ЗАХИРИДДИН
МУҲАММАД БОБУР
НОМИДАГИ АНДИЖОН
ДАВЛАТ УНИВЕРСИТЕТИ

ANDIJAN STATE
UNIVERSITY NAMED
AFTER ZAKHIRIDDIN
MUKHAMMAD BABUR

ИЛМИЙ ХАБАРНОМА

Физика-математика
Тадқиқотлари
(Махсус сон)

SCIENTIFIC BULLETIN

Physical and
Mathematical Research
(Special Issue)

Андижон
2023 йил

Муассис

Захириддин Мухаммад Бобур номидаги Андижон давлат университети

**ИЛМИЙ ХАБАРНОМА.
ФИЗИКА-МАТЕМАТИКА
ТАДҚИҚОТЛАРИ**

Журнал бир йилда 2 марта чоп этилади.

Андижон вилояти ахборот ва оммавий коммуникациялар бошқармаси
томонидан 2019-йил 26 декабрда
0452 рақам билан рўйхатга олинган.

Нашр индекси: 344

Нашр учун масъул:
А.Й.Бобоев

Босишга рухсат этилди:
27.12.2019.
Қоғоз бичими: 60х81 1/8
Босма табоғи: 13,5
Офсет босма. Офсет қоғози.
Адади: 110 дона.
Баҳоси келишилган нархда.
Буюртьа №: 165.
"Муҳаррир" нашриёти манбаа бўлимида чоп этилди.
Тошкент шаҳри, Сўгалли ота кўчаси 7-уй

Таҳририят манзили:

170100, Андижон шаҳри, Университет кўчаси, 129. Телефон: +998911602043.
Факс: (374) 223-88-30

E-mail: adu_xabarnoma@mail.ru Расмий сайт: uzjournals.edu.uz/adu

Сборник статей международной научно-практической конференции по «Полупроводниковая опто- и наноэлектроника, альтернативные источники энергии и их перспективы» Андижан, 12-13 октября 2023 года

ОГЛАВЛЕНИЕ

Yarimo'tkazgich materiallarini qo'rg'oshin selen asosida elektrofizik xususiyatlarini o'rganish.

N.Y. Sharibayev[1], B.M. Baxromov[2], R.M. Jalalov[3], A.A. Yusufjonov[3]

[1]Namangan muxandislik-texnologiya instituti
[2]Milliy universitet huzuridagi Yarimo'tkazgichlar fizikasi va mikroelektronika ilmiy tatqiqot inistituti
[3]Namangan Davlat Universteti

Annotation*:* To study the structure, optical and electrical properties of PbSe films, to establish the relationship between the spectral characteristics and their structural properties with temperature changes, to evaluate the possibility of using a linear-chain carbon film as a protective layer to reduce oxidation. The work lies in the fact that the new effects discovered in the course of research (semiconductor-metal and electrical transition) can be used in microelectronics to develop thermistors with a nonlinear n-shaped flow has a voltage characteristic. The results of the study of the structure, optical and electrical properties of *PbSe* films can also be useful in the analysis of the fundamental physical properties of semiconductor binary systems obtained by solid-phase synthesis.

Keywords: photosensitive, thermoresistive evaporation, Raman spectrum, metal-insulator, glass substrates, diffractometry, atmospheric oxygen, selenide phase

At the current stage of scientific and technical development, special attention is paid to studying the possibilities of creating various devices and devices of thin film technologies. thin films are widely used in the electronics industry to create semiconductor devices, microcircuits, and other thin film elements. To date, the physics of thin films has made significant progress in understanding their formation processes and properties. however, there are many questions that interest researchers in this area. These include, for example, film synthesis issues, parameter measurement methods, and computational models of various physical processes and, of course, physical phenomena that are not present in bulk samples in films. properties of thin films are mainly determined by the technology of synthesis, as well as the material and quality of the surface of the sample, the composition of the sprayed substance, and chemical reagents. therefore, it is important to develop methods of synthesizing films, to study their optical, magnetic, electrical and structural properties, to study various surface phenomena, to establish the relationship between the studied properties and performance indicators.

Among widely used materials, lead selenides occupy one of the most important places due to the variety of optical, electrical and other properties. in particular, it was found that lead selenide has photosensitive properties [1], it is necessary to improve technological processes for obtaining photosensitive films and production devices based on them. this work is dedicated to studying the structure, optical and electrical properties of lead selenide-based thin films obtained by solid-phase synthesis - thermoresistive evaporation of lead and selenium, followed by annealing in a nitrogen atmosphere . A problem in the practical application of pbSe films is the instability of the properties associated with oxidation, which leads to complete destruction over time.

1. Development of a low-temperature technology to form thin PbSe films suitable for the fabrication of semiconductor elements [2].

2. To study the electrophysical properties and composition of the obtained PbSe films and to study their structural state in detail.

3Studying the effect of carbon in the Sp1 state on the properties of PbSe films and its electrophysical parameters.

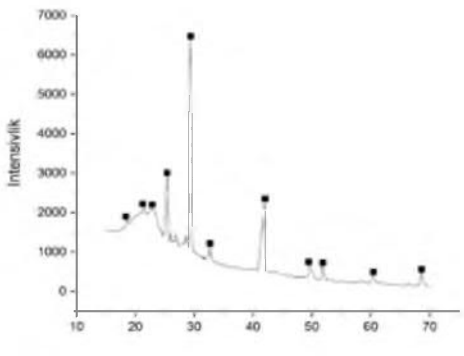
4. To establish the relationship between the structure and spectral characteristics of PbSe films and changes in its electrophysical properties under the influence of temperature.

On the basis of a comprehensive study of the properties of PbSe films obtained by solid-phase synthesis, the appearance of the transition to the semiconductor metal phase and the effect of electrical exchange were determined [3]. It was found that the switching effect with the n-type current-voltage characteristic is related to the semiconductor-to-metal phase transition in the PbSe film. atomic force microscopy of the surface structure of lead selenide films obtained by solid-phase synthesis revealed the homogeneity of the surface structure, including deep voids that interact with atmospheric oxygen. it was found that by coating these films with linear chain carbon, the temporal stability of the samples can be increased many times [4-5]. In the analysis of reflection spectra and Raman spectra of PbSe films at temperatures of 300 K and 370 K, a change in spectral properties was revealed: an increase in the reflection spectrum, a change in intensity, and modes of vibrational displacement. Information on the most characteristic properties of lead selenide and the main methods of obtaining, results of studying the structure and properties of linear chain carbon films, phase transition models of semiconductors - the effect of metal and electrical conductor, as well as , $A^{IV}B^{V}I$ type semiconductors, the possibility of a phase transition of a different nature is considered.Particular attention is paid to the samples of two-phase composition of PbSe+PbSeO3 composition [6], in which anomalous change of conductivity was determined at temperatures around Tp=360 K. The temperature close to the metal-insulator transition characteristics is Tp. the possibility of electronic instability for the development of thermistors operating at the phase transition temperature is described.

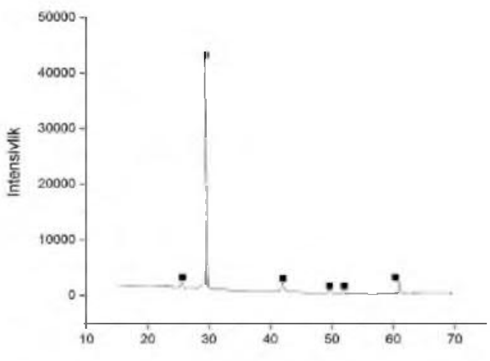
Films were placed on quartz glass substrates for optical measurements of the studied samples. In order to study the electrophysical properties of semiconductors, they were synthesized on glass substrates with pre-deposited aluminum electrodes. A second aluminum electrode is placed on top of the samples.X-ray diffraction (diffractometry), X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES) methods were used to study the composition and structural properties of the films. X-ray phase analysis (XPA) of the samples revealed the NaCl (B1)-type cubic structure characteristic of lead selenide PbSe crystals and the monoclinic structure associated with the lead selenide *$PbSeO_3$* phase [7-8] (Figure. 1, Table 1). both samples show that the lead selenide phase is dominant. The concentration of the existing phases was calculated.

Table 1. Composition and structural properties of PbSe film phases.

№	Phase					
	Stex. formula	Name	Singoniy	Structure	Denotation Figure 1	Sod.mass %
1,a	PbSe	Clausthalitis	Kub.	Fm-3m	■	55
	$PbSeO_3$	Molybdenum	Monokl.	P21/m	◊	45
1,b	PbSe	Clausthalitis	Kub.	Fm-3m	■	83
	$PbSeO_3$	Molybdenum	Monokl.	P21/m	◊	17



a) 2nd level



b) 2nd level

Figure 1. *PbSe (a) and Al-PbSe (b) diffraction patterns of films*

XPS analysis revealed the presence of the following elements in the surface layers of PbSe films: *Pb, Se, O, C* and *Na*. when calculating the atomic composition, the presence of carbon, whose appearance in the spectrum mainly depends on surface contamination, was not taken into account [9-10]. The composition of elements on the surface of the sample before cutting varies within a few percent at different points: lead (Pb) 21-27%, oxygen (O) 45-55%, selenium (Se) 15-16% . All samples contained sodium, whose appearance could be related to the substrate. the presence of oxygen in the studied films is explained, first of all, by the specific characteristics of their synthesis and heat treatment, the mechanism of which allows introducing oxygen-containing phases into the volume and surface layers of the material. secondly, the surface of PbSe tends to oxidize during storage in air [11-12].The sequence disorder on the surface appeared due to the presence of Al not being detected in the Al-PbSe sample, which may be due to the lack of diffusion and the settling time at a temperature of 523 K (melting point of aluminum is 933 K), further analysis was carried out with PbSe film.

The analysis of the elemental composition during ion treatment for one hour (Figure 2) shows a relative stabilization of the composition, which is characterized by a monotonic decrease in the amount of oxygen and an increase in the content of lead from the 4^{th} minute of growth, which continues reaches 30 to the minute.then the amount of selenium gradually decreases and begins to decrease to statistically insignificant values. According to the results of ion etching, it was found that the thickness of the PbSe phase during sample synthesis was 250-300 nm.

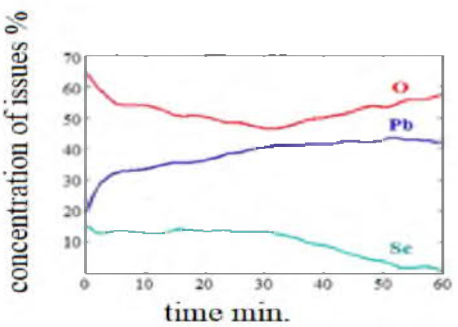


Figure 2: *Distribution of elements Se, O, Pb by depth of PbSe film according to XPS data. speed ~6 nm/min.*

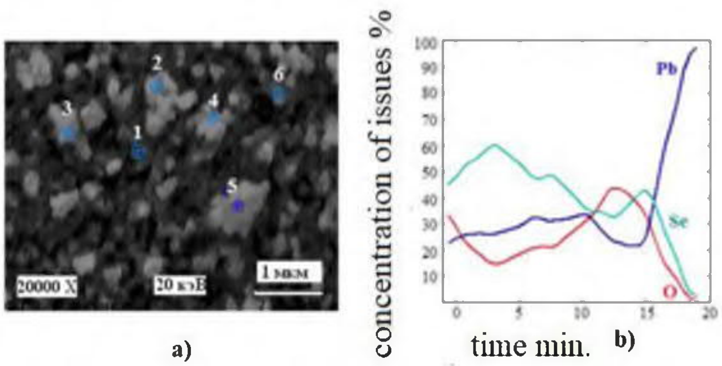


Figure 3. *Electron microscopic image (a) depth distribution of Se, O, Pb (b) elements of PbSe film according to AES data.*

External impact electron spectroscopy (AES) was used to conduct local elemental analysis of PbSe films at different points on the surface [13-14]. The electron microscopic image (Figure 3a) shows the points where the elemental composition was studied. the plank consists of intergrown microcrystalline formations, the size of their particles is 0.2÷0.25 μm. The composition was analyzed at six points in different areas of the sample. In the aES method, layer by layer ionization for 20 min (Figure 3b) indicates that individual grains may have higher selenium content [15]. thus, the percentage concentration of elements (Pb, Se and O) may different at individual points of the film, which indicates the presence of X-ray amorphous phases of lead, selenium and their oxides.

Summarizing the results of X-ray studies, it is shown that PbSe films obtained by solid phase synthesis are homogeneous in structure and composition, but homogeneities in the form of defects are revealed as the studied area decreases [16-17]. It was found that the temperature (523 K) and time (45 min) of the heating are sufficient to form the lead selenide phase.

A comprehensive study of PbSe required further study of their structure [18-19]. surface topographies of the samples were obtained using an atomic force microscope (Figure 4). Scanning was performed in semi-contact mode, the size of the scanned area was 3x3 μm. as shown, the films have a polycrystalline structure with a size of about 250 nm, with many voids prominent. A film with such a surface actively interacts with atmospheric oxygen. according to our research, the introduction of oxygen leads to chemical interaction, the formation of oxides [20].

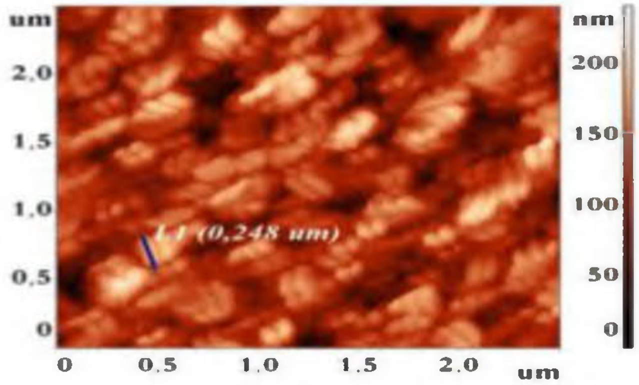


Figure 4. *AFM image of pbSe film, scan area size 3 x 3 mkm.*

Presents the results of a study of the effect of a linear chain carbon film on the properties of PbSe samples. When studying the Raman spectra of pbSe, PbSe-LCC films (Figure. 5) at room temperature, the positions of the peaks in both spectra in the region of 132 and 795 cm–1 related to PbSe were determined. It doesn't change, only the intensity changes. moreover, a maximum at 1563 cm-1 attributed to the double bond between carbon atoms was found in the PbSe-LCC system [21-22]. The reflectance spectra R(l) of pbSe and PbSe-LCC films in the wavelength range of 2-16 μm were studied by Fourier-IR spectroscopy 10 days after their preparation. Two minima of the reflection coefficient associated with the PbSe and $PbSeO_3$ phases were found in the R(l) spectra [23]. the minima of the reflection coefficient are associated with plasma resonance of free charge carriers. The two plasma minima observed in the reflection spectra are further confirmation of the presence of two phases, PbSe and $PbSeO_3$, in PbSe films, consistent with the XRD data [24-25]. For the pbSe LCC film, the plasma minimum associated with the PbSe phase is shifted to the long wavelength region. According to, as the oxidation time increases, the mass of PbSe in the film decreases, while the mass of PbSeO3 increases. The plasma minimum associated with the PbSe phase shifts to the short wavelength region. Thus, the PbSe film coated with the LCC layer is less oxidized. moreover, according to the R(l) spectra, it was determined that the PbSe crystal phase of the studied samples belongs to n-type conductivity.

Conclusion.A new modification of the method of obtaining lead selenide films by three-layer phase synthesis was developed using the method of layer-by-layer deposition of Pb, Se films and subsequent spinning in a nitrogen atmosphere.

Structural, phase, chemical analyzes of polycrystalline layers of pbSe were carried out.

X-ray diffraction analysis and IR reflection spectra showed that the studied samples mainly contain two phases RbSe and $PbSeO_3$. it was found that the PbSe crystal phase of the studied samples belongs to n-type conductivity.

More accurate XPS and AOS methods show the non-uniformity of the element concentration distribution over the depth of the film, which leads to the formation of defects. surface morphology of lead selenide films was studied using atomic force microscopy. An inhomogeneous surface structure containing deep voids leading to active interaction with atmospheric oxygen is identified.

References.

1. O.O. Mamatkarimov, B.H. Kuchkarov, N.Yu. Sharibaev, A.A. Abdulkhayev "Influence Of The Ultrasonic Irradiation On Characteristic Of The Structures Metal-Glass-Semiconductor" European Journal of Molecular & Clinical Medicine 2021/1/1 8/01 str 610-618.
2. B.Kh.Kuchkarov, O.O.Mamatkarimov. "Influence of ultrasonic action on the rate of charge formation of the inversion layer in metal-glass-semiconductor structures" Vestnik KRAUNC. Fiziko-Matematicheskie Nauki 2019 y 29/4 str 125-134.

3. S.I. Vlasov, A.V. Ovsyannikov, B. Kh. Kuchkarov “Influence of thermo cyclic treatments on SiO_2-Si interface properties in Al-SiO_2-n-Si structures” Uzbekiston Fizika Zhurnali 2012 y 14/1 стр 20-22.

4. Б.Х. Кучкаров “Влияние ультразвукового воздействия на скорость формирования заряда инверсионного слоя в структурах метал-стекло-полупроводник Вестник КРАУНЦ” Физико-математические науки 2019y 29/4 стр 125-134.

5. B.Kh. Kuchkarov, O.O Mamatkarimov, A.A. Abdulkhayev “Relaxation dependence of the capacity of a three-layer structure in the process of charge formation of an inversion layer” Scientific and Technical Journal of Namangan Institute of Engineering and Technology 2019 y 1/6 str 26-33.

6. S. Zaynobiddinov, B.Kuchqarov “Development of effective methods of teaching theoretical electrotechnics Web of Scientist” International Scientific Research Journal 14/4/2022 y 3/4 str 431-437.

7. B. Kuchkarov, A. Abdulkhayev “Factors providing the efficiency of semiconductor lazers” Scientific and Technical Journal of Namangan Institute of Engineering and Technology 2022 y 3/5 str 48-52.

8. SI Vlasov, FA Saparov, B Kh Kuchkarov “ Effect of the semiconductor-insulator interface on the characteristics of the metal-insulator-semiconductor structures ” Uzbekiston Fizika Zhurnali 2009 y 11/3 стр 203-206.

9. B.H. Kuchkarov, O.O. Mamatkarimov, A.A. Abdukarimov, A. Khalmirzayev, and D.M. Mirtojiyeva “Influence of All-Round Compression on Formation of the Mobile Charge in Lead-Borosilicate Glass Structure” AIP Conference Proceedings 2432, 030039 (2022); https://doi.org/10.1063/5.0089980 2432, 030039 © 2022 Author(s)..

10. Б.Х. Кучкаров, М. Кахаров “МДП-структура и ультразвук” Экономика и социум 2019 г. 12/ (67) стр 623-626.

11. D.E. Nazirov, S.I. Vlasov, B. Kh. Kuchkarov, K.U. Bobokhuzhaev “Influence of gadolinium on the electric properties on the interphase boundary of silicon–silicon oxide” Science and world 9/2013y 12/88 str 26-28.

12. О.О. Маматкаримов, Р.Х. Хамидов, Р.Г. Жабборов, У.А. Туйчиев, Б.Х. Кучкаров “Релаксационные изменения подвижности и концентрации носителей заряда в Si с глубокими примесными уровнями при воздействии импульсного давления” Физическая инженерия поверхности 2012.

13. B. X. Qo’chqarov, A. Nishonov, X.O. Qo’chqarov “The effect of tunneling current on the speed surface generation of charge carriers” Scientific Bulletin of Namangan State University 2019y 1/7 str 3-6.

14. B.Kuchkarov. O. Mamatkarimov, A. Abdulkhayev, ICECAE IOP Conf. Series: Earth and Environmental Science 614 012027 “Influence of the ultrasonic irradiation on characteristic of the structures metal-glass-semiconductor”, (2020) y. Paper ID 116.

15. B.X. Qo’chqarov, A.Nishonov, X.O. Qochqarov, Scientific bulletin of Namangan State University, “The effect of tunneling gurrent on the spedd surface generation of charge garries”, (2020)y. 1(7), 3-6.

16. S. I. Vlasov, D. N. Nazirov, B.K. Kuchkarov, K.U. Bobokhujayev, “Influence of all-round compression on formation of the mobile charg in Iead-borosilicate qlass structure”. “Uzbekiston Fizika Zhurnali”, (2014) y. 3(16), 231-233.

17. B.Kh. Kuchkarov, O.O. Mamatkarimov, “Influence of ultrasonic action on the rate of charge formation of the inversion layer in metal-glass-semiconductor structures” Vestnik KRAUNC. Fiziko-Matematicheskie Nauki, (2019) y. 4(29), 125-134.

18. S.I. Vlasov, A.V. Ovsyannikov, B.K. Ismailov, B.H. Kuchkarov, Effect of pressure on the properties of Al-SiO_2-n-Si<Ni> structures. “Semiconductor Physics Quantum Electronics & Optoelectronics”, (2012) y. 2(15), 166-169.

19. S.I. Vlasov, D.E. Nazyrov, B. Kh. Kuchkarov, K.U. Bobokhujayev “Influence of all-round compression on formation of the mobile charge in lead-borosilicate glass structure” Uzbekiston Fizika Zhurnali 16/3 стр 231-233.

20. S.I. Vlasov, F.A. Saparov, B. Kh. Kuchkarov “Effect of the semiconductor-insulator interface on the characteristics of the metal-insulator-semiconductor structures” Uzbekiston Fizika Zhurnali 2009 y. 11/3 str. 203-206.

21. B.T.Abdulazizov, G.Gulyamov, P. J. Baymatov, Sh. T. Inoyatov,M. S. Tokhirjonov and Kh. N. Juraev//Peculiarities of the Temperature Dependence of the Chemical Potential of a Two-dimensional Electron Gas in Magnetic Field// SPIN Vol. 13, No. 1 (2022) .pp (2-7), https://doi.org/10.1142/S2010324722500023.

22. B.T. Abdulazizov/Cyclotron mass of an electron in strong magnetic fields in a wide InAs quantum well/ *Eurasian Journal of Physics and Functional Materials (*2022), 6(1), pp 32-37, doi.org/10.32523/ejpfm.2022060103.

23. G.Gulyamov, B.T.Abdulazizov, P.J.Baymatov.Three-band simulation of the g-factor of an electron in an InAs quantum well in strong magnetic fields .Journal of Nanomaterials ,Volume (2021), Article ID pp (559-563), https://doi.org/10.1155/2021/5542559.

24. P.J. Baymatov, B.T. Abdulazizov. Concentration dependences of the electron effective mass , Fermi enerjy, and filling of subbands in doped InAs/AlSb quantum wells.Украинский Физический Журнал. Ukr. J. Phys.2017. Vol. 62, No. 1, стр 46-50 , https://doi.org/10.15407/ujpe62.01.0046.

25. G Gulyamov, BT Abdulazizov. On the thermodynamics of a two-dimensional electron gas with non-parabolic dispersion. World Journal of Condensed Matter Physics.pp 294-299. doi: 10.4236/wjcmp.2016.64028.