UZHHOROD NATIONAL UNIVERSITY

XIII International seminar

“Properties of ferroelectric and superionic systems”

Uzhhorod, October 29, 2024

Programme and abstracts

http://seminar.pp.ua

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Uzhhorod 2024

XIII International seminar "Properties of ferroelectric and superionic systems"

Uzhhorod, October 29, 2024

ORAL SESSION

	OPENING	9.50
	Chairman Yu. Vysochanskii	
1	**Ag(Tl)–Sb(In)–P–Se SYSTEMS: phase formation, crystal chemistry, technology and properties.** I. Barchiy[1], V. Sabov[1], M. Sabov[1], A. Pogodin[1], M. Piasecki[2], V. Pavlyuk[2,3], O. Khyzhun[4], A. Fedorchuk[5] *[1] Uzhhorod National University, Ukraine* *[2] J.Dlugosz University, Częstochowa, Poland* *[3] I.Franko Lviv National University, Ukraine* *[4] Institute for Problems in Materials Sciences NAS of Ukraine, Kyiv, Ukraine* *[5] Lviv National University of Veterinary Medicine and Biotechnologies, Ukraine*	10.00 - 10.30
2	**Size-Induced, Strain-Induced and Ionic-Induced Effects in Low-Dimensional Ferroelectric Materials** A. N. Morozovska[1], E. A. Eliseev[2], Yu. M. Vysochanskii[3], and S. V. Kalinin[4] *[1] Institute of Physics, NASU, Kyiv, Ukraine* *[2] Frantsevich Institute for Problems in Materials Science, NASU, Kyiv, Ukraine* *[3] Institute of Solid-State Physics and Chemistry, Uzhhorod University, Ukraine* *[4] Department of Materials Science and Engineering, University of Tennessee, USA*	10.30- 11.00
3	**Dielectric, elastic, and thermal characteristics of NH_4HSO_4 ferroelectric within the framework of a two-sublattice pseudospin model** A.S.Vdovych[1], I.R.Zachek[2], O.B.Bilenka[2] *[1] Institute for Condensed Matter Physics of the NASU, Lviv, Ukraine* *[2] Lviv Polytechnic National University, Ukraine*	11.00- 11.30
4	**Ground state study of local potential transformation in the $Sn_2P_2S_6$-type ferroelectrics** O.V. Velychko Institute for Condensed Matter Physics of the NAS of Ukraine, Lviv, Ukraine	11.30- 12.00
5	**Ferro-Ionic Coupling Impact on Polarization Switching and Electrophysical Properties in $Bi_{1-x}Sm_xFeO_3$ Nanoparticles** A. N. Morozovska[1], E. A. Eliseev[2], O. S. Pylypchuk[1], I. V. Fesych[3], and S. V. Kalinin[4] *[1] Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine* *[2] Frantsevich Institute for Problems in Materials Science, NAS of Ukraine, Kyiv, Ukraine* *[3] Taras Shevchenko National University of Kyiv, Ukraine* *[4] Department of Materials Science and Engineering, University of Tennessee, USA*	12.00- 12.30
	POSTER SESSION (online)	12.30- 13.30
	BREAK	
	Chairman A. Grabar	
6	**Investigation of macroscopic polarization switching in layered $CuInP_2S_6$ crystals** D. Gál [1,2], H. Bán [3], V. Minkovich [3], V. Gerasimov[4], Á. Horvat[3], A. Molnar[3] *1 HUN-REN Wigner Research Centre for Physics, Budapest, Hungary* *2 University of Pécs, Pécs, Hungary* *3 Uzhhorod National University, Ukraine* *4 Mukachevo State University, Ukraine*	14.00- 14.30
7	**Enhancement of the efficiency of acousto-optic diffraction in electric and magnetic fields** O. Mys, D. Adamenko, R. Vlokh *O.G. Vlokh Institute of Physical Optics of the Ivan Franko National University of Lviv, Ukraine*	14.30- 15.00
8	**Co-doped $Sn_2P_2S_6$ crystals: photorefractive parameters and possible applications** V. Voloshyn, M. Tsyhyka, K. Glukhov, R. Pavlyshyn, A. Grabar *Uzhhorod National University, Ukraine*	15.00- 15.30
9	**Raman scattering study of $CuInP_2S_6$ type 2D ferrielectrics near the monoclinic-trigonal boundary.** Yu. Vysochanskii, V. Liubachko, R. Yevych, K. Glukhov, V. Hryts,, M. Medulych, A. Pogodin, A. Kohutych *Uzhhorod National University, Ukraine*	15.30- 16.00
	CLOSING	16.00

POSTERS

1. **On the 'bond length versus bond valence/order' correlation curve for hydrogen–oxygen bonds in solids**
   V. Sidey
   Uzhhorod National University, Ukraine

2. **Refractive and dilatometric parameters of rubidium sulfate crystals**
   I.A. Pryshko[1], V.Yo Stadnyk[1], P.A. Shchepanskyi[1], I.M. Matviyishyn[2], V.Ya. Baliga[1]
   [1] Physics Faculty, Ivan Franko National University of Lviv, Ukraine
   [2] Faculty of Electronics and Computer Technologies, Ivan Franko National University of Lviv, Ukraine

3. **Investigation of microhardness of single crystal of $Ag_{7+x}(P_{1-x}Ge_x)S_6$ solid solutions**
   I. Shender[1], A. Pogodin[1], M. Filep[1,2], T. Malakhovska[1], O. Kokhan[1], L. Suslikov[1], V. Bilanych[1]
   [1] Uzhhorod National University, Ukraine
   [2] Ferenc Rákóczi II Transcarpathian Hungarian Institute, Beregovo, Ukraine

4. **Exciton Luminescence of $CsSnBr_3$ crystals**
   V. Shvets, A.Pushak, O. Antonyak, T.Demkiv, A. Voloshinovskii
   Ivan Franko National University of Lviv, Ukraine

5. **Acoustic properties of $Cu(Ag)_7SiS_5I$ crystals in the temperature range 300÷380 K**
   Mykyta O.I., Fedelesh V.I., Shender I.A., Pogodin, A.I.
   Uzhhorod National University, Ukraine

6. **EPR spectra of Mn ions in the paraelectric phase of $LiNaGe_4O_9$: crystal**
   M.P. Trubitsyn[1,2], V. Laguta[1,3], A.O. Diachenko[2], M.D. Volnianskii[2]
   [1] Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
   [2] Oles Honchar Dnipro National University, Ukraine
   [3] Frantsevich Institute for Problems of Materials Science NAS Ukraine

7. **Temperature-spectral properties β-$LiNH_4SO_4$ crystals with an admixture of Mn^{2+} and Cu^{2+}**
   R. S. Brezvin, A. O. Shapravskyi, P. A. Shchepanskyi, M. Ya. Rudysh, V. Yo. Stadnyk, A. V. Larchenko, T. M. Pasitskyy, V. Ya. Baliha
   Physics Faculty, Ivan Franko National University of Lviv, Lviv 79005, Ukraine

8. **Influence of X-ray irradiation on the thermochromic effect in polymer microcomposites based on $[NH_2(C_2H_5)_2]_2CuCl_4$ crystals**
   V. Davydovych, V. Kolomiiets, Yu. Chornii, V. Kapustyanyk,
   Faculty of Physics, Ivan Franko National University of Lviv, Ukraine

9. **Characteristics of a pulsed-periodic gas-discharge source of ultraviolet radiation fluxes and microstructures of silver sulfide**
   R. Hrytsak, O. Shuaibov, O. Minya, Z. Homoki, R. Holomb, A. Pogodin
   Uzhhorod National University, Ukraine

10. **Structural and electronic properties of Ag_3AsS_3: A first-principles density-functional theory study within DFT-D and DFT-D+U methods**
    T. Babuka[1], I. Babuka[1], O.O. Gomonnai[1], A.V. Gomonnai[2]
    [1]Institute of Physics and Chemistry of Solid State, Uzhhorod National University, Ukraine
    [2] Institute of Electron Physics, Nat. Acad. of Sci. of Ukraine, Uzhhorod, Ukraine

11. **Demultiplexing of optical beam with using of Raman-Nath acousto-optic diffraction and singular acoustic beam**
    I. Skab, M. Kostyrko, O. Krupych, R. Vlokh
    O.G. Vlokh Institute of Physical Optics of the Ivan Franko National University of Lviv, Ukraine,

12. **Modeling of van der Waals heterostructures based on β-InSe and $MoSe_2$ crystals: electronic and optical properties**
    O. I. Korolov, L. Yu. Kharkhalis, K. E. Glukhov
    Institute for Physics and Chemistry of Solid State, Uzhhorod National University, Ukraine

13. **Classical models of long-term mechanical relaxation in As-Se glasses**
V. Minkovich, M. Povhanich, Y. Tsisaruk, A. Horvat
Department of Semiconductor Physics, Uzhhorod National University, Ukraine

14. **Dielectric properties of polycrystalline and single-crystalline $TlInS_2$ in the vicinity of phase transitions**
P. Huranych[1], A. G. Slivka[1], P. P. Guranich[1], R. R. Rosul[1], O. O. Gomonnai[1], A. V. Gomonnai[2], V. M. Rubish[3]
[1] *Uzhhorod National University, Uzhhorod, Ukraine*
[2] *Institute of Electron Physics, NAS of Ukraine, Uzhhorod, Ukraine*
[3] *Uzhhorod Laboratory of Optoelectronics and Photonics Materials. Institute for Information Recording, NAS of Ukraine*

15. **Features of the relaxation behavior of the dielectric properties of $CuInP_2S_6$ layered crystals at high hydrostatic pressures.**
V. S. Shusta[1], A. G. Slivka[1], V. A. Kalytyn[1], V. Y. Biganich[1], A. I. Susla[1], V. Y. Shusta[2]
[1] *The Department of Physics, Uzhhorod National University, Ukraine*
[2] *SE"IVANO-FRANKIVSKSTANDARTMETROLOGY" Ivano-Frankivsk, Ukraine*

16. **Phonon spectra and states densities of cubic system crystals in the concept of superspace symmetry**
A. Korneychuk, M. Pino, E. Yakyma, V. Senko, I. Nebola
Uzhhorod National University, Faculty of Physics, Uzhhorod, Ukraine

17. **Electronic structure and optical properties of zinc-containing halide perovskites**
M. Ya. Rudysh, A.V. Larchenko, A. O. Shapravskyi, P. A. Shchepanskyi, T.M. Pasitskyy, A. S. Voloshinovskii
Physics Faculty, Ivan Franko National University of Lviv, Lviv 79005, Ukraine

Characteristics of a pulsed-periodic gas-discharge source of ultraviolet radiation fluxes and microstructures of silver sulfide

R. Hrytsak[1], O. Shuaibov[1], O. Minya[1], Z.Homoki[1], R. Holomb[1], A.Pogodin[1]

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The use of an overvoltage nanosecond discharge (OND) in inert gases at atmospheric pressure may be promising for the synthesis of surface structures based on superionic conductors such as Ag_2S, Ag_8GeS_6, and others. Such compounds are synthesized by various chemical methods, initially in the form of macroscopic polycrystalline elements. However, their use in micronanotechnology requires the synthesis of such compounds in the form of thin films.

Physical methods for the synthesis of thin films based on superionic conductors were used in [1], where the synthesis of thin films from Ag_2S compound in a magnetron discharge was reported, and the results of the synthesis of films from Ag_2S compound excited as a vapor by a low-voltage electron beam (E = 800-1600 eV) are given in [2].

To optimize the process of gas-discharge synthesis of superionic conductor films, it is necessary to study the characteristics and parameters of the plasma of an overvoltage nanosecond discharge in inert gases between electrodes made of superionic conductors in the form of polycrystalline samples. Such characteristics and parameters of the plasma are currently not available. This hinders the development of new supercapacitors, batteries, photovoltaic devices, and sensitive The results of an experimental study of electrical and optical characteristics in atmospheric pressure helium between silver sulfide electrodes are presented in the abstract. Thin films of electrode destruction products in plasma were synthesized and their qualitative composition was determined. Experimental measurements were performed using the technique of spectral analysis of light source radiation. A bipolar high-voltage discharge with a duration of 100-450 ns was ignited between two electrodes made of polycrystalline Ag_2S compound. The distance between the electrodes was 2 mm. The radius of curvature of the end parts of the cylindrical electrodes was 10 mm. The diameter of the electrodes was 5 mm.

Silver sulfide is a superionic conductor, and thin films based on it are promising for use in high-voltage pulse technology (supercapacitors, etc.). Since such films contain silver, they may have bactericidal properties along with high ionic conductivity.

The installation scheme, the structure of the discharge device, and other conditions for studying the characteristics of the surge protector are given in [3].

The discharge was ignited when the discharge gap was overvoltage, when a beam of electrons was formed in it [4]. Under the action of such a beam, the discharge in atmospheric pressure helium was homogeneous and had a close-to-square aperture with an area of 4 mm2. In a strong electric field on the working surface of the electrode based on the superionic conductor Ag_2S, microexplosions of inhomogeneities occurred on the electrode surface [5], which contributed to the introduction of vapors of superionic conductor Ag_2S products and their decay (Ag, Ag^+, S ....) into the plasma and the formation of a stream of clusters and nanoparticles based on Ag_2S compound and its dissociation products in the plasma, which were subsequently deposited on the quartz substrate in the form of thin films. The power density of the UV radiation of the discharge was measured using a TKA-PKM UV meter at a distance of 15 cm from the discharge center.

The surface of the synthesized thin film samples was examined using a microscope with a 50x magnification.The polycrystalline silver sulfide (Ag_2S) compound used to make the electrodes was synthesized in the technological laboratory of the Uzhhorod National University.

The study of Ag_2S thin films in helium at atmospheric pressure was carried out under the following conditions: the voltage at the anode of the thyratron modulator of high-voltage nanosecond pulses was 13 kV, the pulse rate of the voltage pulses was 80 Hz, the distance from the center of the discharge to the glass plate was 10 mm, and the sputtering time was five cycles of 30 minutes. The thin films were analyzed using three available laser wavelengths - 532, 633, and 785 nm on a Renishaw InVia confocal Raman microscope, at 100% power, respectively, 60.6, 9.2, and 32 mW. The diameter of the laser beam was 1-2 µm.

The study of electrical characteristics showed that the total duration of the voltage pulses reached 450 ns. The voltage pulse included time-decaying oscillations with a duration of 40-50 ns. The maximum values of the electrical characteristics of the OND were observed at atmospheric helium pressure. Thus, the largest drop in the value of the positive polarity voltage over the discharge interval was 17 kV, and the maximum amplitude of the positive polarity current pulse reached 150 A. The maximum pulse discharge power was observed at p(He) = 101 kPa in the first 110 ns after its ignition and reached 2.3 MW (at t = 110 ns).

The energy of a single electric pulse at p(He) = 101 kPa was 91 mJ, and at p(He) = 13.3 kPa it decreased to 35.6 mJ. Let us consider the dependence of the intensity of discharge radiation in He-Ag_2S gas-vapor mixtures on the value of helium pressure and the main parameters of its excitation system: pulse repetition rate and the value of the charging voltage of the working capacitor of the high-voltage nanosecond pulse modulator. The highest value of the average plasma UV radiation power was observed at a helium pressure of 101 kPa at a maximum frequency of f = 1000 Hz and a charging voltage of 19 kV.

The radiation spectra of the OND in the He-Ag_2S gas-vapor mixture at different helium pressures and different repetition rates of voltage pulses are shown in Fig. 1. The results of the identification of spectral lines are given in Table 1 for the spectrum from Fig. 1. Reference [5] was used to decipher the spectrum.

In the ultraviolet part of the spectrum of the PRN plasma, the radiation at the transitions of the atom and the single-charged silver ion prevailed. The most intense were the resonant spectral lines of the silver atom 328.06 nm Ag I and 338.28 nm Ag I. The most intense ionic spectral lines were 224.64 and 232.02 nm.

The most intense spectral lines include the lines 388.86; 447.14; 501.56; 587.59; 667.81; 706.51 nm He I. These lines of the He atom in a pulsed plasma of atmospheric pressure are observed when the process of energy transfer from the lower metastable levels of He I to some impurity (silver sulfide molecules and its dissociation products) is effective.

When the frequency of the voltage pulses was reduced to 80 Hz and the He pressure to 13.3 kPa, a decrease in the intensity of all silver spectral lines was observed, which was due to a decrease in the concentration of the electrode material in the discharge plasma.

The formation of excited silver atoms and ions can occur during the excitation of a silver atom by electrons, in the processes of excitation of a single-charged silver ion by electrons with subsequent recombination of silver ions (Ag II; Ag III).

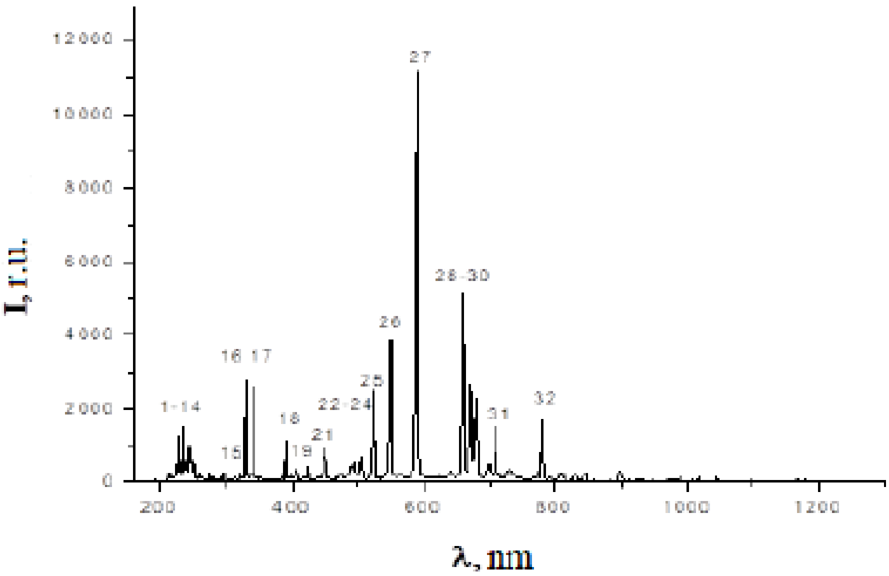

Figure 1 Radiation spectra of the OND plasma between electrodes of Ag_2S compound at: p(He) = 101 kPa; f = 1000 Hz.

Table 1. The results of identification of the plasma radiation spectra of the supervoltage nanosecond discharge between the electrodes of Ag_2S compound at atmospheric helium pressure (f=1000 Hz).

№	λ_{tab}, nm	I_{exp} r.u.	Object	E_{lower}, eV	E_{upper}, eV	$Term_{lower}$	$Term_{upper}$
1	211.38	250	Ag II	4.85	10.71	$4d^9(^2D_{5/2})5s\ ^2[^5/_2]_3$	$4d^9(^2D_{5/2})5p\ ^2[^5/_2]^\circ_3$
2	224.64	1226	Ag II	4.85	10.37	$4d^9(^2D_{5/2})5s\ ^2[^5/_2]_3$	$4d^9(^2D_{5/2})5p\ ^2[^7/_2]^\circ_4$
3	227.99	582	Ag II	5.70	11.05	$4d^9(^2D_{3/2})5s\ ^2[^3/_2]_2$	$4d^9(^2D_{3/2})5p\ ^2[^5/_2]^\circ_3$
4	232.02	1514	Ag II	5.05	10.36	$4d^9(^2D_{5/2})\ 5s^2[^5/_2]_2$	$4d^9(^2D_{5/2})\ 5p\ ^2[^3/_2]^\circ_1$
5	238.62	584	Ag II	11.14	16.34	$4d^9(^2D_{3/2})5p\ ^2[3/2]^\circ_1$	$4d^9(^2D_{3/2})5d\ ^2[3/2]_2$
6	241.13	975	Ag II	5.42	10.56	$4d^9(^2D_{3/2})5s\ ^2[3/2]_1$	$4d^9(^2D_{5/2})5p\ ^2[5/2]^\circ$

							2
7	243.77	952	Ag II	4.85	9.94	$4d^9(^2D_{5/2})5s\ ^2[^5/_2]_3$	$4d^9(^2D_{5/2})$ $5p\ ^2[^3/_2]^{\circ}_2$
8	244.78	580	Ag II	5.70	10.77	$4d^9(^2D_{3/2})5s\ ^2[3/2]_2$	$4d^9(^2D_{3/2})5p\ ^2[5/2]^{\circ}$ 2
9	260.59	251	Ag II	10.18	14.94	$4d^9(^2D_{5/2})\ 5p\ ^2[^7/_2]^{\circ}_3$	$4d^9(^2D_{5/2})6s\ ^2[^5/_2]_3$
12	271.17	254	Ag II	10.37	14.94	$4d^9(^2D_{5/2})\ 5p\ ^2[^7/_2]^{\circ}_4$	$4d^9(^2D_{5/2})$ 6s 2[5/2] 3
13	276.75	150	Ag II	5.70	10.18	$4d^9(^2D_{3/2})5s\ ^2[3/2]_2$	$4d^9(^2D_{5/2})5p$ $^2[7/2]^{\circ}_3$
14	293.83	280	Ag II	10.77	14.99	$4d^9(^2D_{3/2})5p\ ^2[5/2]^{\circ}_2$	$4d_9(^2D_{5/2})6s\ ^2[5/2]_2$
15	318.77	256	He I	19.81	23.70	$1s2s\ ^3S_1$	$1s4p\ ^3P^{\circ}_2$
16	328.06	2793	Ag I	0.00	3.77	$4d^{10}5s\ ^2S_{1/2}$	$4d^{10}5p\ ^2P^{\circ}_{3/2}$
17	338.28	2589	Ag I	0.00	3.66	$4d^{10}5s^2S_{1/2}$	$4d^{10}5p^2P^{\circ}_{1/2}$
18	388.86	1129	He I	7.42	23.00	$1s2s\ ^3S_1$	$1s3p\ ^3P^{\circ}_1$
19	405.54	356	Ag I	3.66	6.72	$4d^{10}5p\ ^2P^{\circ}_{1/2}$	$4d^{10}6d\ ^2D_{3/2}$
20	421.09	417	Ag I	3.77	6.72	$4d^{10}5p\ ^2P^{\circ}_{3/2}$	$4d^{10}6d\ ^2D_{5/2}$
21	447.14	905	He I	20.96	23.73	$1s2p\ ^3P^{\circ}_1$	$1s4d\ ^3D_2$
22	487.41	465	Ag I	7.30	9.84	$4d^95s(^3D)5p\ ^4F^{\circ}_{9/2}$	$4d^95s(3D)6s\ ^4D_{7/2}$
23	490.24	508	S II	15.55	18.08	$3s^23p^2\ (^3P)4p\ ^2S^{\circ}_{1/2}$	$3s3p^4\ ^2P_{1/2}$
24	501.56	673	He I	20.61	23.08	$1s2s\ ^1S_0$	$1s3p\ ^1P^{\circ}_1$
25	520.90	2482	Ag I	3.66	6.04	$4d^{10}5p\ ^2P^{\circ}_{1/2}$	$4d^{10}5d\ ^2D_{3/2}$
26	546.54	3888	Ag I	3.77	6.04	$4d^{10}5p\ ^2P^{\circ}_{3/2}$	$4d^{10}5d\ ^2D_{5/2}$
27	587.59	11174	He I	20.96	23.07	$1s2p\ ^3P^{\circ}_2$	$1s3d\ ^3D_2$
28	657.07 - 328.06 (2)	5157	Ag I	0.00	3.77	$4d^{10}5s\ ^2S_{1/2}$	$4d^{10}5p\ ^2P^{\circ}_{3/2}$
29	667.81	2663	He I	21.21	23.07	$1s2p\ ^1P^{\circ}_1$	$1s3d\ ^1D_2$
30	679.2 - 338.28(2)	2253	Ag I	0.00	3.66	$4d^{10}5s$ $^2S_{1/2}$	$4d^{10}5p\ ^2P^{\circ}_{1/2}$
31	706.51	1498	He I	20.96	22.71	$1s2p\ ^3P^{\circ}_2$	$1s3s\ ^3S_1$
32	777.19	1669	O I	9.14	10.74	$3s\ ^5S^0_2$	$3p\ ^5P_3$

When the quartz substrate was installed at a distance of 2-3 cm from the center of the discharge gap and the discharge burning time was 30-60 minutes, the deposition of a thin film from the products of electrode material sputtering in atmospheric pressure helium was recorded on the substrate. As can be seen from this photo, the surface of the synthesized thin film is quite homogeneous. Against the background of a homogeneous surface, one can see some surface microstructures with characteristic dimensions of 10-20 μm (in the photo they are dark gray in color and ellipsoidal in shape).

Figs. 2-4 show the Raman spectra of a thin film synthesized from the products of the OND between silver sulfide electrodes at atmospheric helium pressure using laser radiation at wavelengths λ = 785 nm, λ = 532 nm and λ = 633 nm, respectively. The use of different wavelengths of laser radiation provides additional information about the properties of Ag_2S nanoparticles, since the intensity and position of the bands in the Raman spectra depend on the wavelength of the excitation radiation. The wavelength affects the depth of radiation penetration into the sample and the efficiency of the induced vibrations in the crystals. This can lead to differences in the intensity and position of the spectral bands of the scattered light.

The identification of Raman spectra was carried out using [6].

When studying the samples using laser radiation at λ = 785 nm, the spectra in Fig. 2 ((a), (b), (c)) are characterized by bands in the range of 100-300 cm^{-1}, in particular at 228 cm^{-1} (Fig. 2 (a)), 235 cm^{-1} (Fig. 2 (c)), laser at λ = 532 nm spectrum in Fig. 4 (a), (characterized by bands in the range of 100-300 cm^{-1}, in particular at 242 cm^{-1} (Fig. 3 (a)), laser at λ = 633 nm spectra are characterized by bands in the range of 100-300 cm^{-1}, in particular at 238 cm^{-1} (Fig. 4 (a)), 242 cm^{-1} (Fig. 4 (b)). The broad bands in the range of 210-250 cm^{-1}, in particular, the above maxima in this range, which are caused by Ag_2S nanoparticles, are associated with symmetrical longitudinal vibrational modes of Ag-S-Ag bonds. The bands with a maximum of 604 cm^{-1} (595 cm^{-1} (Fig. 3(a), 602 cm^{-1} (Fig. 4(b)) can be attributed to O-S-O bonds (asymmetric bending). The bands with a maximum of 960 cm^{-1} (Fig. 3(c)), 957 cm^{-1} (Fig. 4(a)-Fig. 4(b)) are related to the symmetric stretching of S-O bonds. In Fig. 3 (b), Fig. 4 (b), broad bands in the range of 1460-1600 cm^{-1} are associated with vibrations of silver and sulfur oxide compounds formed during the photoinduced decomposition of Ag_2S.

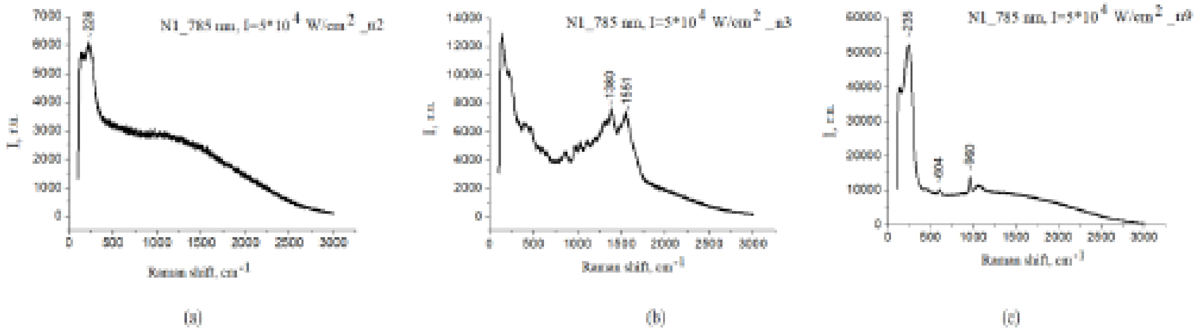

Figure 2 Raman scattering spectra of light by a thin film deposited from the OND plasma at atmospheric helium pressure obtained using laser radiation at λ = 785 nm ((a), (b), (c)).

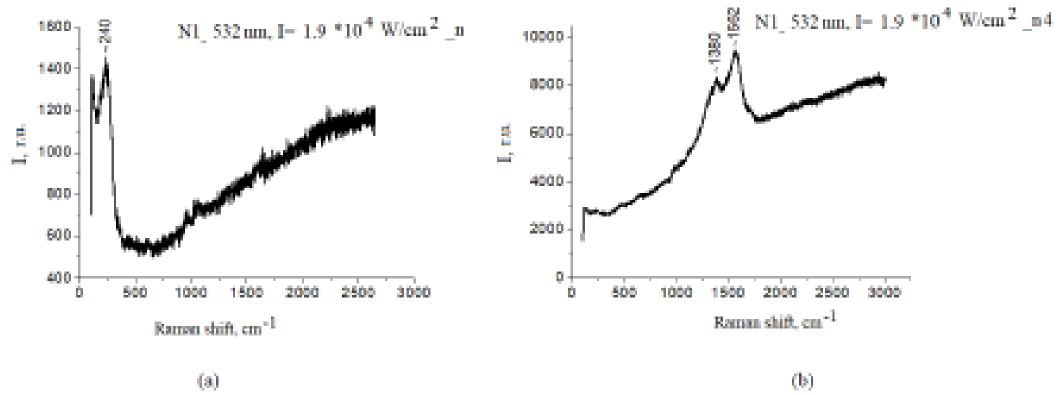

Figure 3 Raman spectra of light scattering by a thin film deposited from the plasma of the OND at atmospheric pressure of helium, obtained using laser radiation at λ = 532 nm ((a,b)).

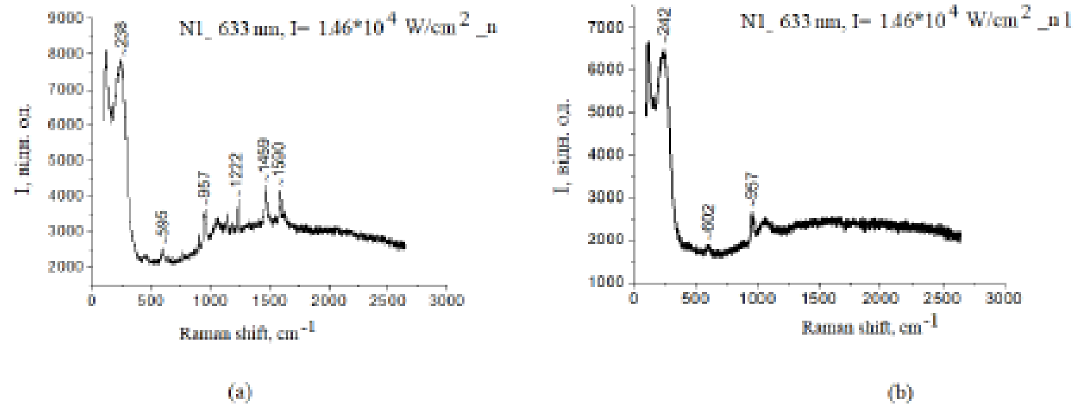

Figure 4 Raman spectra of light scattering by a thin film deposited from the OND plasma at atmospheric helium pressure obtained using laser radiation at λ = 633 nm ((a)-(b)).

Thus, the results showed that the Raman spectra reflect the characteristic features of Ag_2S films and their oxides. In particular, bands corresponding to chemical bonds in the composition of Ag_2S compounds were observed. This indicates the successful synthesis and formation of films with the desired properties.

[1] Zhubo Liu, Rogachev A.A., Yarmolenko M.A., Jang H.N., Rogachev A.V., Gorbachev D.L., Influence of assisting radiation during electron beam dispersion on the molecular structure of formed polyethylene-silver nanocomposite coatings, Problems of Physics, Mathematics and Technology, vol.14, pp. 13 – 37 (2013).
[2] Sadovnikov, S.I., Rempel', A.A. & Gusev, A.I., Ag_2S/Ag heteronanostructure, Jetp Lett., vol. 106, pp. 587–592 (2017).
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