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Preparation of YbSe Films and Electrophysical Properties

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Abstract. For the first time was developed technology preparation of polycrystalline yterbium monooselenide films by discrete vacuum-thermal evaporation of pre-synthesized bulk material, which is synthesized by direct synthesis of composite components in a sealed quartz ampoule. Films have been grown on substrates prepared from monocrystalline silicon, sapphire, glass-ceramic and melted quartz, substrates had the shape of a rectangular parallelepiped with dimensions 15x8x1 mm. Experiments have shown that the used substrate materials does not influence the phase composition and crystallinity of the prepared films. Optimum substrate temperature is equal to 830-950 K, and spraying rate is - 50-75 Å/s, The films have NaCl type cubic structure with lattice parameters a=5,81 Å. The distribution of the components is the same both on the surface and on the volume of the films and is equal to 49,05 at% Yb and 50,95 at% Se. In the temperature range of 90-300 K, the specific electrical resistance, Hall constant and thermoelectric force were measured. Measurements showed that all films have an electron conductivity type, the concentration of electrons at room temperature is 2.2×10^{27} m^{-3}, specific electrical resistance 1.8×10^{-2} Ω.m, mobility of electrons – 1.6×10^{-7} $m^2/(V.s)$, absolute value of thermoelectric power - 1.2×10^{-6} V/K.

Keywords: Concentration; Film; Hall coefficient; mobility; Specific electrical resistance; Thermoelectric power.

Introduction

The development of such branches of science and technology as electronics, tele mechanics, production of semiconductors, phosphors and others, implies the use of several materials that have been little studied so far. These include rare earth element (REE) selenides, especially films of these compounds. As is known, the physical properties of films often differ from the properties of bulk materials, therefore, the development of film preparation technology and the study of their physical properties often allows for a better understanding of the physical processes occurring in the corresponding materials.

There is very few work in the scientific literature on the technology and physical properties of rare earth selenide films [1-3]. The purpose of this work was to develop a technology for preparing crystals films of ytterbium monoselenide, their X-ray and electron diffraction studies and microprobe X-ray analysis, as well as measurement of the temperature dependences of electrical resistivity, Hall coefficient and thermo electromotive force.

Main Part

YbSe films with a thickness of 0.5-2.0 μm were prepared by discrete vacuum-thermal evaporation of pre-synthesized bulk crystals of YbSe composition. Bulk crystals synthesis from components in sealed quartz ampoules [4]. The starting materials were Yb grade YbM with a purity of 99.9 at% and Se grade SeT-0 with a purity of 99.99%.

As is known, for the preparation of films of stoichiometric composition by discrete vacuum-thermal evaporation, the grain size of the evaporated powder is of great importance. Numerous experiments have shown that the optimal grain diameter of YbSe powder is 0.10-0.35 mm, when the diameter of the powder is less than 0.10 mm, the material does not have time to evaporate, large losses of material are observed, and when the diameter is more than 0.35 mm, the film is two-phase. During the film preparation process, the vacuum in the working chamber was ~10^{-6} Pa; the YbSe evaporator temperature was ~1400 K. The distance from the material evaporator to the substrate was 60 mm to the substrate and the spray speed was in the range of ~50-75 Å/s, in different spraying series, the temperature of the substrate varied from 700 K to 1000 K with an accuracy of 3 K. The films were deposited on substrates shaped like a rectangular parallelepiped with dimensions of 15x8x1 mm. The substrate materials were fused quartz, glass-ceramic, sapphire and monocrystalline silicon with (111) plane orientation. Before spraying, the substrates underwent thorough chemical treatment, first in a 20% NaOH solution and then in a mixture of 30%HCl+60%HNO_3+10%H_2O, after which they were washed with distilled water, transferred to a vacuum chamber, annealed at a temperature of 800-1200 K for 45- 40 min in a vacuum of 10^{-6} Pa, All films deposited on substrates treated by the described method were characterized by high adhesion. The phase composition and crystalline of the prepared films were studied by X-ray diffraction and electron diffraction methods. Diffraction patterns were recorded on a DRON-2 installation using CuKα radiation with a nickel filter in continuous recording mode, and electron diffraction patterns were recorded on a UEMV-100K "reflection" installation at an accelerating voltage (75-100)x10^3V. The surface of the prepared films was studied in secondary X-rays on a Camebax-Microbeam installation. The composition of the films was determined using X-ray microprobe analysis on the same installation using a PLP-11/73 computer, as well as by Auger spectrometry on a LAS-200 installation from Riber.

In the temperature range of 90-300 K, the temperature dependences of electrical resistivity, Hall constant and thermo-electromotive force were measured. All measurements were carried out on the same films deposited on sapphire substrates with a thickness of 1.3 μm. All films deposited on substrates treated by the described method were characterized by high adhesion.

Specific electrical resistivity was measured by the compensation method, the Hall constant at a constant magnetic field of 16 A/m, and the thermo electromotive force, corrected for the electromotive force of copper. The accuracy of measuring electrical resistivity and thermo-electromotive force was about 5%, and the Hall constant was 9-10%.

Results and discussion

To study the influence of the material and substrate temperature on the crystallinity and phase composition of the prepared films, we tested in which the temperature substrates varied within the range of 700-1000 K, and substrates were monocrystalline silicon with an orientation of the sputtering plane (111), sapphire, glass-ceramic and fused quartz. Experience has shown that the substrate material does not affect the phase composition and crystallinity of the films, and the optimal substrate temperature is 830-950 K below and above this temperature the film is not single-phase - its composition does not correspond to YbSe.

According to X-ray and electron diffraction analysis, it can be concluded that all films have a cubic lattice of the NaCl type with a lattice parameter of 5.81 Å, which coincides well with the volume crystal parameter [5]. According to X-ray microanalysis, the films contain 49.05 at% Yb and 50.95 at% Se. The auger electron spectrum analysis showed that components of films distributed evenly over both surface and film depth.

In figures 5, 6 and 7 were shown the temperature dependences of the specific electrical resistivity, Hall coefficient, and thermo electromotive force in the temperature range from 90 to 300 K. As can be seen from the figures presented in the entire temperature measurement area, the Hall coefficient and thermo-electromotive force have a negative sign, which indicates that the charge carriers are electrons.

As can be seen from the Fig.6 with an increase in temperature the absolute Hall factor decreases non-linearly from $2.9x10^{-9}$ to $3.8x10^{-9}$ m^3/C and the thermo electromotive force also decreases but more slowly from $1.3x10^{-6}$ to $1.8x10^{-6}$ V/K. In Fig.8, the temperature dependence of specific electrical resistivity, it is shown that with increasing temperature, the resistivity increases linearly slightly from $1.5x10^{-2}$ Ω.m to $1,8x10^{-2}$ Ω.m. Based on the measurements taken, the tempera-ture dependencies of electron concentration (Fig.8) and mobility (Fig.9) were calculated. As can be seen from the graphs with increasing temperature, the electron concentration increases from $1.6x10^{27}$ to 2.2 $x10^{27}$ m^{-3} and mobility decreases from $2,5x10^2$ $m^{-7}/(V.s)$ to $1,6x10^{-7}$ $m^2/(V.s)$.

Main electrophysical parameters of YbSe films at room temperature, the preparation technology of which was developed in this work.

Specific electrical resistance $\rho, 10^{-2}$, Ω.m	Hall Constant R, 10^{-9}, m^3/C	Thermo- electromotive force $\alpha, 10^{-6}$, V/K	Concentration of electrons n, 10^{27}, m^{-3}	Electron mobility $\mu, 10^{-7}$, $m^2/(V.s)$
1.8	-2.9	-1.3	2.2	1.6

Conclusion

For the first time, technology has been developed for preparing thin polycrystalline films of ytterbium monoselenide by discrete vacuum-thermal evaporation of pre-synthesized bulk material. Silicon, glass-ceramic, sapphire and fused quartz are used as substrates. Experiments showed that the substrate material had no effect on the phase composition and the crystal quality of the prepared films. The optimum substrate temperature is 830-950 K. All prepared films have a cubic crystal structure of the NaCl type with a lattice parameter of 5.81 Å, which is in good agreement with the lattice parameter of the bulk crystal. Studies have shown that, in the prepared films the components are distributed uniformly over both the surface of the films and in thickness. In the temperature range of 90-300 K, the main electro-physical parameters were measured: specific electrical resistance, Hall constant, thermo electromotive force. It was shown that all films have electron conduction.

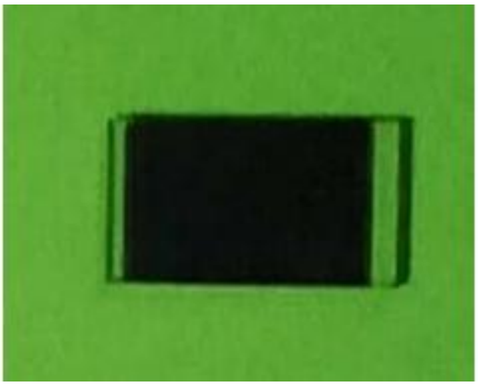

Fig.1. Foto of a YbSe film on saphire subbstrate

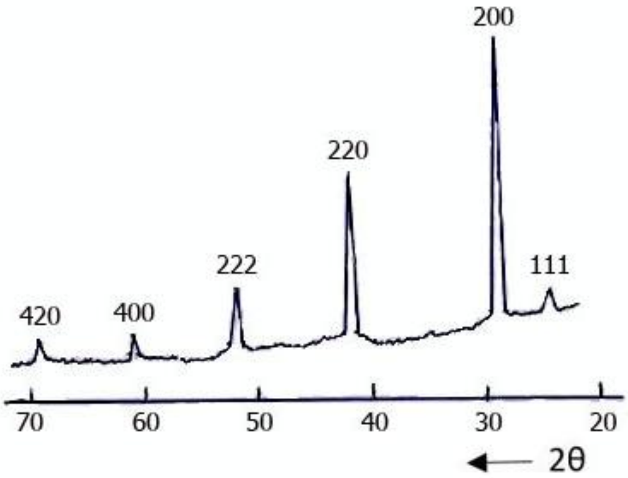

Fig.2. Roentgenogram of a YbSe film

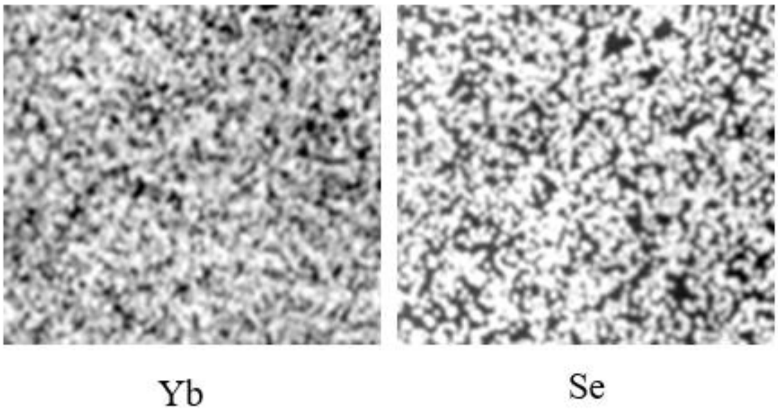

Fig.3. Distribution of components on the surface of YbSe film

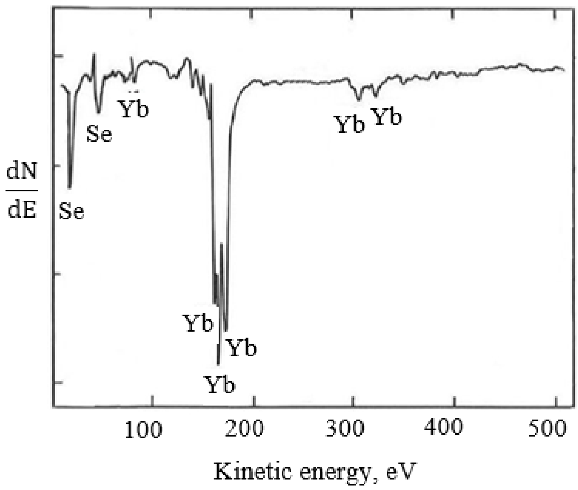

Fig.4. Auger electron spectrum of a YbSe film

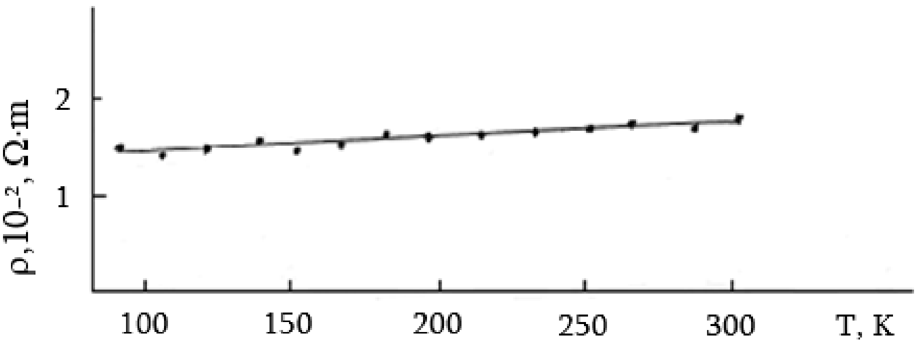

Fig.5. Temperature dependence of resistivity of YbSe film

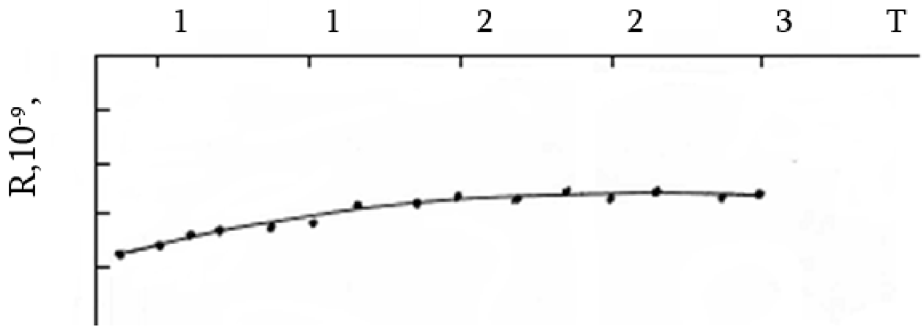

Fig.6. Temperature dependence of the Hall coefficient a YbSe film

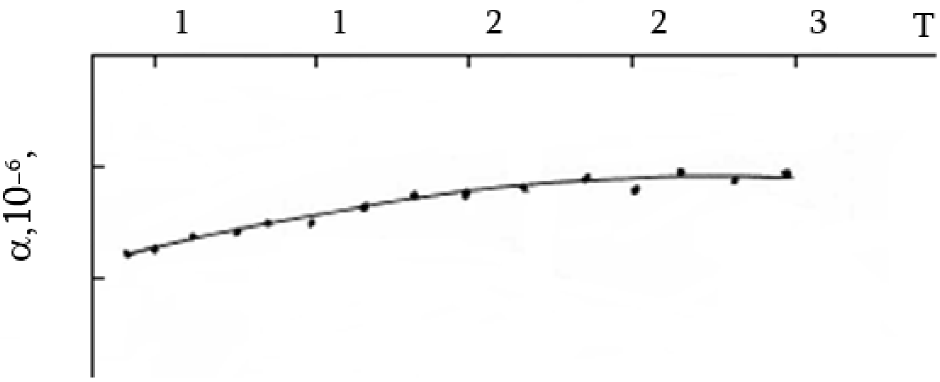

Fig.7. Temperature dependence of electromotive force of YbSe film

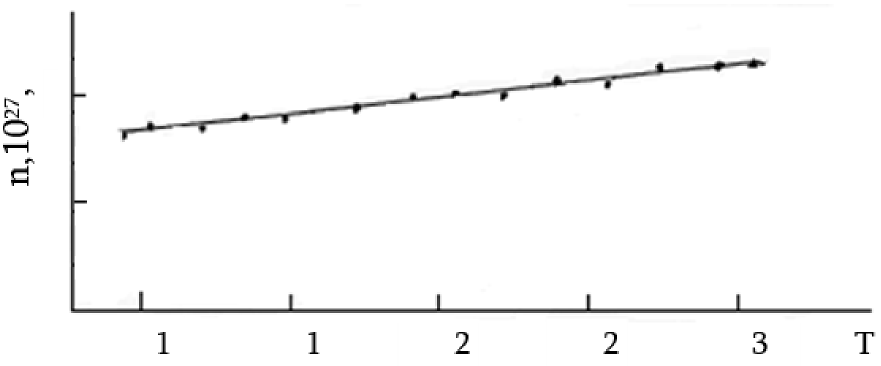

Fig.8. Temperature dependence of concentration of YbSe film

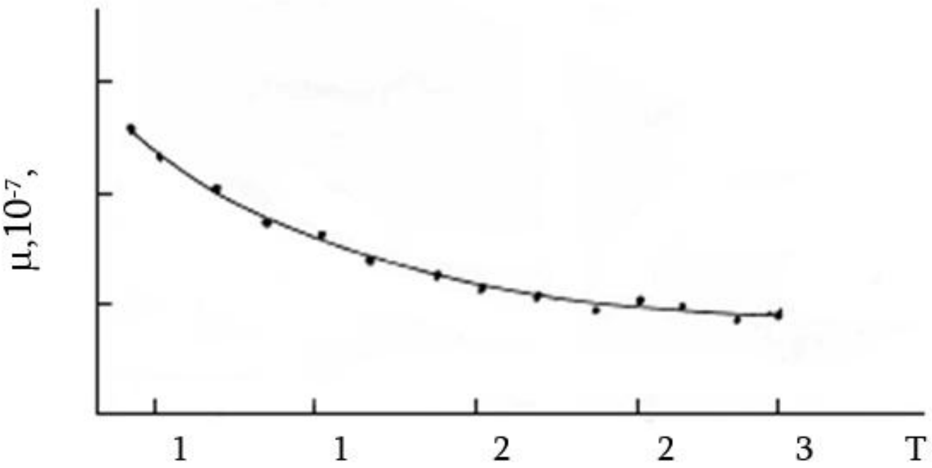

Fig.9. Temperature dependence of electron mobility of YbSe film

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ანოტაცია. იტერბიუმის მონოსელენიდის პოლიკრისტალური ფირების მომზადების ტექნოლოგია პირველად დამუშავდა წინასწარ სინთეზირებული მოცულობითი კრისტალების დისკრეტული ვაკუუმურ-თერმული აორთქლების მეთოდით, რომელიც შემადგენელი კომპონენტების პირდაპირი სინთეზით მიიღეს კვარცის დარჩილულ ამპულაში. ფირები მოამზადეს 15x8x1მმ ზომის მართკუთხა პარალელეპიპედის ფორმის მქონე მონოკრისტალური სილიციუმის, საფირონის, სიტალისა და კვარცის ფუძეშრეებზე. ცდებმა აჩვენა, რომ ფუძეშრის მასალა ზეგავლენას არ ახდენს დაფენილი ფირების ფაზურ შედგენილობასა და კრისტალურობაზე. ფუძეშრის ოპტიმალური ტემპერატურა 830-950 K ტოლია, დაფენის სიჩქარე კი – 50-75 Å/წმ. მომზდებულ ფირებს აქვს NaCl ტიპის კრისტალური მესერი a=5,81 Å პარამეტრით. კომპონენტების განაწილება ერთნაირია როგორც ფირის ზედაპირზე, ისე სიღრმის მიხედვით და 49,05 ატ.% Yb და 50,95 ატ.% Se შეადგენს. 90–300 K ტემპერატურის შუალედში გაზომეს ფირების კუთრი ელექტროწინაღობა, ჰოლის მუდმივა და თერმოელექტრომამოძრავებელი ძალა (თემძ). გაზომვებმა აჩვენა, რომ ყველა მომზადებულ ფირი ელექტრონული გამტარია. ოთახის ტემპერატურაზე ელექტრონების კონცენტრაცია ტოლია $2.2x10^{27}$მ$^{-3}$, კუთრი ელექტროწინაღობა – $1.8x10^{-2}$ ომი.მ, ელექტრონების ძვრადობა – $1.6x10^{-7}$ მ^2/(ვ.წმ), ხოლო თერმული ემ ძალის აბსოლუტური მნიშვნელობა – $1.2x10^{-6}$ ვ/K.

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