_{1-x}Fe_xS$ (x=0.03) thin films.

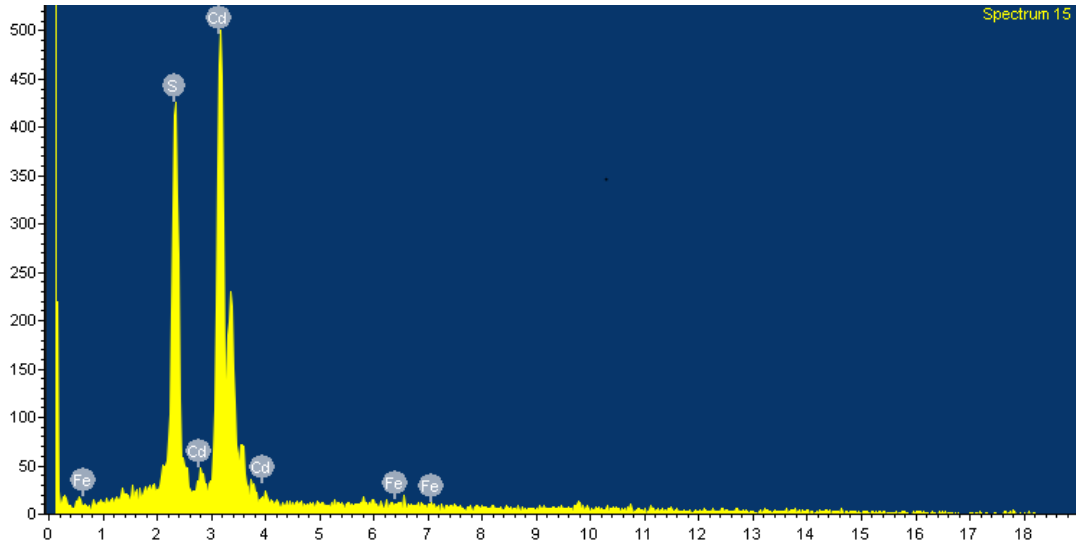


Figure 3. Energy-dispersive X-ray spectrum of $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions.

The SEM method was used to study the effect of γ-irradiation on the surface morphology of $Cd_{1-x}Fe_xS$ (x=0.03) thin films. The morphology of the $Cd_{1-x}Fe_xS$ thin films was analyzed by SEM method (figure 2).

$Cd_{1-x}Fe_xS$ (x=0.03) solid solutions were irradiated with γ-quanta at a dose of D_γ=100 kGy, which is caused by the interaction of γ-quanta with atoms in their paths during irradiation. It was reveiled, that after γ-irradiation, the $Cd_{1-x}Fe_xS$ crystallite size increased, which is in profitable consent with the XRD results.

The elemental chemical composition was studied using Energy Dispersive X- ray (EDX) analysis (figure 3).

The ratio of Cd: Fe: S is observed to be about 46.2 at %: 2.89 at %: 50.91 at % for films with x=0.03 which indicated that the composition was nearly

stoichiometric. The results did not deviate much from the structure of starting precursor alloys.

4. CONCLUSION

In the current research, $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions were synthesized and thin films were obtained on their basis by molecular beam condensation method. We studied the effect of γ-irradiation on growth properties of obtained thin films. Properties of $Cd_{1-x}Fe_xS$ (x=0.03) solid solutions exposed to 50, 100 and 150 kGy doses of γ-rays from ^{60}Co source were characterized by XRD, SEM, EDX methods.

XRD analysis revealed that the peak intensity of the (101) plane of $Cd_{1-x}Fe_xS$ increased with dose. Crystallite size increased after γ-irradiation. Finally, it was realized, which is possible to control some crystal properties with γ-irradiation. The results obtained from XRD investigation demonstrates, that thin films with polycrystalline structure grow on glass substrates at substrate temperature T_{sub} = 470 K, and monocrystalline structure grow at substrate temperature T_{sub} = 670 K.

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