Article has been reported and discussed at 17th International Conference on Advanced Laser Technologies, ALT09,
26 September – 01 October 2009, Antalya/Turkey.

GROWTH FEATURES AND STRUCTURE OF THE EPITAXIAL FILMS OF GaSe, InSe COMPOUNDS IN CORRELATION WITH PHYSICAL PROPERTIES

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Research of growth features and structure of the epitaxial films of GaSe, InSe compounds have been carried out in correlation with their physical properties. The films were obtained by the molecular beam condensation method on various substrates. Optimum conditions of reception amorphous, polycrystalline, oriented and epitaxial films of the specified compounds have been determined. Correlation between structural perfection and electrophysical parameters for received epitaxial films has been established. It is shown that depending on temperature of a source and a substrate it is possible to receive a film with various crystal structure and electrophysical parameters.

Layered GaSe, InSe semiconductors widely attract attention of researchers. Numerous works [1-10] are devoted to research of physical properties of these compounds. Interest to studying physical properties of the specified layered semiconductors is caused by features of their crystal structure.

The elementary cell contains two and more number of identical layers with various atoms in them. Inside the layers bonds between atoms is carried through the forces of ionic-covalent character, at the same time bond between the next layers – by the Van-der-Vaals forces. It is necessary to note that physical properties of A^3B^6 compounds since 1960 were investigated in the Institute of Physics of the Azerbaijan NAS together with a number of other research centers. In 1963 in GaSe compound induced radiation is revealed and in 1972 effective nonlinear optical properties, effects of switching and memory, etc. have been revealed. It is of big interest the found out by authors of the work [9] quantum oscillations in gallium selenide and results on exciton dynamics. Effective nonlinear optical properties of the селенида gallium selenide have been found out [2]. In [10] attempt of generalization of a material available in the literature devoted to researches of the dynamic and static nonlinear effects observed at interaction of coherent radiation with layered crystals of gallium selenide type was carried out.

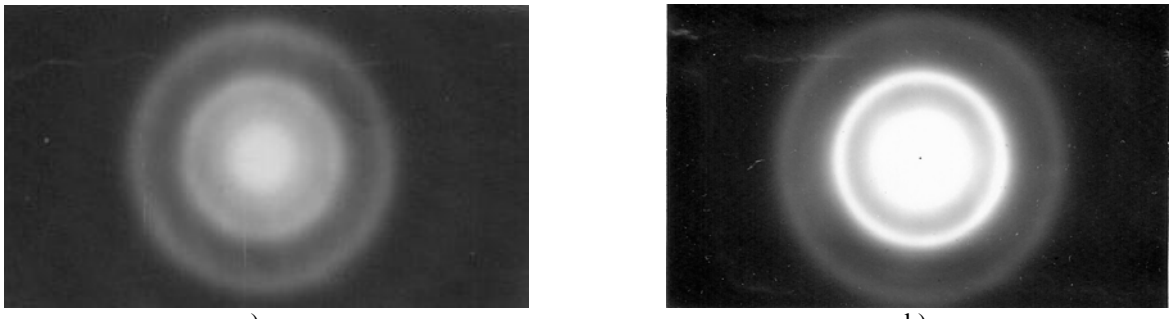
These researches were carried out on massive single crystals of the specified compounds. For modern electronics more perspective are their epitaxial films. In this connection, in the given work research of features of growth and structure of epitaxial films of GaSe, InSe compounds received on various substrates are carried out in correlations with their physical properties.

The structure of the films were controlled by the electron-diffraction method. Samples for electron-diffraction researches in thin film type were prepared in vacuum 10^{-4} Pa by the molecular beam condensation method from beforehand synthesized GaSe, InSe alloys.

Evaporator source was Knudsen cell, the cylinder made of especially pure graphite with two fuses heated by a current and with an aperture in the center in diameter of 0.1 mm. The temperature of the evaporator and a substrate was controlled using chromel-copel thermocouples. As substrates celluloid films and fresh chips of BaF_2 single crystals, as well as mica were used

Samples for research of physical properties have been received by use of a special mask during the growth process, made of stainless steel.

Electron-diffraction researches have shown that condensation of GaSe, InSe on the celluloid substrates which are taking place at room temperature was invariable accompanied by formation their amorphous пленок (Fig. 1, a, b).



a) b)

Fig. 1. Electron-diffraction pattern of the amorphous films: a) GaSe, b) InSe.

To avoid oriented influence of single crystal substrates BaF_2 substrates and mica, as well as possible reflection of molecules from their hot surface during sublimation, the special condition was created and substrates was supported at room temperature. By this way on the specified single crystalline substrates also possible to prepare above-stated amorphous films of the researched compounds.

Annealing of the received films within 1 hour at t≈200°C has not changed a pattern, they remained amorphous. This result is in the consent with the data [11].

It is established by as that amorphous GaSe phase in conformity with [11] extremely stable at room temperature. By the authors of work [12] the structure of this phase is determined and it was shown that in the first coordination spheres at amorphous GaSe there is no conformity with a lattice of the crystal phase. At the same time their physical properties, i.e. conductivity, energy of activation, thermo-e.m.f. and others are characteristic for crystal substances.

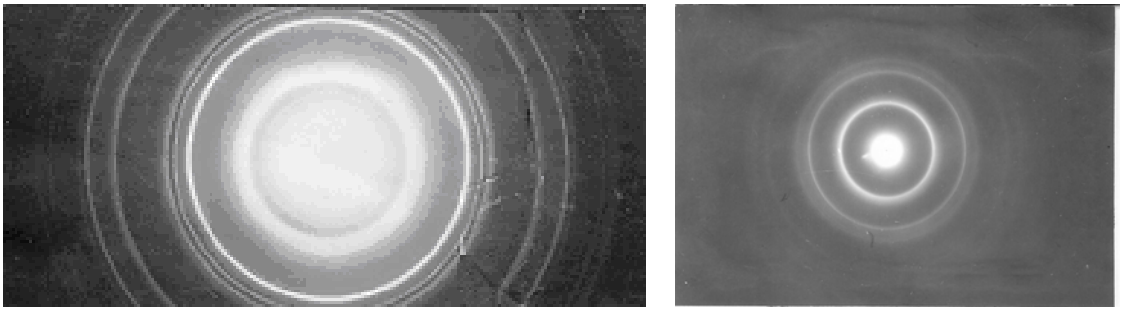
Thin films of GaSe, InSe compounds, received on BaF_2 single crystalline substrates and mica taking place at ≥200°C have polycrystalline structure. On fig. 2, a, b electron-diffraction pattern of the films received on BaF_2single crystalline substrates are presented. The received films crystallize in hexagonal lattice with parameters:

a=3,74 Å; c=15,89 Å for GaSe in conformity [11],
a=4,04 Å; c=16,90 Å for InSe in conformity [13].

Calculation of the presented electron-diffraction pattern shows that small crystals of these compounds on the specified substrates grow by (001) plane and partial off-orientation of small crystals is observed, therefore only lines with hk0 indexes appear on electron-diffraction patterns.

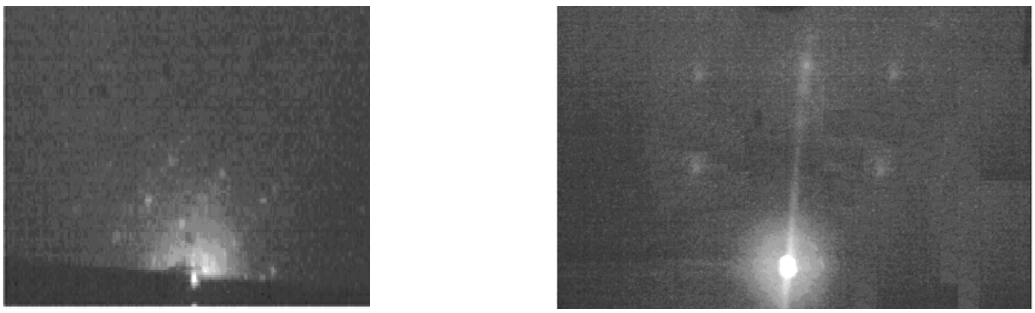
It is shown that at annealing temperatures higher ≥300°C with enough fair speed a crystallization of amorphous films of the above-stated compounds occurs. Thus depending on annealing temperature for the films, more or less fast transformation of an amorphous phase into an oriented crystal phase is observed in them.

Rise in temperature of substrates to ≥ 350°C results in growth of epitaxial films of the specified compounds (Fig. 3, a, b). On this electron-diffraction patterns as against above-stated ones, vertically located reflexes with hexagonal the symmetry are observed, testifying reception of structurally perfect epitaxial films of the specified compounds.



a) b)

Fig. 2. Electron-diffraction pattern of the polycrystalline films: a) GaSe, b) InSe.



a) b)

Fig. 3. Electron-diffraction pattern of the epitaxial films: a) GaSe, b) InSe.

Structurally perfect epitaxial GaSe film are received at temperatures of source T_{source} = 950÷980°C and substrates $T_{substrate}$ = 350÷380°C; InSe at T_{source} = 980÷1100°C and $T_{substrate}$ = 200÷300°C. It is shown that with increase of condensation speed and substrate temperature, thickness of the epitaxial layer grows and perfection of the film structure improves.

It is necessary to note that the samples received in such a way differed from each other by the color: the some samples had a brown shade, and the some samples - grey -steel shine. Samples with a brown shade give diffuse electron-diffraction patterns. Electron-diffraction patterns for samples of grey-steel color have shown presence of the oriented layer. Such distinction of samples is connected, probably, with non-uniform evaporation of the initial material, resulting in other arrangement of packages in this structure.

Thus, optimum conditions of reception of the epitaxial films with high crystal perfection are determined, and it is shown that depending on temperature of the source and the substrate it is possible to receive films of GaSe and InSe compounds with various crystal structure.

From Hall measurements for received epitaxial films values of electrophysical parameters have been calculated.

The calculated values of these parameters: at T=77 K for InSe films $n=(1\div1,2)\cdot10^{12}$ cm^{-3}, $\mu=(4,6\div4,7)\cdot10^{2}$ $cm^2V^{-1}s^{-1}$ and for GaSe films $p=(0,9\div1,0)\cdot10^{12}$ cm^{-3}, $\mu=(5\div6)\cdot10^{2}$ $cm^2V^{-1}s^{-1}$, are in a good agreement with the literary data.

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