ELECTRICAL PROPERTIES OF THIN-FILM CdTe:CdFeTe HETEROJUNCTIONS

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In this work, the recombination processes of charge carriers and electrical properties of CdTe/$Cd_{1-x}Fe_xTe$ (x=0.08) thin film heterojunction are investigated. It was determined obtain conditions of heterojunction. XRD investigations confirm that thin films have a face-centered cubic structure with a crystal lattice parameter a=6.47 Å. SEM imagines which show smooth surface of obtained thin films. Lifetime of charge carriers defined which is was τ=28-35 μs, and the surface recombination rate was s=50 sm/s. The study showed that the decay of the photocurrent is not mono-exponential, which indicates the presence of several types of recombination. Depending on the energy state of these centers, the effective lifetime was 10^{-6}-10^{-3} c. VAX confirm the heterojunction structure of investigated samples.

Keywords: Semimagnetic semiconductor, heterojunction, electrical, lifetime, XRD, SEM, VAX.
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One of the current directions in the development of alternative energy is building photovoltaics, which implies the integration of solar panels with residential buildings or industrial facilities. As a rule, such devices are assembled on a rigid base, however, the assembly of panels on a flexible base would significantly reduce their specific weight, as well as facilitate installation. Thin films based on cadmium telluride can serve as a material for the absorbing layer of flexible solar cells. The advantages of this material include the optimal value of the band gap equal to ~1.45 eV, as well as a large absorption coefficient of solar radiation (~$5\cdot10^5$ cm^{-1}). Thin films of semimagnetic semiconductors (SMSC) based on CdTe are of particular interest for the use of these materials in photovoltaics [1–4].

In this work, CdTe/$Cd_{1-x}Fe_xTe$ (x=0.08) heterojunction (HJ) was grown on a glass substrate with a SnO_2 conductive layer at a source temperature *Tsour*=1100 K and substrate temperature *Tsub*=670 K by molecular beam condensation method in a UVN-71-P3 vacuum assembly in a vacuum 10^{-4} Pa. Ni contacts were deposited on front and back side (fig.1).

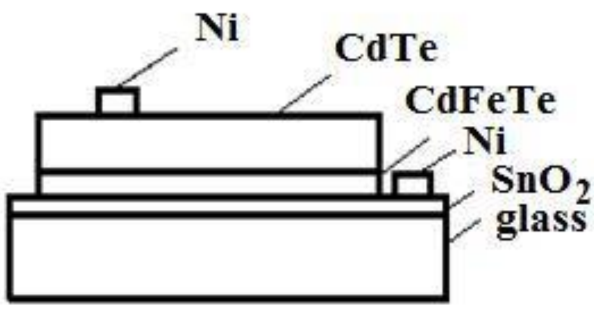

Fig.1. Construction of thin film CdTe:CdFeTe heterojunction.

The crystal structure of the obtained thin films was studied by XRD method on XRD Broker, D8 ADVANGE, Germany X-Ray diffractometer. On X-ray diffraction patterns of $Cd_{1-x}Fe_xTe$ (x=0.08) thin films, all diffraction peaks (111), (220), (311), (400), (331) and (422) confirm that thin films have a face-centered cubic structure with a crystal lattice parameter a=6.47 Å (fig. 2).

The surface morphology was studied using electron microscopy method on a JEOL JSM-7600F Field Emission Scanning Electron Microscope (SEM) (fig. 3), which confirms the smooth surface of obtained thin films.

In previous works, we have studied a number of physical properties of $Cd_{1-x}Fe_xTe$ SMSC [5-7]. İn this work, the recombination processes of charge carriers and electrical properties are investigated.

The study of recombination processes is a necessary essential step in the study of the physical properties of semiconductor materials and devices based on them. The mechanism of recombination of charge carriers determines the features of photoelectric, luminescent, and injection phenomena that consist of most areas of practical use of semiconductors.

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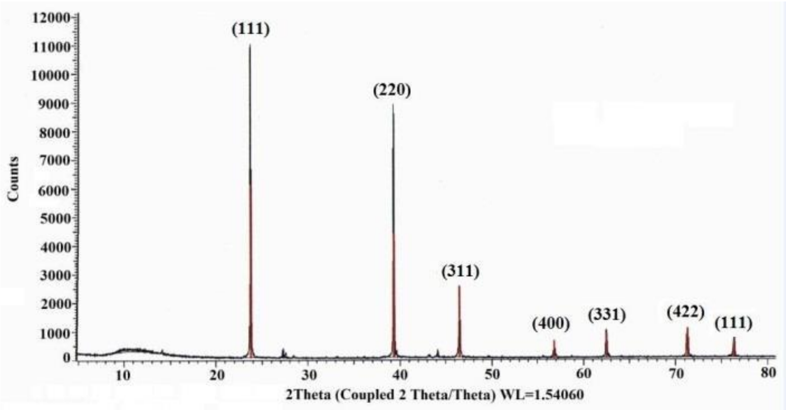

Fig.2. XRD images of $Cd_{1-x}Fe_xTe$ thin films (x=0.08)

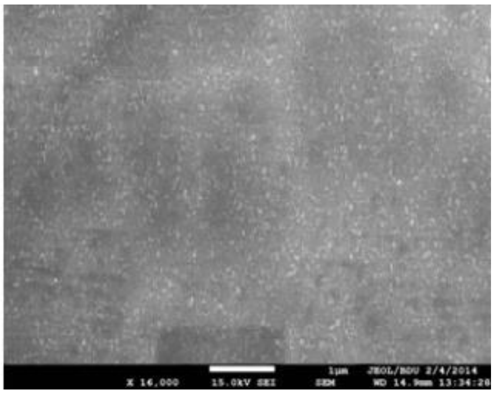

Fig.3. SEM images of $Cd_{1-x}Fe_xTe$ thin films (x=0.08)

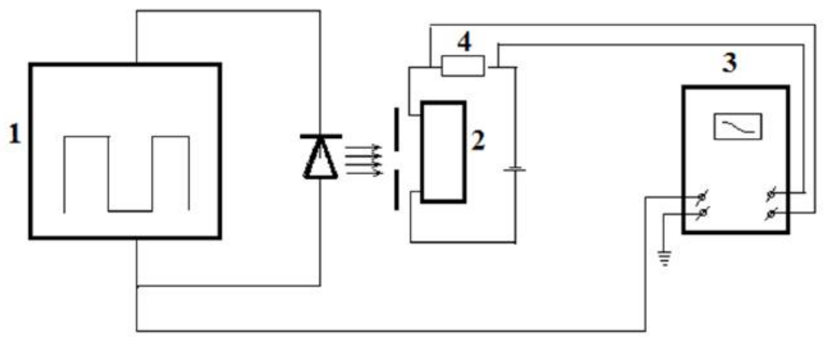

Fig.4. Block diagram of the setup for measuring the kinetics of the photoelectric effect: 1 – give generator; 2 - cell; 3 – amplifier with polarization unit; 4 – oscilloscope.

In order to determine the recombination mechanism, the parameters of recombination centers, and the processes of electronic transitions in HJ, we used a set of stationary and kinetic research methods (fig4). To obtain kinetic characteristics, the HJ was illuminated with short pulses ($t\sim10^{-6}$ s) of LEDs. The photoelectric signal caused by a change in the HJ potential under the action of pulsed illumination after preliminary amplification by a broadband transistor amplifier was fed to the input of an oscilloscope and recorded by a computer. The temporal resolution of the electoral circuit was no worse than 10^{-8} s, which made it possible to register the signal in the time interval $10^{-8}\div10^{-2}$ s (fig5).

It was considered the possibility of estimating the lifetime of nonequilibrium charge carriers in a near-surface layer with defects. In the presence of several types of recombination, the effective carrier lifetime can be found from the expression

$$\frac{1}{\tau_{eff}} == \sum_i \frac{1}{\tau_l}$$

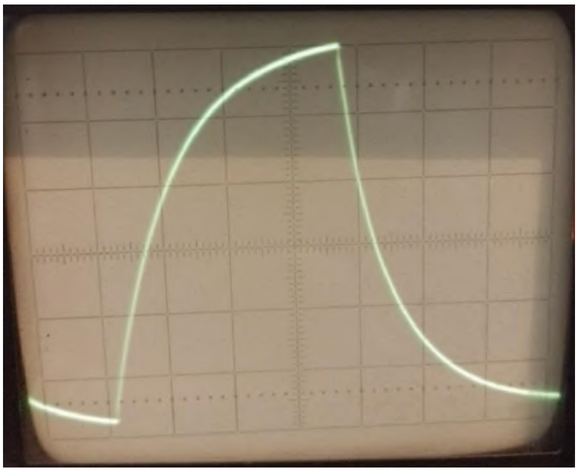

Fig.5. Relaxation of the photoconductivity of a sample excited by rectangular light pulses in CdTe/CdFeTe thin film heterojunction.

For a thin film heterojunction CdTe/CdFeTe, taking into account structural defects and the influence of the surface, the effective lifetime can be determined as

$$\frac{1}{\tau_{eff}} = \frac{1}{\tau_l} + \frac{1}{\tau_s}$$

where $\frac{1}{\tau_s} = \frac{2s}{d}$; τ_l -lifetime taking into account carrier recombination at structural defects in a CdTe:CdFeTe HJ; τ_s - is the surface lifetime; s - is the rate of surface recombination; d - is the thickness of the plate. The analyzes of fig.6 showed that the lifetime of charge carriers is τ=28-35 µs, and the surface recombination rate is s=50 sm/s. The study showed that the decay of the photocurrent is not mono-exponential, which indicates the presence of several types of recombination. Depending on the energy state of these centers, the effective lifetime was 10^{-6} -10^{-3} c. Under pulsed illumination, the lifetime of charge carriers was determined from the kinetic decay of the photocurrent.

To study the mechanism of current flow in the HP, we studied the dark current-voltage characteristics and photoconductivity at room temperature. The results showed that the obtained HJs can be used as photoconverters of solar energy.

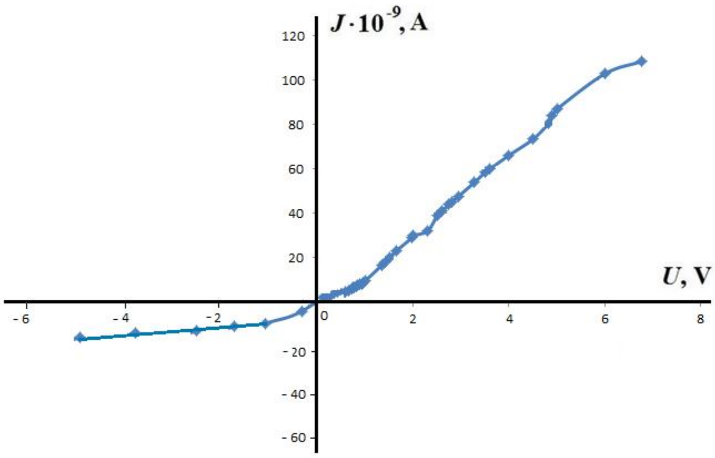

Fig.6. Volt-ampere characteristic of CdTe:CdFeTe thin film heterojunction.

[1] *F. Afaneh, M. Okasha, K.J. Hamam, A. Shaheen, M. Maghrabi, B. Lahlouh, H.K. Juwhari*. The γ-irradiation Effect on the Optical Properties of CdTe Thin Films Deposited by Thermal Evaporation Technique. 2018, v.24, №1, p.3-9.

[2] *A. Ait Raiss, Y. Sbai, L. Bahmad, A. Benyoussef*. Magnetic and magneto-optical properties of doped and co-doped CdTe with (Mn, Fe): Ab-initio study.

Journal of Magnetism and Magnetic Materials. 2015, v.385, p.295–301.

[3] *M.A. Mehrabova, H.S. Orujov, N.H. Hasanov, A.I. Kazimova, A.A. Abdullayeva.* Ab initio calculations of defects in CdMnSe semimagnetic semiconductors. Mechanics of Solids, 2020, v.55, №.1, p.108–113.

[4] *M.A. Mehrabova, I.R. Nuriyev, R.N. Hasanli.* Obtaining of perfect Cd1-XMnXTe epitaxial thin films and their use potentials. 5th WSEAS Int. Conf. Nanotechnology, Cambridge, UK. 2013, p.316-320.

[5] *M.A. Mehrabova, H.S. Orujov, H.R. Nuriyev, N.H. Hasanov, A.A. Abdullayeva, Z.I. Suleymanov.* Ab-initio calculations of electronic structure of CdFeTe and optical properties. Conference Proceedings Modern Trends In Physics. 2019, p.39-42.

[6] *M.A. Mehrabova, A.A. Abdullayeva.* Electrical properties of Cd1−xFexTe thin films. The 10th International Conference: “Technical Thermodynamics: Thermophysical Properties and Energy Systems”, September, 9th 2021, University of Rostock, Germany, p.120.

[7] *M.A. Mehrabova, H.R. Nuriyev, H.S. Orujov, N.H. Hasanov, T.I. Kerimova, A.A. Abdullayeva, A.I. Kazimova.* Effect of gamma irradiation on conductivity of $Cd_{1-x}Fe_xTe$. Semiconductors, 2020, v. 61, № 12, p. 2306-2309.