Preparation and relative mechanical strength of erbium monoselenide films

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For the first time the technology of preparation of thin crystalline films of ErSe has been developed, by vacuum–thermal evaporation from two independent sources of the components and from presynthesized bulk ErSe. The relative mechanical strength of the prepared films was evaluated by complete attrition. It was shown that this strength of films depends on the method of preparation. Films prepared by bulk evaporation have 30–35% higher mechanical strength than films prepared by evaporation from two independent sources. This may be due to the crystalline structure of the films prepared by bulk evaporation being more perfect.

Compounds of rare-earth elements with elements of the sixth group of the periodic table have interesting electrophysical, optical and other properties,[1,2] but their mechanical properties have not been studied. Recently, great attention has been drawn to the mechanical properties of films, since films with interesting electrical properties often exhibit low mechanical strength, which limits their practical application. The aim of the present work was to develop a technology for preparing thin crystalline ErSe films on different substrates by vacuum–thermal evaporation, either from two independent sources of erbium and selenium, or by bulk evaporation from presynthesized ErSe, and to evaluate the relative mechanical strength of these films using the method of complete attrition.

ErSe films were deposited on parallelepiped polycrystalline glass–ceramic substrates with dimensions $8 \times 15 \times 1$ mm. Before the preparation of the films, the substrates were chemically cleaned in a mixture of nitric and hydrochloric acid and then washed with distilled water and heated in a vacuum at 650 K for 30 min. Experiment showed that films with good adhesion were formed on substrates treated in this way.

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1 Gasgnier, M. Rare earth compounds (oxides, sulfides, silicides, borides,..) as thin films and crystals. *Phys. Status Solidi A* **114** (1989) 11–71.

2 Verna, A.S. Electronic and optical properties of rare earth chalcogenides and pnictides.African Phys. Rev. **3** (2009) 11–29.

Nanotechnology Perceptions **15** (2019) 257–259
Received 7 October 2019; *accepted* 30 November 2019
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doi: 10.4024/N28JA19L.ntp.15.03

For the preparation of films by evaporation from two independent sources, the evaporation of Er and Se was carried out respectively at temperatures of 1250 and 645 K; the distances between evaporators and substrate were 50 and 35 mm. The angles between the evaporator axes and the substrate normal were 25° (Er) and 40° (Se). The rate of deposition was 35~45 Å/s and the substrate temperature was 650 K. The final thickness of the films was 1.5–1.9 μm. The source of Er was metal (designated ErM-1) in which the total content of Dy, Ho, Tm and Y was 0.1%; the source material also contained Fe (0.01%), Ca (0.01%), Cu (0.03%) and Ta or Mo (0.02)%. The source of Se had a high purity of ≤ 99.999 atom%.

According to our X-ray and electron diffraction studies the films have a NaCl-type structure with lattice constant $a = 5.62 \pm 0.05$ Å, which agrees well with the literature data for bulk ErSe crystals $a = 6.661$ Å.[3]

ErSe films were also obtained by evaporation of presynthesized bulk material. The temperature of the evaporator was 2700 K and substrate temperature was 570 K. As in the first method the substrate was glass-ceramic. Deposition rate was 40~50 Å/s and final film thickness was 1.6–2.0 μm. Analysis of the X-ray diffractograms and electron diffraction patterns showed that all films had the structure of NaCl with lattice parameter $a = 5.66 \pm 0.05$ Å, which is the same within experimental uncertainty as that of the films obtained by evaporation of two independent source components.

We investigated the relative mechanical strengths of the prepared films by complete attrition. The essence of this method lies in the fact that the mechanical strength of the film and the degree of its adhesion to the substrate can be estimated from the work that must be done in order to completely remove the film from the substrate. The device for measuring this work is shown in Fig. 1. It is similar to the one described in ref. 4.

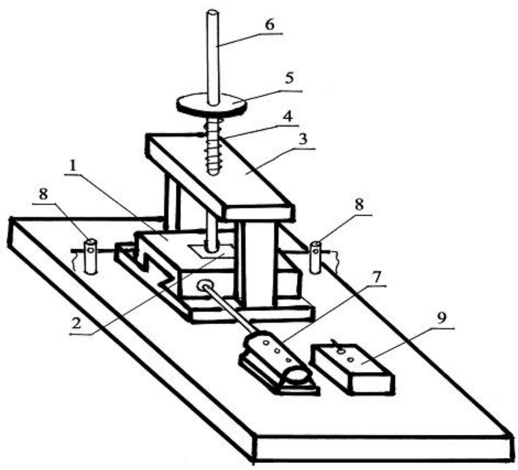

Figure 1. Schematic drawing of the device for measuring thin film relative mechanical strength. The test film (2) is attached to a massive plate (1). To a rod (6) supported from above is attached a piece of suede, which is covered with diamond paste, and placed on the film. The load on the rod is adjusted by different weights placed on the disk (5). The film is made to move forward and backward with a special mechanism (7, 8) and the number of passes needed to completely remove the film is counted.

[3] Iarembash, E.I. and Eliseev, A.A. *Chalcogenides of Rare Earth Elements*. Moscow: Nauka (1975) (in Russian).

[4] Sinelnikov, K.D. and Shkliarevski, N.N. Dependence of mechanical strength of aluminum coverings on glass substrate temperature. *Trans Phys. Office Phys. Math. Faculty Kharkiv State Univ.* **2** (1950) 9–15 (in Russian).

To maximize reliability of the results, the measurements were carried out on films of the same thickness (1.1 μm) and under identical load (400 g). Results are given on Table 1. It shows that the relative mechanical strength of the films prepared from the presynthesized bulk material is almost 35% greater than the strength of the films prepared from the two independent sources.

Table 1. Relative mechanical strengths of ErSe films prepared by different techniques on a glass-ceramic substrate.

Method of film preparation	Film thickness / μm	Load / g	Number of passes for complete removal
Evaporation from two independent sources	1.1	400	62–67
Evaporation of presynthesized compound	1.1	400	112–120

This difference could be due to the fact that the crystal lattice of films prepared by bulk evaporation was more perfect than that of films prepared by evaporation from two independent sources. The results obtained are in concordance with some data for $PrSb_2$.[5]

[5] Jabua, Z., Kupreishvili, I., Gigineisvili, A., Iluridze, G. and Minashvili, T. The relactive mechanical strength of praseodymium diantimonide thim films. *Proc. Intl Sci. Conf. 90th Anniv. Georgian Technical University: Basic Paradigms in Science and Technology Development for the 21st Century*. Tbilisi, 19–21 September 2012, pp. 326–330.