INFLUENCE OF $\gamma$-IRRADIATION ON CRYSTAL STRUCTURE OF Pb$_{1-x}$Mn$_x$Se THIN FILMS

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Abstract: - In the given paper the obtaining of Pb$_{1-x}$Mn$_x$Se (x=0.01, d=10nm) epitaxial nanofilms and influence of $\gamma$-irradiation on their crystal structure have been investigated. Pb$_{1-x}$Mn$_x$Se (x=0.01) nanofilms have been grown on freshly broken and polished substrates of BaF$_2$ in a vacuum $10^{-4}$Pa in YBH-71 ПЗ vacuum assembly by the molecular beams condensation method. In the present report are given investigation results of the structure, morphology of a surface and physical properties of Pb$_{1-x}$Mn$_x$Se (x=0.02) nanofilms grown by the molecular beams condensation method. It has been defined, that after the $\gamma$-irradiation doses 25 kGy the parameters of nanofilms become the worst.

Key-Words: - semimagnetic semiconductor, epitaxial nanofilms, crystal structure, morphology, substrates, $\gamma$-irradiation

1 Introduction

Spintronics or electronics using spinrelated phenomena has been attracting attention because of its potential applicability to new functional devices combining transport and magnetic properties [1]. Spintronic devices came into action after the discovery of powerful effect called “giant magnetoresistance (GMR)” in 1988 by French and German physicists [2]. It results from subtle electron-spin effects in ultra-thin 'multilayers' of magnetic materials, which cause huge changes in their electrical resistance when a magnetic field is applied.

Then it was obtained giant Faraday rotation in semimagnetic semiconductors (SMS). When certain materials are subjected to magnetic fields, they rotate the plane of polarization of light traveling through them. This effect, known as Faraday rotation, is important technologically because it can be used to construct optical isolators, unidirectional optical amplifiers, and other nonreciprocal devices. To be practical, however, most devices of this type require materials with very large Faraday rotations [3]. In 1978, it was discovered that SMS display an extremely large Faraday rotation. In 90’s authors [4-6] theoretically investigated Faraday rotation in SMS thin films and defined, that the Faraday rotation increases by increasing of film thikness. At that time there was no large-scale technological need for such materials. Magnetic semiconductors, in which spin- and charge-dependent properties of electrons coexist, are now the most important topics of investigation in the field of new functional semiconductor devices.

In last 20 years SMS of lead chalcogenides (Pb$_{1-x}$Mn$_x$S, Pb$_{1-x}$Mn$_x$Se, Pb$_{1-x}$Mn$_x$Te) have been subject of intensive experimental and theoretical researches. They attracted attention because of free carrier induced magnetism [2]. Unlike II-VI SMS, these materials can be grown with higher concentration of free band carriers. Their magnetic properties can be controlled by modifying the carrier concentration through control of native defects.

In these SMS lead (Pb) atoms are partly replaced by uncompensated magnetic momentum manganese (Mn) transition element atoms. As a result of Mn ions’ introduction in a lattice of lead chalcogenides compounds. In these SMS the lattice constant insignificantly decreases and so the width of the band gap sharply increases. In this case the energy spectrum of charge carriers in magnetic field extraordinarily changes. In result, occur opportunities to make devices controled by magnetic field and temperature on the basis of these structures.

Although there is a lot of literary information on studying SMS nanolayers, the influence of
ionizing radiation on physical parameters of these materials has not been studied to this day.

Development of new generation radiation resistant spintronic devices operating in IR region of spectrum is the important task of modern science and engineering, as the characteristics of materials, using in engineering nowadays are considerably worse under the ionizing radiation. As a result transformations occur in them.

In order to study the preparation possibilities of radiation-resistant devices on the base of Pb$_{1-x}$Mn$_x$Se thin films and to improve their parameters, we have researched the obtaining technology of Pb$_{1-x}$Mn$_x$Se thin films (thickness d=10nm), their crystal structure, surface morphology and ionizing radiation influence on these properties.

The aim of this work were obtaining and investigation of Pb$_{1-x}$Mn$_x$Se SMS epitaxial nanolayers, to obtain their optimum and perfect samples with high sensitivity and radiation resistance properties for spintronic and IR electronics.

### 2 Experiments

Pb$_{1-x}$Mn$_x$Se (x=0.01) nanofilms have been grown on freshly broken and polished plates substrates of BaF$_2$ in a vacuum $10^{-3}$Pa in YBH-71 П3 vacuum assembly by the molecular beams condensation (MBC) method. As a substrate it has been used natural layers of BaF$_2$ monocryystals, cut of accordingly on its plane (111). The choice of BaF$_2$ as a substrate is due to that it has cubic structure of with the parameter of elementary unit of 6.19Å. It is dielectric, has good mechanical strength and chemically inert. The obtained epitaxial nanofilms was grown along the surface parallel to substrate.

More crystal perfect film ($W_{1/2}=80\div100^\circ$) of 10nm thickness was obtained at condensation rates $\nu_c=8\div9Å$/sec and substrate temperature $T_s=612\div645K$. It was established, that epitaxial growth occurs at film temperature $T_f=462\div511K$.

On the basis of developed regime there have been obtained high ohmic epitaxial films Pb$_{1-x}$Mn$_x$Se of n- and p-type conductivity with concentration $n(77K)=5\cdot10^{15}\div1.6\cdot10^{16}cm^{-3}$, charge carriers mobility $\mu(77K)=2.7\div3\cdot10^4cm^2/V\cdotsec$ and lattice constant $a=6.11\div6.05Å$ (Fig.1)

The Pb$_{1-x}$Mn$_x$Se (x=0.01) nanofilms with different types of conductivity have been obtained by changing of temperature and by using an additional compensating Se (selenium) vapor source during the growth.

We have been studied crystal structure and surface morphology of Pb$_{1-x}$Mn$_x$Se nanofilms. Crystal perfection of the films has been studied by electron diffraction, X-ray diffraction methods (Fig.2), and its surface morphology by the method of atomic-force microscope (AFM) (Fig.3). Lattice constants of nanofilms have been calculated from X-ray diffraction curves. It has been determined three-dimensional topography of the sample, studied by AFM and its surface roughness (Fig.3).

We have defined, that after the $\gamma$-irradiation doses 25 kGy the parameters of nanofilms become the worst.
epitaxial nanofilms. The samples were irradiated at room temperature in $^{60}$Co Isotopic Radiation Source (in $\gamma$-irradiation doses till 25kGy) (Fig.4a). The influence of ionizing radiation on crystal structure of Pb$_{1-x}$Mn$_x$Se SMS nanofilms have been investigated.

Fig.3 The view of surface layer of Pb$_{1-x}$Mn$_x$Se (x=0.01) epitaxial nanofilms in atomic-force microscope: 1. before $\gamma$-irradiation, 2. after $\gamma$-irradiation, doze energy was 25kGy

It has been investigated the influence of electron rays and $\gamma$–irradiation on Pb$_{1-x}$Mn$_x$Se SMS nanofilms. The samples were irradiated at room temperature in $^{60}$Co Isotopic Radiation Source (in $\gamma$-irradiation doses till 25kGy) (Fig.4a). The influence of ionizing radiation on crystal structure of Pb$_{1-x}$Mn$_x$Se SMS nanofilms have been investigated.

Fig.4 Samples are irradiated in $^{60}$Co Isotopic Radiation Source

3 Conclusion

We have defined the optimum values of physical parameters of Pb$_{1-x}$Mn$_x$Se nanofilms and ionizing radiation dose, which give us possibility to make radiation resistant and high sensitive spintronic devices controlled by magnetic field and temperature. After the $\gamma$-irradiation doses 25 kGy the parameters of nanofilms become the worst.

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2. INTAS Project 01-0190, 01.01.2002 - 01.01.2004, “Pb$_x$Mn$_{1-x}$Te epitaxial films and photosensitive homo- and heterostructures on their base”.

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