Optical Properties of γ – Irradiated $Cd_{1-x}Fe_xS$ Thin Films

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Abstract: - The transmission spectra of γ-irradiated $Cd_{1-x}Fe_xS$ *(x*=0.05*)* thin films were carried out to study the effect of γ-irradiation upon optical properties and dispersion parameters. It was found that the optical properties of $Cd_{1-x}Fe_xS$ thin films were highly affected by the exposure to *γ*-irradiation. The optical absorption spectra showed that the absorption mechanism is a direct allowed transition. The optical energy gap increases with the increase in irradiation dose. The values of optical constants were affected obviously with the increase in irradiation dose.

Key-Words: - semimagnetic semiconductor, thin film, γ - irradiation, energy gap, optical
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1. Introduction

Recently, peaceful use of nuclear energy has increased radiation contamination factor in the world and caused the radiation safety problems become actual. Radioactive contamination of the environment may occur due to the development of nuclear energy, preservation and processing of radioactive waste of nuclear reactors, use of radioactive isotopes in national economy, nuclear explosions, industrial waste etc. reasons. During such contamination the environment, including living organisms are exposed to radioactive irradiation *(α-, β-, γ-* etc.).

Radioactive rays are produced by radioactive substances and as their decomposition period is different for natural and artificial radioactive substances, their environmental impact period can be from few to million years.

New specific features – ecological, psychological, biological and so on are observed as a result of radiation exposure. To identify the harmful effects of radioactive contaminated sites on the environment, as well as human life and to protect the area, food and people from this impact it should be defined the irradiation dose rate. In order to neutralize the effects of radiation in the environment and living organisms, the development of radiation resistant devices and highly effective dosimeters detecting γ-radiation dose in a wide range of energy for revealing the features of radiation and assessing its safety is of great importance. On the other hand, radiation detectors have a great importance in medicine. It is impossible to imagine the modern medicine without ionizing radiation therapy. *γ* – and *X*-ray radiation are currently being used successfully in the treatment of various diseases. For this reason, choosing the right radiation dose in radiation procedures and accurate detection of radiation background in the environment is one of the important issues. The above-mentioned dosimeters can be used for environmental monitoring purposes, in radioecological service in sanitary epidemiological stations, for detecting radioactive materials and facilities in customs service, in emergency situations, military threat and medicine. By means of dosimeters, the contaminated areas affected by radiation, the type and nature of the radiation, *γ*- and x-ray radiation equivalent dose, and the exposure dose rate are determined, and research of radioactive materials and ionizing sources is conducted.

$Cd_{1-x}(TM)_xTe(S)$ (TM-transition metals: Fe, Co, Mn, etc.) semimagnetic semiconductors (SMSC) are considered the most promising materials for *γ*- and *X*-ray radiation detectors. SMSC incorporating the features of ordinary and magnetic semiconductors, belong to a new class of semiconductor materials. The main distinguishing feature of SMSC is that there is an exchange-interaction between magnetic ions and charge carriers in external magnetic field and it leads to strengthening of some effects in those semiconductors. The energy spectrum of charge carriers change extra-ordinarily in the magnetic field and it enables to manage the properties of the structures based on these semiconductors by magnetic field and temperature. On the other hand, by inserting TM ions into the crystal lattice of $A^{II}B^{VI}$ compounds and as a result, with the formation of solid solutions the band gap width grows sharply, and it causes a shift of its photosensitivity towards short wavelength range - to the γ-ray and X-ray range of the electromagnetic wave spectrum. It enables us to prepare devices working in short-wave range and at room temperature. By varying of the type and content, *TM* element ions in the composition of SMSC the photosensitivity range of the materials can be managed [1-17].

Over the past few years, the possibilities of developing X-ray and γ-ray detectors based on $A^{II}(TM)B^{VI}$ SMSC have been studied. Unlike others, these detectors can operate at room temperature and without the scintillation material. The working mechanism of these detectors is based on the principle of electrical conductivity change under the influence of different type of ionizing rays. The superior feature of these detectors than scintillated ones is - lack of multi-stage mechanism such as transforming energy of particles to electric signal. On the other hand, they have a number of advantages in comparison with gas ionizing cameras. Another advantage is that density of substance in SMSC is of great importance and detectors prepared on their base enable to reduce sharply the volume of the functional material.

In recent years small-size semiconductors are successfully applied in microelectronics, spintronics, optoelectronics, integral optics, astrophysics, medicine and other fields. $A^{II}(TM)B^{VI}$ SMSC thin films are considered to be very perspective and unique for making of detectors of γ-ray and X-ray [18-22]. Thin films of these SMSC have been studied less in comparison with other semiconductors. Therefore, obtaining of their perfect samples and investigate of their physical properties before and after γ –irradiation as well as study of their application perspectives in device-building is one of the scientific problems and of great importance.

This paper is aimed to study of optical properties induced by gamma irradiation of the $Cd_{1-x}Fe_xS$ (x=0.05) SMSC thin films. The evaluation is made for different γ- irradiation at doses of D_γ = 10–100 kGy.

2. Material and method

$Cd_{1-x}Fe_xS$ (x=0.05) SMSC thin films of thickness 1.5 μm were deposited on cleaned glass substrates at the rate of υ=18-20 Å/s by a Molecular Beam Condensation (MBC) technique. All technical details of the preparation methodology were given in our earlier works [23-27]. The 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 as-deposited and irradiated films were checked at room temperature by means of X-ray powder diffraction (XRD) using BRUKER XRD D8 ADVANCE.

The optical transmittance (T) of the irradiated films were measured at normal incident using a double beam spectrophotometer UV-Visible SPECORD 210 PLUS.

3. Results and discussion

Thin films of $Cd_{1-x}Fe_xS$ (x=0.05) thin films were obtained by the Molecular Beam method in a vacuum of $(1\div2)10^{-4}$ Pa on glass substrates. It is determined the optimal conditions to obtain thin films with perfect structure and a clean, smooth surface. The substrate temperature was T_{sub}=440 ÷ 470K and source temperature was T_{sub} = 1100 ÷1200K.

Crystal structure of investigated thin films was studied by X-ray diffraction (XRD) method on Bruker, Germany D8 ADVANGE X-ray diffractometer. XRD studies show that thin films grown on glass substrates at temperature T_{sub} = 440 ÷470 K have a polycrystalline (fig.1) structures. To characterize a film quality, the full width at half maximum (FWHM) of diffraction peak is used.

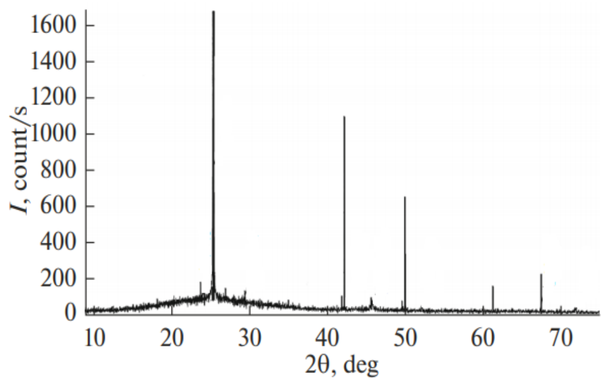

Fig. 1. *XRD* images of $Cd_{1-x}Fe_xS$, $x = 0.05$ thin films

The variation of the transmittance $T(\lambda)$ versus wavelength λ, as measured at normal incidence for the as-deposited and γ-irradiated $Cd_{1-x}Fe_xS$ (x=0.05) thin films, is investigated. The samples showed a sharp transmittance drop at the fundamental absorption band edge (fig.2). This sharp edge corresponds to electron excitation from the valance band to conduction band and is related to the nature and value of the optical band gap. Furthermore, the transmission spectra show a cleared-shifting the absorption region with the increase in radiation dose.

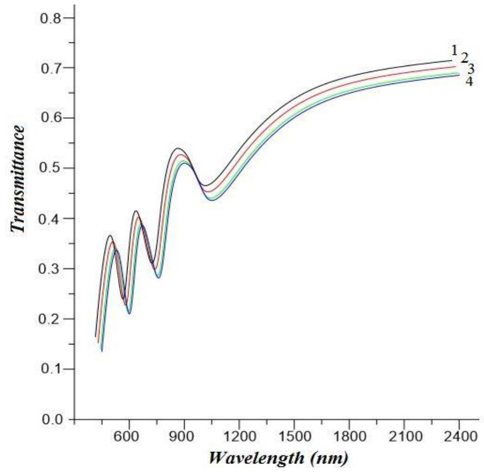

Fig. 2. The spectral transmittance T in $Cd_{1-x}Fe_xS$ (x=0.05) thin films 1) D_γ=0, 2) D_γ=10 kGy, 3) D_γ=50 kGy, 4) D_γ =100 kGy

The optical absorption coefficient α of as-deposited and irradiated $Cd_{1-x}Fe_xS$ (x=0.05) thin films with different doses is evaluated from the experimental data of transmittance through the film/glass layered structure. The optical band gap E_g of the thin films is determined from optical measurements. It was determined that the direct optical band gap E_g decreases as doses of γ – irradiation increase from D_γ = 10 ÷100 kGy (fig.3).

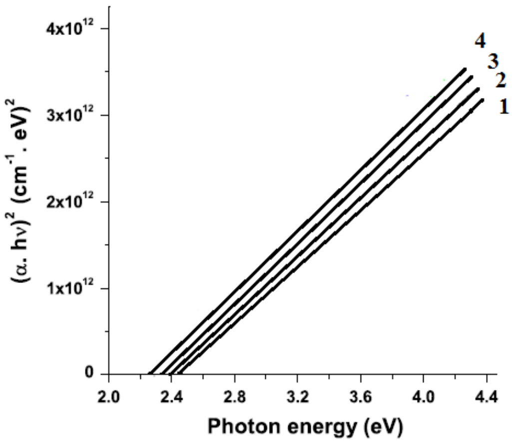

Fig. 3. The dependence of $(\alpha h\nu)^2$ on photon energy ($h\nu$) in $Cd_{1-x}Fe_xS$ (x=0.05) thin films 1) D_γ=0, 2) D_γ =10 kGy, 3) D_γ =50 kGy, 4) D_γ =100 kGy

The decrease in band gap energy with increasing dose may be attributed to increase in structural disorder and defects of the irradiated films. It is well known that exposure of the film to γ-irradiation induces defects, resulting in disorder in the structure of the thin film. Moreover, the decrease of E_g can also be explained by the fact that the binding energy of the Cd–S bonds (208kJ/mol) is smaller than that of the Fe–S (322kJ/mol). In consequence, it is expected that Cd–S bonds are more sensitive to γ- irradiation; accordingly, upon γ-irradiation some of the Cd–S bonds are broken. Accordingly, one can expect that defects can be formed which produce localized states that change the effective Fermi level due to an increase in carrier concentrations. This increase in carriers in localized states will lead to a decrease in the transition probabilities into the extended states, resulting in additional absorption and reduction in the gap.

4. Conclusions

To study the effect of γ-irradiation effect on optical properties, the transmission spectra of thin films of γ-irradiated $Cd_{1-x}Fe_xS$ (x=0.05) were investigated. It was found that the optical properties of $Cd_{1-x}Fe_xS$ thin films were highly affected by the exposure to γ-irradiation. The optical absorption spectra showed that the absorption mechanism is a direct allowed transition. The optical energy gap increases with the increase in irradiation dose. The values of optical constants were affected obviously with the increase in irradiation dose.

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