Photo- and electroluminescence properties of $Pb_{1-x}Mn_xTe(Se,S)$ thin films

M.A.Mehrabova, H.R.Nuriyev, T.H.Ismayilov

Abstract— In the given work the energy spectrum and wave functions have been theoretically calculated for quantum-sized films of $Pb_{1-x}Mn_xTe(Se,S)$ semimagnetic semiconductors. The photo- and electroluminescence properties of $Pb_{1-x}Mn_xTe(Se,S)$ thin films by the method of molecular beams epitaxial on BaF_2 substrates were studied. It was established that band gap width of epitaxial layers expanded by the change in Mn amount. In the present report are given investigation results of the structure, morphology of a surface and physical properties of epitaxia $Pb_{1-x}Mn_xTe$ (x=0.02) films grown by the «hot wall» method in ultrahigh vacuum ($\leq(3 \div 5) \cdot 10^{-9}$ Torr) unit with oil free evacuation. It is established, that at ultrahigh vacuum residual pressure of gases in working volume plays an appreciable role during growth of epitaxial films with perfect structure and high electrophysical properties. Comparison and generalization of the received results with other A^4B^6 chalcogenides grown in ultrahigh vacuum have been carried out.

Keywords— semimagnetic semiconductor, nanolayer, sensitive, detector, infrared, electroluminescence, photoluminescence, energy spectrum, ultrahigh vacuum

I. Introduction

Today, IR technology widely intrudes into all spheres of our life. So, modern devices make it possible to follow volcano activity, to inform about oncoming tsunami, to record other signs of nature activity, which is invisible to human eye.

IR detectors play an important role in our life. They have a lot of application fields: defense-industrial sector, science, industry, medicine, and security. It is the receiver of radiation energy, which converts IR energy to a measurable form. IR detectors detect the energy, radiated from objects, then the uncovered energy is transformed to the image, which shows the difference in objects' energy, and in this way they all become visible.

IR thermograph –the method of recording IR radiation from human body surface. It is a unique wide range method of diagnostics and control method of patient's status in the case of abnormalities of wide range. This method is applied in oncology for differential tumor diagnostics. It is a secure, reproducible method, which does not make any way for other diagnostic methods on sensitivity and specificity. Depending on rise or decrease of local temperature on the phone of habitual profile of organ or extremities, become stronger or on the contrary weakens weavings glow in pathology field. Thermal imaging method is notable for absolute security, simplicity and rapid examination, lack of any contraindication.

IR detectors: movements, magnetocontact, radial, perturbed buttons are used for any control of access, perimeter, guarded and not guarded objects (house, farm, campsite, storehouse, oil storages and etc).

IR – passive transducer, also called optoelectronic, concern to the movement detector class and react to thermal radiation of moving body. Mechanism of these transducers is based on the record of time change differences between IR radiation intensity from human and background thermal radiation. Nowadays IR-passive transducers are very popular; they present an integral element of guard system practically of each object.

IR transducers – perimeter conservation create an invisible fence around our yards. Transmitters and detectors are settled opposite of each other along the whole perimeter of the yard. It creates a barrier of IR rays and signal is transmitted at discontinuity of such ray on control panel in order to take appropriate measures.

Today the pyrometer is relatively an inexpensive noncontact method of temperature measuring. The mechanism of pyrometer is based on the measuring the absolute value of IR radiation of the researched object. Pyrometers are able to be induced on object from any distance; their capabilities are restricted only with diameter of measured spots and environment transparency. Pyrometers are ideal for portable models. Modern sensing technology enables to perform the pyrometer without moving elements, and in this way it ensures great longevity for the pyrometer. Besides this, such kind of pyrometers is notable for its high electromagnetic noise immunity and measurement accuracy

I Author M.A.Mehrabova is with the Institute of Radiation Problems of Azerbaijan National Academy of Sciences, AZ1143, Baku, 9, B.Vakhabzadeh str., Azerbaijan Republic (phone:+99450 7318177, E-mail: mehrabova@mail.ru)
II Author H.R.Nuriyev is with the Institute of Physics of Azerbaijan National Academy of Sciences, AZ1143, Az-1143, Baku, 33, H.Javid ave. Azerbaijan Republic (phone: +99450 641 83 88,E-mail: h.nuriyev@gmail.com)
III Author T.H.Ismayilov is with the Baku State University , AZ1143, Baku, 23, Z.Khalilov str., Azerbaijan Republic, (phone:+ :(+994 12) 439 11 65, E-mail: tariyel.i@gmail.com)

(an up-to-the-minute processing technology, digital multipoint linearization). They are applied for lens system of special structure, which ensure color correction both visible and IR radiation.

We are surrounded with various electric and electronic facilities, devices and equipments, wherever we are. They solve lots of daily problems, facilitate our life, and make it comfortable and pleasant. These facilities are developed day by day, by becoming more complicated system, but reserving special unique property – simplicity in utilization and consumer comfort. Majority of these electronic systems help us not only in creating comfort, watching over our health, ensuring safety, but also considerably saving facilities.

Energy-saving technology did not by-pass the house lighting system, also door intercommunication system and surveillance cameras. IR-passive transducers belong to movement detectors class and react to thermal radiation of moving body. Transducer, which reacts to movement, can control not only room lighting, but also it can be connected practically to any electric apparatus, which is essential for us, in entering into any room. Therefore, IR movement transducer is very convenient for energy and expenses saving, related to its consumption. Besides this, the light regulator is widely used, which enables us not just to switch on/off the light, but also to regulate its intensity.

Today, the majority of fuel and mineral kinds and alternative energy sources have become an integral part of our daily life and production. These inexpensive energy sources and objects bring people comfort and convenience on one hand, but at the same time – a big threat in moderate treatment (not following fire safety measures). Fire-alarm box detectors, which are performed by using the most widespread technologies for today, are used for detection of different explosive and toxic gas concentrations, which practically all of us have met in our life, the effects connected with them: temperature, gas, smoke.

IR currency detector defines the currency authenticity. An image, special invisible to naked eye– so called element "M" is displayed on bank notes In IR rays, which is the proof to the authenticity.

Water leak detectors react to the presence of water, door detectors to the open doors, broken glass detectors are settled on the glass doors and windows, and record the broken glass.

The experience of instrumental researches enables to assume the existence of life mode in plasma state beyond the bounds of our physical nature. These life modes are able to move from one density degree into another, from invisible spectral region to full physical density, which can be observed visually, without any devices. The photos, taken from the airplane, showed that glowing in IR-spectrum or dark invisible objects fly nearby or directly behind the airplanes. For detecting UFO in invisible spectral region, reasonably to use the devices for noctovision in two-stage execution or by image intensifier, which sensitivity enables to detect the object in IR spectral region with enough optical resolution.

All these make a big interest to various detectors, put on the world market. Increased demands for new generation of IR detectors, which overbalance its analogs on sensitivity and effectiveness of IR rays record, for spatial resolution and fast-acting, for lack of hygroscopicity, for availability in extreme climate conditions (temperature stability, high radiation field) come up by developing and creating a new generation of highly-sensitive, fast-acting, radiation-resistant devices (as well as for optoelectronics, industry, cosmic researches in extreme conditions, in instrument engineering, in medicine). Therefore, the investigation on search and development of new IR detectors, which exceed its analogs on physical parameters, come to the first plan. Some crystals, for example, $Pb_{1-x}Mn_xTe(Se,S)$ SMS possess hightened chemical stability and radiational resistance, fast response, sensitivity to IR spectral region. Epitaxial layers of these semiconductors are of special interest in optoelectronics from the standpoint of small-size and optimization of some physical parameters. The development of the technology of obtaining highly sensitive, radiation resistant $Pb_{1-x}Mn_xTe(Se,S)$ SMS nanolayers is considered very expedient for the purpose of development and formation of IR devices with optimal parameters on their base.

$Pb_{1-x}Mn_xTe(Se,S)$ SMS epitaxial layers have a special place among great variety of produced materials. These crystals have perspective to be applied in semiconductor instrument making as photodetectors, photoreceivers. $Pb_{1-x}Mn_xTe$ nanofilms have been the object of researches of many scientists in last ten years.

Previously, it has been worked out the method of obtaining $Pb_{1-x}Mn_xTe(Se,S)$ nanofilms, and their physical properties have been researched in [1]. The authors obtain $Pb_{1-x}Mn_xTe$ epitaxial layers, and research their physical properties, also influence of γ-radiation influence to their properties with the purpose of obtaining radiation resistant and perfect crystals. In the magnetic field it is observed interesting effects qualitative of other character. The energetic structure and interband Faraday effect in SMS $Pb_{1-x}Mn_xTe$ nanofilms has been theoretically studied by [2].

The aim of the work is investigation of $Pb_{1-x}Mn_xTe(Se,S)$ SMS nanolayers to obtain their optimum and perfect samples with high sensitivity and radiation resistance.

II. Energy Spectrum And Wave Functions

In the given work the energy spectrum and wave functions have been theoretically calculated for quantum-sized films of $Pb_{1-x}Mn_xTe(Se,S)$ SMS. The properties of the electrons and holes in the exchange semiconductors $A^{IV}B^{VI}$ are described by Dimmock model [3]. But at the energies $E \leq E_g$, where E_g-band gap can be limited by a double-band model, as in this case Dimmock model doesn't lead to qualitatively new results [4]. For the calculation of the spectra and wave functions double-band Kane model has been used. The κ_z=0 case is considered. Let's assume that the surface of the film is perpendicular to the axis x. In the model of rectangular wells with infinite walls in the double-band approximation, when the spin-spin exchange interaction occurs between the electrons in the conductivity band (valence band) and the electrons of half-filled d-shells of manganese ions as well as taking into account electron spins and the band nonparabolicity we have:

$$E_{jn_j} = -\frac{E_g}{2} + s\left(\frac{2}{3}\mu H + \frac{A}{2} - \frac{B}{6}\right) \pm$$

$$\sqrt{\left[\frac{E_g}{2} - s\left(\frac{\mu H}{3} + \frac{A}{2} + \frac{B}{6}\right)\right]^2 + P_\perp^2 k_y^2 + P_\perp^2 \alpha_j^2} \qquad (1)$$

$$\psi_{j\sigma_j n_j \overline{k_t}}(\overrightarrow{r_t}, x) =$$

$$\sqrt{\frac{2}{Sd}}\{A_{j\sigma_j n_j \overline{k_t}}(\overrightarrow{r_t}, x)\sin\alpha x + B_{j\sigma_j n_j \overline{k_t}}(\overrightarrow{r_t}, x)\cos\alpha x\}e^{ik_t \overline{r_t}}$$

$$(2)$$

$$A_{jn_j \overline{k_t}\uparrow}(\overrightarrow{r_t}, x) = L_{jn_j\uparrow} i(U_1 - U_4 \frac{iP_\perp k_y}{E_{jn_j\uparrow} + E_g - \mu H - A})$$

$$A_{jn_j \overline{k_t}\downarrow}(\overrightarrow{r_t}, x) = L_{jn_j\downarrow} i(U_2 + U_3 \frac{iP_\perp k_y}{E_{jn_j\downarrow} + E_g + \mu H + A}) \qquad (3)$$

$$B_{jn_j \overline{k_t}\uparrow}(\overrightarrow{r_t}, x) = -L_{jn_j\uparrow} U_4 \frac{P_\perp \alpha_{j\uparrow}}{E_{jn_j\uparrow} + E_g - \mu H - A})$$

$$B_{jn_j \overline{k_t}\downarrow}(\overrightarrow{r_t}, x) = -L_{jn_j\downarrow} U_3 \frac{P_\perp \alpha_{j\downarrow}}{E_{jn_j\downarrow} + E_g + \mu H + A})$$

$$L_{jn_j\uparrow} = \{\frac{E_{jn_j\uparrow} + E_g - \mu H - A}{2E_{jn_j\uparrow} + E_g - \frac{4}{3}\mu H - A + \frac{B}{3}}\}^{1/2}$$

$$(4)$$

$$L_{jn_j\downarrow} = \{\frac{E_{jn_j\downarrow} + E_g + \mu H + A}{2E_{jn_j\downarrow} + E_g + \frac{4}{3}\mu H + A - \frac{B}{3}}\}^{1/2}$$

where $\alpha_j = \pi n_j / d$, S=± 1 spin-top and spin-down states, E_g band gap, j=c,υ. P - is the Kane constant.

A= $\frac{1}{2}N_s\alpha\langle S_z\rangle$, B= $\frac{1}{2}N_s\beta\langle S_z\rangle$

Are exchange parameters, arrows indicate the spin state.

III. «HOT WALL» METHOD

Epitaxial films of A^4B^6 compounds and their solid solutions take an important place in infra-red techniques. On the basis of these narrow-band semiconductors have been made and applied various optoelectronic devices for 3÷ 5 and 8÷ 14m spectral region [5]. It is well known, that devices with high parameters are created on homogeneous-pure, structurally perfect, mirror smooth surfaces of crystals [6]. All structural changes occurring in thin near-surface layers are reflected in characteristics of the devices made on their basis. For this reason modern electronic techniques demands reception of perfect epitaxial films with the set properties, free from a various sort of undesirable superficial conditions. For this purpose a big prospect possess epitaxial films grown in ultrahigh vacuum.

In this connection research of structure, morphology of a surface of the epitaxial films of A^4B^6 type semiconductors received in ultrahigh vacuum, in correlation with physical properties, has important scientific - practical interest.

It is necessary to note, that now for growth of epitaxial films of A^4B^6 type semiconductors alongside with methods liquid and molecular-beam epitaxy also is successfully applied epitaxy in the chamber with hot walls (HWE).

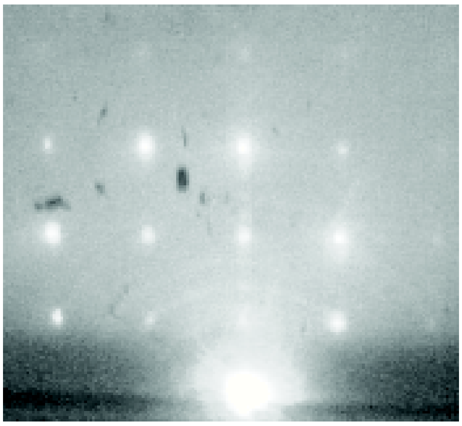
Prominent feature of the HWE method is that growth of epitaxial layers occurs in conditions, maximum close to thermodynamic balance at the minimal losses of the material. “Hot wall” serves for a direction of molecules from a source to a substrate. HWE method allows us to receive epitaxial films with perfect structure and high values of electrophysical parameters. According to literary data, by the application of this method have been received lasers on the basis of two-layer hetero-structures [7]. There is also a report on use of the given method for reception films with a super-lattice on the basis of structure PbTe $Pb_{1-x}Sn_xTe$ [8,9]. Elsewhere [10,11] it is reported creation of the detector on the basis of epitaxial $Pb_{1-x}Sn_xSe$ films grown on BaF2 substrates. Authors of [12] succeed to make hetero-structures for injection lasers with 8 ÷10 m wavelengths.

In the present report the structure, morphology of a surface and physical properties of epitaxial $Pb_{1-x}Mn_xTe$ (x=0.02) films grown by the «hot wall» method on freshly cleaved faces (111) of BaF_2 and single crystalline plates (100) of $PbTe_{1-x}Se_x$ (x=0.08) have been investigated. The films were received in ultra-high vacuum (≤(3÷5) $\cdot 10^{-9}$Torr) installation with oil less evacuation, developed and introduced in the Institute of the Photoelectronics (nowadays Institute of Physics) NAS of Azerbaijan [13].

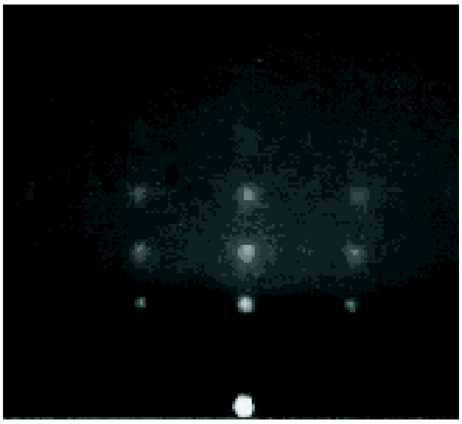
In the capacity of evacuation system it was used ultrahigh vacuum unit SVA-0.25, allowing to receive pressure (≤(3÷5) $\cdot 10^{-9}$Torr) in quartz ampoule. The ampoule used in the given installation contains two sources, one (basic) - for lead chalcogenides and their solid solutions, and another - for compensating Te element and the substrate-holder with a substrate provided with shutter. A distance between a substrate and an evaporated material was 24 cm, and between an evaporated material and a source of chalcogen - 15 cm

The choice of single crystalline plates (100) of $PbTe_{1-x}Se_x$ (x=0.08) as substrates is connected with the purpose of reception films of more perfect structure and creation isoperiodic hetero-structures. Comparison and generalization of the received results with the literary data for others A^4B^6chalcogenides grown in ultrahigh vacuum have been carried out.

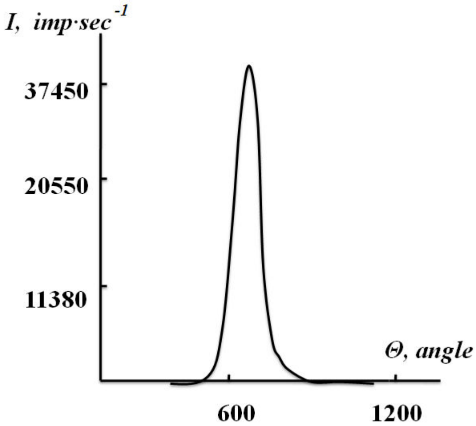
Structural perfection of the films was supervised by electron-diffraction, X-ray diffraction and electron microscopic methods.



a)



b)



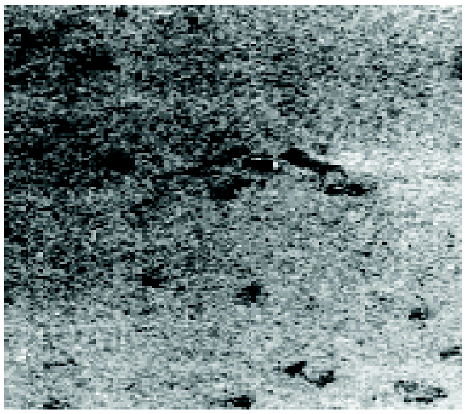
c)

Fig.1. Electron diffraction pattern (a, b) and rocking curve for X-ray diffraction (c) for $Pb_{1-x}Mn_xTe$ (x=0.02) epitaxial films; *a* is substrate $PbTe_{1-x}Se_x$ (x=0.08), *b* is substrate BaF_2 .

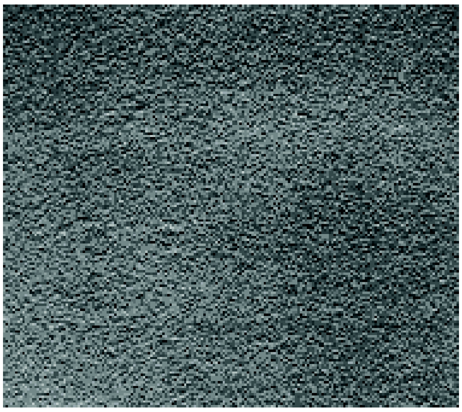
Optimum conditions for reception structurally perfect epitaxial $Pb_{1-x}Mn_xTe$ (x=0.02) films have been determined: temperature of the basic source is 560 to 580°C (υ_k=8÷9 A°/s), a hot wall -630 to 650°C and substrates - 380 to 410°C. It is established that under the above-stated conditions films grow on planes (111) and (100), repeating orientation of substrates (Fig.1,a, Fig.1,b). Value of the half-width of the rocking curve for X-ray diffraction equals $W_{1/2}$=(90÷100) (Fig.1,c).

Electron microscopic researches have shown that on a surface of the received films black congestions are observed (Fig.2,a). According to the literary data, these congestions are products of the oxidation formed during growth and resulting in reception of films with small values of mobility of the charge carriers (μ_{77K}=(1,5÷2,0)·10^4cm^2/V·s).With the purpose of reception films with clean surface without the black congestions observable on Fig.2, being inclusions of the second phase, an additional compensating source of tellurium (Te) vapors was used during growth. Application of such sources resulted in reception epitaxial films with clean surface free from black congestions (Fig.2,b).

This films, in conformity the literary data, have optimum values of electrophysical parameters (μ_{77K} =(2.5÷3)·10^4 cm^2/V·s), necessary for creation on their basis high-sensitivity optoelectronic devices applied in various areas of IR-techniques. Comparison with the literary data has shown that the received results take place also in research of other A^4B^6 chalcogenides grown in ultrahigh vacuum [14-17].



a)



b)

Fig. 2. Electron microscope images of the surface of $Pb_{1-x}Mn_xTe$ (x =0.02) epitaxial films; a) without additional compensating Te vapors source, b) with additional compensating Te vapors source.

IV. Photo- and Electroluminescence Spectra

In the present work the dependence of band gap on $Pb_{1-x}Mn_xTe(Se,S)$ thin films' composition was determined out of photoluminescence spectra. The magnitude of exchange interaction was estimated in magnetic field due to the experiments on photo-and electroluminescence for $Pb_{1-x}Mn_xTe(Se,S)$ crystals.

The structural perfection of the films was controlled by electronographic, electromicroscopic and X-ray diffraction methods. Epitaxial films were grown by the mathematically modeled method of molecular beam condensation in vacuum 10^{-4} Pa.

Optimal conditions ($\upsilon_к$=8÷9 Å/sec; $T_п$=663÷673 K) of manufacturing epitaxial films with a perfect crystal structure ($W_{1/2}$=80÷100$^{//}$), growth plane (111), lattice parameter α=6.10÷6.05 Å and charge carrier mobility $\mu_{77K}=2.53\cdot10^4$ cm^2/V·sec were determined.

It was established that structurally perfect $Pb_{1-x}Mn_xSe$ films with different (n,p) conduction types and specified electrophysical properties can be obtained by regulating the temperature of compenrating Se source.

As far as we know, it's necessary to manufacture films with a clean and smooth surface without switching the second phase for making various photosensitive epitaxial structures. For this purpose additional compensating source Se was used in the process of film growth. The application of this source resulted in manufacturing $Pb_{1-x}Mn_xSe$ films with a clean and smooth surface without switching the second phase.

Photoluminescence excitation was realized by an impulse YAG laser ($h\nu_0\approx1.17$ eV). Pumping intensity equaled to~10^5 W/cm^2. The measurement was carried out on reflection geometry at 77.4 K. The magnetic field was parallel to a crystallographic direction [100]. Radiation spectra were recorded with the help of a lattice monochromator and two radiation detectors on Ge‹Au› and Ge‹Cu› base. Band gap *Eg* was determined along the long-wave edge of radiation spectra. The accuracy of *Eg* determination depended on a concrete sample and equaled to 0.1÷0.2%. Within energy region of 0.15 eV where magnitooptical measurements were carried out spectral resolution was 0.15÷ 0.20 MeV. High spectral resolution allowed observing material heterogeneity according to the composition (up to $\Delta x\sim10^{-4}$) as well as luminescence intensity during scanning on the sample surface. The regions with maximal photoluminescence intensity were selected for conducting measurements.

In Fig.3 the dependence of radiation quantum energy on the compositions of three thin films - $Pb_{1-x}Mn_xS$ ($0\leq x\leq0.014$), $Pb_{1-x}Mn_xTe$ ($0\leq x\leq0.05$), $Pb_{1-x}Mn_xSe$ ($0\leq x\leq0.04$) was shown.

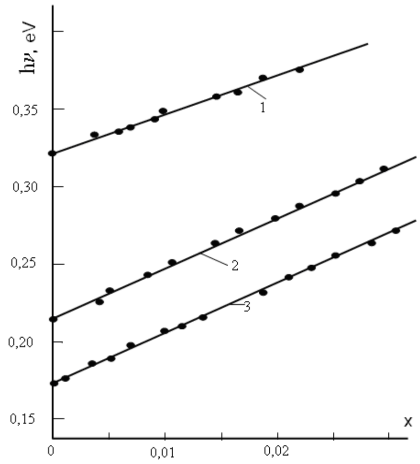


Fig.3. Dependence of band gap Eg on $Pb_{1-x}Mn_xS$ (1), $Pb_{1-x}Mn_xTe$ (2), $Pb_{1-x}Mn_xSe$ thin films composition (3): T - 77 K.

It becomes evident that the dependence *Eg*(*x*) can be considered linear one in the given region. The inclination d *Eg*/d *x* is practically the same at 77 K temperature and equals to 3.2, 3.4 and 3.8 eV/fraction *x* correspondingly for $Pb_{1-x}Mn_xS$, $Pb_{1-x}Mn_xTe$, $Pb_{1-x}Mn_xSe$. For two samples with high manganese (Mn) composition - $Pb_{0.95}Mn_{0.05}Te$, $Pb_{0.96}Mn_{0.04}Se$ the radiation quantum energy was considerably lower (correspondingly 273 and 267 MeV at 77 K) than appropriate linear inclination values d *Eg*/d *x*.

V. Conclusion

It is established, that at ultrahigh vacuum residual pressure of gases in working volume plays an appreciable role during growth of epitaxial films. To it testifies observable on a surface of A^4B^6 films (though in insignificant amount) micro inclusions as black spots which strongly influence on physical properties.

It should be mentioned that radiation quantum energy for binary crystals (without manganese) grown by Bridgman method is more than band gap energy measured on qualitative epitaxial layers with charge carrier concentration of $\sim 10^{17}$ cm^{-3}. In dependence with the sample, charge carrier concentration and excitation level this difference reaches ~10 MeV.

It is conditioned by relatively low quantum yield in the crystals grown by Bridgman method. In this connection high excitation level is required which leads to Burstein shift and crystal heating, i.e. to radiation quantum energy increase. It means that conservative values *Eg* (within 10 MeV) are acquired for Bridgman crystals with manganese (Mn). However, it has weak effect on inclination magnitudes [18-20].

During manganese introduction the number of the observed transitions obviously decreases due to low radiation quantum yield of the material. Thereby, during Mn introduction into $A^{IV}B^{VI}$ type semiconductor the band gap rises with x growth, and at low values $x(x \leq 0.02)$ this dependence becomes linear. Besides, Mn introduction violates mirror symmetry of energy bands in magnetic field because of the fact that the contribution of exchange interaction to g-factor is more for holes than for electrons. It's necessary to use epitaxial layers for carrying out more accurate photoluminescence measurements, as Bridgman crystals have low radiation quantum yield and considerable composition heterogeneity.

REFERENCES

[1] I.R.Nuriyev, R.M.Sadigov, A.A.Mashnin, XI Conf. Crystal growth, Moscow, 2004, pp.284
[2] B.M.Askerov, T.G. Ismailov, M.A. Mekhrabova. Interband Faraday effect on size-quantized thin films of semimagnetic semiconductors $Pb_{1-x}Mn_xTe$. Satellite conf. of the XXX annual meeting of the europ. high pres.research group. Baku, 1992.
[3] P.I.Nikitin, A.I.Savchuk, Sov. Phys. Usp., 1990, v. 33, pp.974
[4] J.O.Dimmock, J.Phys. and Chem. Solids, 1972, v.32, №1, pp.319-330
[5] F.F. Sizov. Foreign electronic technics. v.24. pp. 3-48. 1977.
[6] A.M Afanasyev, P.A. Aleksandrov, R.M. Imamov. Moscow, Nauka Publishers. pp. 151, 1989
[7] H. Clemens, E.Fantner, G.Bauer. Rev. Sci. Instrum. 1983. v. 5, 6. pp. 685-689.
[8] H. Kinoshita,H. Fujiyasu. J. Appl. Phys. 1980. v. 51, 11. pp. 5845-5846.
[9] H. Kinoshita, T. Sakashita,H. Fujiyasu. J. Appl. Phys. 1981, v. 52, 4, pp. 2869-2871
[10] R.B. Schoolar, J.D. Jensen. Appl. Phys. Lett. 1977. v.31,8, pp.536-538.
[11] D.K.Hohke, H.Holloway, K.F.Yeung, M.Hurley. Appl. Phys. Lett.. 1979, v.29,2, pp.98-100 .
[12] K.V.Vyatkin, A.P.Shotov, V.V. Uretsiki. Izv. AN SSSR, Neorgan. Materials, 1981, v.17, 1,pp.24-27
[13] I.R. Nuriyev, R.N. Nabiyev, E.A. Ahmedov. Elektronnaya tekhnika. 1991, 3, 166, pp. 49-52
[14] I.R. Nuriyev, R.N. Nabiyev, E.A. Ahmedov. Elektronnaya tekhnika. 1991, 10, 264, pp.36-39
[15] I.R. Nuriyev, E.A.Ahmedov, E.Yu.Salayev, M.I. Abdullayev. Prikladnaya Fizika. 1999, 3, pp. 126- 127.
[16] I.R. Nuriyev, M.I. Abdullayev, A.M. Nazarov, S.I. Gadzhiev. 12-th International symposium "Thin films in electronics", Kharkov, Ukraine, 2001, 23-27, pp. 210-212
[17] E.Yu. Salayev, I.R. Nuriyev, A.M. Nazarov, S.I. Gadzhiev. Prikladnaya Fizika. 2003, 4, pp.91-94
[18] A.V.Lyubchenko, E.A.Salkov, F.F.Sizov. Physical bases of semiconductor infrared photoelectronics, Naukova Dumka, 1984, 254 pp.
[19] I.I. Lyapiline, I.M. Cidilkovskiy. Progress in Physical Science, 1985, v. 146, 1, pp. 35-72.
[20] D.G. Andrianov, N.M. Pavlov, A.S. Savelyev, V.I. Phystule, G.P. Ciskarishvili. Physics and Technology of Semiconductors , 1980, v. 14, 6, pp. 1202-1212

[a]**Name**: Mehrabova Matanat Ahmad ;
Place and date of birth: Baku, Azerbaijan, 28.04.1964;

Education and academic degrees:
primary school №159 (1971-1981), Azerbaijan
Baku State University (1981-1986), Azerbaijan
post graduate student (1988-1991), Azerbaijan
Ph.D in physics-mathematics (1992), Azerbaijan,
Professor of International Ecoenergy Academy (2011), Azerbaijan.
Associate professor (2011), Azerbaijan,

Scientific activity: Physics of solid state, theoretical study of physical effects in solid states, semiconductors, radiation physics, radioecology, biophysics and so on.

M.Mehrabova became a Member of the: V Euroasian Conference on Nuclear Science and İts Application in Turkey (2008), International Conference on Structural Analysis of Advanced Materials in France (2009), Polymer Networks Group20th Conference in Germany (2010), Senior Member of the WSEAS Intern. Conferences in Greece (2010), Barselona, Spain (2011), Prague, Czech.(2011), Catania, Italy (2011)

Career/Employment:
1. Head of the International Projects and Information Department in the Institute of Radiation Problems of Azerbaijan National Academy of Sciences, from 2008 up today
2. Chief Technology Commercialization Officer, member of the Transfer Technology Centre of the ANAS from 2007 up today

Honours, Awards, Fellowships, Membership of Professional Societies:
1. International Diploma №085 of "YOUNG SCIENTISTS OF XXI CENTURE", Winner of the International Project of "YOUNG SCIENTISTS OF AZERBAIJAN", 2004
2. Scientific Technology Centre of Ukraine– «Technological Management: commercialization of R & D results in scientific research institutes», 2007
3. Azerbaijan Bank Training Centre – « Technology Transfer Management», 2007, December
4. Civilian Research Development Foundation –"FROM IDEA TO MARKET" A workshop series for technology entrepreneurs, 2008
5. Civilian Research Development Foundation, Science and Technology Entrepreneurship Program, STEP Venture Forum, 2008
6. Participation in the V Eurasian Conference "Nuclear Science and its Application", Turkey, Ankara, 2008, October
7. Participation in the International Conference of Structural Analysis and Advance Materials, France, Tarbes, 2009, September
8. GRBS SERTIFICATE, Intermediate level of English language, 2009, July
9. SRDF STEP Technology Entrepreneurship Program (Workshop), Baku, Azerbaijan, 2010, July 1-2
10. Specialization course on "Information and innovation: the international experience and modern approach" ANAS, Scientific Innovation Center, 2010, December 15-17
11. Participation in the 20-th International Research Project Exibitions , Turkey, Istanbul, 2011, May.

Consultant and participant of the projects:
1. BII- Project BII-F-249, 2006
2. STCU 4798 - "Biochemicals indicators of venom of Vipera lebetina obtusa (biotic and abiotic factors)" (2008-2010)

3. SRDF Science&Technology Entrepreneurship Program, STEP Venture Forum (2009), Preparation of Aggressive-Resistant Polymer Elastic Materials for Oil and Mechanical Engineering Industries
4. STCU 3913 – “Influence of mineral oil, heavy metals and radiation on biodiversity of spiders”, (2009-2012)
5. MEF, 20th International research projects exhibition, Turkey, Istanbul, 2011, “Influence of heavy metals and radiation on biodiversity of coccinellidae”, head of the project.

Publications: Number of papers in refereed journals: 85
Number of communications to scientific meetings: 50
Language Skills: Azeri, Russian, English, Turkish

Contact: Tel:(+994 50) 7318177
E-mail: mehrabova@mail.ru

[a]**Name**: Nuriyev Hidayat Rahim
Place and date of birth: Marneuli, Georgia, 20.01.1941

Education and academic degrees:
Primary school №2 (1947-1957), Georgia
Azerbaijan State Pedagogical University (1957-1962), Azerbaijan

Ph.D in physics-mathematics (1971), Azerbaijan
Dr. Sc. in physics-mathematics (1988), Azerbaijan
Professor (1991), Azerbaijan

Scientific activity: Specialized on IR photoelectronics, crystal growth, physics of solid state, semiconductors, nanomaterials and so on.

H.R.Nuriyev became a Member of the: International Scientific and Engineering Conference on Photoelectronics and Night Vision Devices in Moscow (1992-2010), 9th International Symposium “High-purity Metallic and Semiconducting Materials” in Kharkov, Ukraine (2003), National Conferences of growth of crystals in Moscow (2004-2008), 3rd International Conference on Technical and Physical Problems in Power Engineering in Ankara, Turkey (TPE-2006), Russian Symposium on Scanning Microscopy, Probe Microscopy and analytic research Technique, Chernogolovka settlement in Moscow (2001-2011), 17th International Conference on Advanced Laser Technologies in Antalya, Turkey (2009), National Conference on application X-ray, Synchrotron radiations, Neutrons and Electrons for research of materials in Moscow (2003-2009), International Conference “Micro- and nanoelectronics 2005” in Moscow, Second International Conference on Technical and Physical Problems in Power Engineering (TPE-2004)in Tabriz, Iran (2004), Photovoltaic and Photoactive Materials-Properties, Technology and Applications, NATO Advanced Study Institute in Sozopol, Bulgaria (2001), Senior Member of the WSEAS –Intern. Conferences in Prague, Czech.(2011), Catania, Italy (2011)

Career/Employment:
Head of the "Diagnostics of Surface Epitaxial and Metal-ceramic Structures" Laboratory in the Institute of Physics of Azerbaijan National Academy of Sciences

Consultant and participant of the projects:

1. STCU Project № 3237, 01.07.2006-01.07.2008, “Make photoreceivers on the base of the epitaxial films of GaSe, GaTe, InSe lamellar semiconductors and monocrystals”.

2. INTAS Project 01-0190, 01.01.2002 - 01.01.2004, “$Pb_{1-x}Mn_xTe$ epitaxial films and photosensitive homo- and heterostructures on their base”.

3. ANAS project, 01.01.2010-31.12.2010, “Complex researches in the direction of making renewable energy sources with high efficiency on the base of nanostructure materials”.

Publications: Number of papers in refereed journals: 200
Number of communications to scientific meetings: 43
Inventions: 6

Language Skills: Azeri, Russian, Georgian

Contact: Tel:(+99450) 641 83 88
E-mail: h.nuriyev@gmail.com

[b]**Name**: Ismayilov Taryel Humbat

Place and date of birth: Shamkir, Azerbaijan, 16.10.1949;

Education and academic degrees:
1967-1972 - A master’s degree in Physics, Baku State University, Azerbaijan.
1981 – PhD in Physics, Dissertation title « The theory of interband Raman scattering and optical absorption in solid solutions».
1993 - Doctor of Sciences, Dissertation title: «Electron Raman scattering and two-photon absorption of light in type semiconductors and semimagnetic semiconductors on their basis».

Career/Employment: Doctor of Sciences, Professor, Solid State Physics chair, department of Physics, Baku State University, Azerbaijan, Baku.

Career/Employment:
From 2000 till present – professor of Chair of Solid State Physics at the Physical Faculty of Azerbaijan State University, Azerbaijan, Baku.
1999-2000 - Institute of Physics, Academy of Sciences Azerbaijan, Baku, head of laboratory.
1992-1999 - Institute of Physics, Academy of Sciences Azerbaijan, Baku, the leading scientific employee.
1985-1992 – Scientific Research Corporation of Cosmic Investigation, the senior scientific employee, the head of the group.
1972-1985 - Institute of Physics, Academy of Sciences Azerbaijan, Baku, the scientific employee
1975-1976 –Institute of Radio Engineering and Electronics (IRE, Moscow), the researcher.
1998 – University Ankara (Ankara, Turkey).

Scientific activity: Semiconductor Physics, Low-dimensional systems, Quantum nanostructures, Spintronica

T.H. Ismayilov became a Member of the: European Materials Research Society, Fall Meeting, Symposium D inWarsaw, Poland, (2003). 3rd International Conference on “Technical and Physical Problems in Power Engineering” (TPE-2006), Gazi University inAnkara, Turkey (2006), 20th Conference on Solid State, EPC in Prague (2004), 13th International Conference on Solid Films and Surface in Argentina (2006), Conference on Nano and Giga problems in Electronics and Photonics in Arizona (2007), Senior Member of the WSEAS Intern. Conferences in Prague, Czech.(2011), Catania, Italy (2011)

International and domestic grants, programs
1. 1994 – Soros grant
2. 1998 – NATO grant

Publications: Number of papers in refereed journals: 90
Number of communications to scientific meetings: 45

Language Skills: Azeri, Russian, English, Turkish
Contact: Tel:(+994 12) 439 11 65
E-mail: tariyel.i@gmail.com