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Effect of Gamma Irradiation on Electrical and Photoelectrical Properties of CdFeTe Thin Films

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Abstract

$Cd_{1-x}Fe_xTe$ solid solutions (purity 99.999%) was used to obtain thin films by the Molecular Beam Condensation method in a vacuum of 10^{-4}Pa at substrate temperature T_{sub}=670 K and source temperature T_{sour}=1100 K. The condensation rate was υ = 18-20Å / s and film thickness was d = 2 µm.

The crystal structure and surface morphology of thin films were studied by XRD method on Bruker D8 Advance XRD and SEM scanning electron microscope on Carl Zeiss Sigma VP.

VAC of $Cd_{1-x}Fe_xTe$, x=0.08 thin films and the effect of γ-irradiation on them were studied at T=300K temperature. VAX measurements were performed at $D_\gamma \leq$ 1kGy γ-irradiation doze. The observed dependence shows that when $Cd_{1-x}Fe_xTe$ (x=0.08) thin films are irradiated with small doses, deep levels are formed in the forbidden zone, and these levels are occupied by a part of electrons, the remaining electrons participate in conduction and cause an increase in current. When samples are irradiated with a dose of D_γ = 500 Gy, decrease in conductivity are observed, which indicates an increase in the concentration of defects. At doses $D_\gamma \geq$ 1kGy, conductivity decreases, which explained by an increase in the concentration of defects and thus a violation of the crystal structure.

Illumination of semiconductors leads to optical filling of local levels, which differs significantly from that in the dark. The effect of γ-irradiation on the photoconductivity can be explained by the formation of various types of defects in them. Spectral characteristics of photoconductivity shows that spectral range covers the wavelength range λ = 400 nm-1500 nm. There is a broad band in the PC spectrum, the width of the forbidden zone calculated from the PC maximum (λ = 800 nm) E_g = 1.55 eV at T = 300 K. The effect of γ-irradiation on spectral characteristics shows that $Cd_{1-x}Fe_xTe$, x=0.08 thin films are sensitive to illumination and γ –irradiation.

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1. Introduction

Since the two decades, semimagnetic semiconductors (SMSC) have been intensively investigated because of their wide applications in spintronics, optoelectronics etc. II–VI binary semiconductors based SMSC are a great importance in technology [1-3].

Cadmium telluride (CdTe) is a wide band gap semiconductor material with an energy gap E_g =1.43 eV at T=300 K and have many excellent physical properties. This semiconductor compound has potential applications as radiation detectors, solar cells, photonic devices etc. CdTe crystallizes in a cubic structure with a lattice parameters a=6.48Å. CdTe of cubic crystalline structure can be obtained by accurate control of temperature and pressure. It should be noted that, Fe is a good ferromagnetic material and have low coercively, high Curie temperature. Fe^{2+} in CdTe have both spin and orbital moment (S = 2, L = 2). Therefore, $Cd_{1-x}Fe_xTe$ SMSC have several unique electronic and magnetic properties, such as tune the band gap by changing the Fe concentration [4-6].

It has been reported on many important physical properties of $Cd_{1-x}Fe_xTe$ SMSC in [4–6]. In our previous works we theoretically studied electronic band structure and magnetic properties of SMSC such as $Cd_{1-x}Mn_xTe$ by using ab initio calculations [7-10]. However, there are few reported theoretical investigations on $Cd_{1-x}Mn_xTe$ SMSC [11,12]. $Cd_{1-x}Fe_xTe$ SMSC in comparison with $Cd_{1-x}Mn_xTe$ not experimentally researched enough. On the other hand, it is important to study physical properties of $Cd_{1-x}Fe_xTe$ thin films under the influence of external factors as γ-irradiation [13]. In the present paper, we investigated effect of gamma irradiation on electrical and photoelectrical properties of $Cd_{1-x}Fe_xTe$ thin films.

2. Technology

$Cd_{1-x}Fe_xTe$ (x=0.08) SMSC thin films were grown on glass substrates at the condensation rate of υ=18-20 Å/s by molecular beam condensation technique in a vacuum of 10^{-4} Pa. Glass substrates (1×1 cm) were cleaned with acetone, methanol, and distilled water. The powder of $Cd_{1-x}Fe_xTe$ solid solutions (purity 99.999%) was used to obtain thin films. The temperature of the substrate was T_{sub} = 673 K and a temperature of the source was T_{sour} = 1100 K, the film thickness was d = 2 μm.

The crystal structure of the obtained thin films were studied in X-ray diffractometer on Bruker D8 Advance XRD (Figure.1).

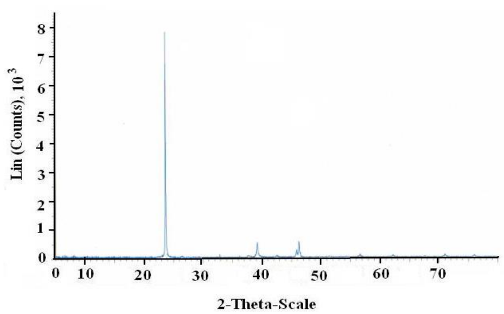

Figure.1. XRD analysis of $Cd_{1-x}Fe_xTe$ thin film obtained on a glass substrate, T=675K

The XRD pattern of $Cd_{1-x}Fe_xTe$ (x=0.08) thin film shows epitaxial nature with a sharp peak between 20°–30°.

The surface morphology was studied in SEM scanning electron microscope on Carl Zeiss Sigma VP, respectively (Figure 2, Table 1).

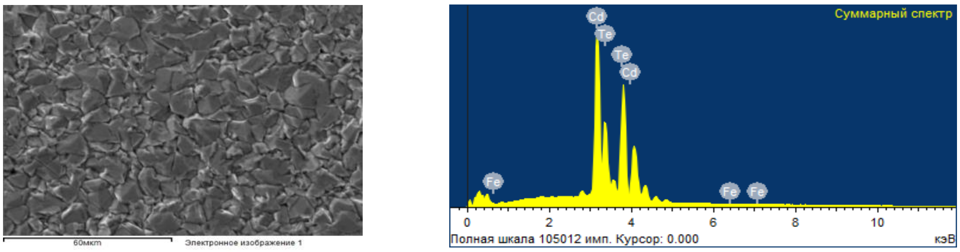

Figure.2. SEM image (a) and EDS spectrum (b) of $Cd_{1-x}Fe_xTe$ (x=0.08)

Table 1. SEM/EDS analysis of $Cd_{1-x}Fe_xTe$ (x=0.08)

Element	Weight %	Atomic %
Fe	0.08	0.16
Cd	47.33	50.45
Te	52.60	49.39
Total	100.00	

3. Experimental

VAC of $Cd_{1-x}Fe_xTe$, x=0.08 thin films and the effect of γ-irradiation on them were studied at temperature T=300K. (Figure 3). The samples were irradiated with γ-quanta in the ^{60}Co source with energy 1.25 MeV and 1.33 MeV. VAX measurements were performed at $D_\gamma \leq$ 1kGy γ-irradiation doze. After γ-irradiation at a dose of D_γ < 100 Gy, the curve increases in the entire voltage range, while the nature of the dependence does not change in principle. The observed dependence shows that when $Cd_{1-x}Fe_xTe$ (x=0.08) thin films are irradiated with small doses, deep levels are formed in the band gap, and these levels are occupied by a part of electrons, the remaining electrons participate in conduction and cause an increase in current.

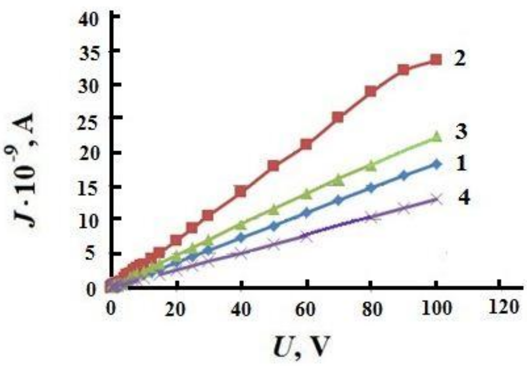

Figure.3.VAX of $Cd_{1-x}Fe_xTe$, x=0.08 thin films:1- D_γ=0, 2- D_γ=100 Gy, 3- D_γ=500 Gy, 4- D_γ=1 kGy

When samples are irradiated with a dose of D_γ = 500 Gy, a parallel downward shift of the curve and a decrease in conductivity are observed in VAX, which indicates an increase in the concentration of defects. At doses $D_\gamma \geq$ 1kGy, conductivity decreases. A significant decrease in conductivity is explained by an increase in the concentration of defects and thus a violation of the crystal structure.

Illumination of semiconductors leads to optical filling of local levels, as a result of which the filling of these levels differs significantly from that in the dark. The effect of γ-irradiation on the photoconductivity of semiconductors can be explained by the formation of various types of defects in them. Complex studies of electrophysical properties and photoconductivity of thin films of initial and irradiated $Cd_{1-x}Fe_xTe$ (x=0.08) thin films were conducted to clarify the reasons for the change in photosensitivity in irradiated crystals.

Spectral characteristics of photoconductivity (PC) at T=300K in $Cd_{1-x}Fe_xTe$ (x=0.08) thin films grown on glass substrates were studied. Spectral dependencies of PC of primary samples are shown in Figure 4. As can be seen from the Figure 4, the spectral range covers the wavelength range λ = 400 nm-1500 nm. There is a broad band in the PC spectrum, the band gap calculated from the PC maximum (λ = 800 nm) which is E_g = 1.55 eV at temperature T = 300 K. The obtained results are consistent with our theoretical calculations [11,13].

The effect of γ-irradiation on the spectral characteristics of $Cd_{1-x}Fe_xTe$ (x=0.08) thin films at T=300 K was studied (Figure 4). The samples were irradiated with γ-quanta at doses D_γ = 100 Gy ÷ 1 kGy. After irradiation of samples at doses of D_γ = 100 Gy, the PC decreased and an additional peak appeared, that indicate to the formation of a defect levels. At doses of D_γ>500 Gy, there is an increase in the post-irradiation PC. Photosensitivity is lost after irradiation at a dose of D_γ = 1 kGy.

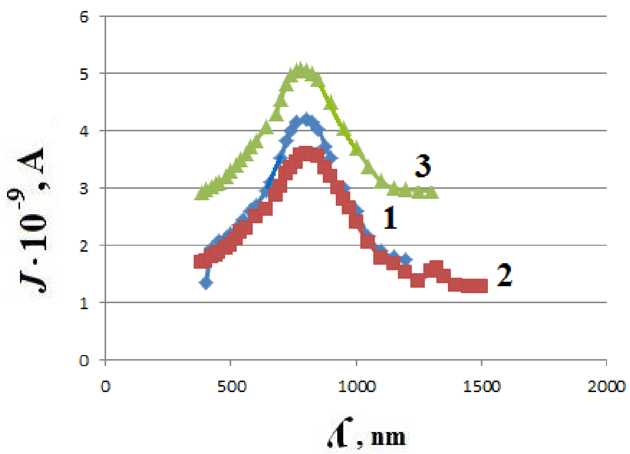

Figure 4. Spectral characteristics of photoconductivity in $Cd_{1-x}Fe_xTe$ (x=0.08) thin films at T=300 K: 1- D_γ =0, 2- D_γ =100 Gy, 3- D_γ =500 Gy

4. Conclusion

In this work, the VAX and photoconductivity of $Cd_{1-x}Fe_xTe$, x=0.08 thin films grown on glass substrates and the effect of γ-irradiation on these properties are studied. It was defined that $Cd_{1-x}Fe_xTe$ (x=0.08) thin films are sensitive to illumination and γ –irradiation. These materials can be used in photo- and ionizing radiation detection.

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