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The edition is designed for scientists, engineers, higher school lecturers, post-graduates and students of corresponding specialities.

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INVESTIGATION CRYSTALLIZATION KINETICS OF Ge-As-TE AND As-S (Sb) -I SYSTEM FILMS USING OPTICAL METHOD

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Investigation of isothermal and nonisothermal crystallization of thin films based on glasses of chalcogenide systems is relevant both in terms of studying the physics of processes occurring on nanostructural and submicrostructural levels, and in connection with the possibility of practical application of these materials as recording material, photosensitive films, temperature sensors.

Alloys of Ge-As-Te ware obtained by using hard hardening of melt. The films obtained by the method of discrete thermal evaporation in a vacuum (10 ~ 5 mm Hg). Condensation was carried out on a non-heated glass substrate. The rate of condensation was within 3-10 A / s. In order to study the influence of structural transformations on the recording processes, the films studied were obtained from glasses having a different crystallization ability, which depends on the composition.

The amorphous condensates of the Ge-As-Te system were irradiated by radiation pulses of an infrared laser (λ = 1.06 microns), duration of 3.0 msec, under the influence of which crystallization, melting and evaporation of films could occur. The dynamics of phase transformations under impulse influence, for example, was investigated by changing the coefficient of reflection R by means of the time scanning of the intensity of the probe beam of a Hi-Ne laser, reflected from the surface of the film. A continuous probing laser beam, getting into photographic recording devices, generates a signal that is recorded by a memory oscilloscope, the launch of which is synchronized with the start of the pulse of an ir-laser.

The boundary value of the energy density E, in which the change in R was recorded, is 0.4 J / cm^2. The saturation of a record characterized by a maximum value $\Delta R = 20 + 25\%$ occurs at E = 1.2 J / cm^2. The oscillogram of the change in the coefficient of reflection of the film $Ge_{13}As_5Te_{82}$ is shown in Fig. 1. In Fig. 2 shows oscillograms for $Ge_{13}As_5Te_{82}$ at different values of the energy density of the recording beam. With increasing E, the value of ΔR is changing, beginning and the steepness of the pulse front, changes the dynamics of changes in R. Curve 5 in Fig. 3 describes the time evolution of crystallization (for $t = 0{,}1 < t < 0{,}5$ ms), melting of crystallites, with some increase of R (t = 0, 55 ms) and film evaporation (t> 0,55 ms) . The oscillograms characterizing R changes with the subsequent increase in the energy density of the laser pulse are shown in Fig. 3

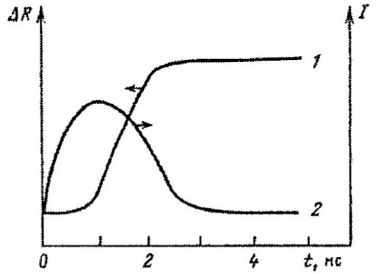

Fig. 1. The oscillogram of change in reflection coefficient ΔR (t) of a $Ge_{13}As_5Te_{82}$ film, at an irradiation energy density of E = 0.5 J / cm^2 (1) and a recording pulse shape (2)

According to the conditions of irradiation, the optical and thermophysical properties of materials, the thermodynamic regime of such pulsed laser treatment is a heat flow regime in which the temperature fields are determined by diffusion processes and there are longitudinal and transverse temperature gradients. The minimum crystallization time for these laser treatment

conditions, determined by the duration of the pulse front ΔR (t), is 100-120 μs (see Fig. 2, Curve 5, and Fig. 3).

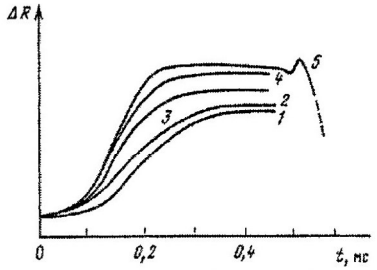

Fig. 2. Oscillograms of changes in the coefficient of reflection of $Ge_{13}As_7Te_{80}$ film at different values of E: 1 - 0.7; 2 - 0.9; 3 - 1.0; 4 - 1.5; 5 - 2.5 J / cm^2

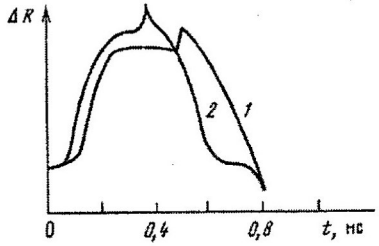

Fig. 3. The oscillograms of changes in the coefficient of reflection of $Ge_{13}As_7Te_{80}$ film at E = 3.0 (1) and 3.2 J / cm^2 (2)

A considerable number of publications are devoted to the study of phase transformations in the Ge-As-Ti system. Although the data given in the literature is somewhat contradictory, the ability of the amorphous condensates of the Ge-As-Ti system to form, depending on the external influence, is different, for both metastable and stable phases.

Thus, the complex structure of the oscillogram ΔR (t) should be expected. However, the integral contribution to the increase of ΔR of individual crystalline modifications is shown for most oscillograms only in the amplitude of the jump ΔR and the steepness of the front of the corresponding pulse (Fig. 2). This is due to the conditions of measurements in which the mode of thermal flow of laser processing is implemented: there is a superposition of crystallization processes of individual phases with close values of the crystallization temperatures. The minimum increase in ΔR is corresponding to the lower boundary value of the energy density of the recording beam, is obviously due to the crystallization of the low temperature modification of tellurium. To select the individual components of ΔR, should be use the adiabatic irradiation mode that is implemented with shorter recording impulses.

With a further increase of the power of laser radiation and achievement of a power density of more than 1.5 J / cm^2, melting is occurs (peak values of R are associated with melting material) and subsequent evaporation of the film. At the same time, for a number of oscillograms, a complicated character of both melting and evaporation of a film, which is associated with a multiphase material, was observed. One of such oscillograms, for which the two-stage character of the change of ΔR in the process of film evaporation is clearly documented, it is shown in Fig. 3 (curve 2).

It should be noted that with a laser energy density of large 1.5 J / cm^2, when the crystallization of the melt occurs, on the oscillograms before the peak increase ΔR due to the melting of crystallites, there is a reflection decrease, possibly related to scattering of probe radiation on a microscopic relief on the surface due to its local melting.

Thus, for layers of compression-containing materials of complex composition, thermal laser radiation can selectively heat certain phases, which leads to a significant change in the nature of the proceeding of nonequilibrium processes.

Comparison of the results of measurements carried out on films deposited on a substrate absorbing and non-absorbing infrared radiation confirm that the crystallization of the Ge-As-Ti layers is due to thermal heating, and the contribution of known chalcogenide glass to reversible photostructure transformations is negligible. Consequently, the multiphase environment of the type considered can be used to record the laser beam power density in time or space.

The study of isothermal and nonisothermal crystallization of thin film condensates on the basis of glasses of the As_2S_3-SbSI system by an optical method and the possibility of their use as temperature sensors. Thin films $(As_2S_3)_x$ $(SbSI)_{100-x}$ $(10 < x < 30)$ in thickness of 1-2 microns were obtained on non-heated glass substrates by the method of resistive evaporation of glass in vacuum of the corresponding compositions from quasi closed ejection cells. In the study of processes of isothermal crystallization of films, the change in their optical passage from time at constant exposure temperatures, which were selected on the basis of thermographic studies of glasses, was recorded. The temperature dependences of the relative change in the transmission of films were investigated at constant heating rates q = 0.64, 1.28 and 2.56 K / s. Registration of the change of transmission was carried out at a wavelength of 850 nm.

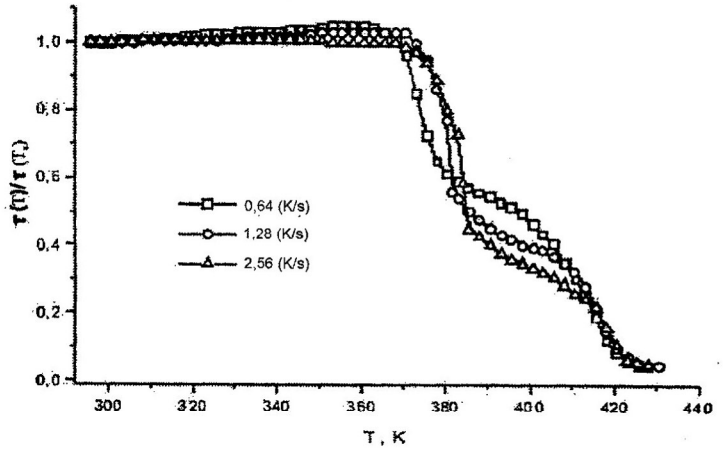

Fig.4 Dependence of the relative change in $(As_2Se_3)_{10}(SbSJ)_{90}$ film transmission from temperature

In nonisothermal crystallization, the dependence of the passage from temperature is complex (Fig. 4). Several distinct features are revealed on these dependencies, the temperature position and shape of which depend on the chemical composition of the films and the heating rate due to the transition of the amorphous film to the metastable state by the formation of crystalline nuclei and their growth. The mechanism of formation and the nature of the crystalline phase in an amorphous matrix are discussed. The stepwise nature of the change in transmission indicates the possibility of using these materials as threshold temperature sensors.

OBTAINING A SUBMICROCRYSTALLINE Zr-Ti-Nb ALLOY USING HIGH PRESSURE TORSION

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In this work, a low-modulus Zr-51% Ti-31% Nb-18% (at. %) alloy is used. The alloy was synthesized from a powder blend of TiH_2, ZrH_2 and Nb. The powder size was less than 100 μm for both hydrides and less than 63 μm for Nb. The powders were mixed for 6 hours using rotating cylinder blender. The powder blend was pressed in a cylindrical mold at 640 MPa. The obtained samples were 10 mm in diameter with a height of 10 to 15 mm. The compacts were sintered in vacuum at 1250°C for 4 hours. The vacuum level at the beginning of sintering was 10^{-3} Pa. During the sintering, chemical homogenization of the powder blend and, concurrently, the removal of hydrogen took place. The residual hydrogen content in the alloy has been determined to be less than 0.01 wt. %. During sintering the diameter of the samples decreased to ~9 mm. The cylindrical samples were cut into 1.5 mm thick discs, which were then processed using High Pressure Torsion (HPT). HPT deformation was carried out using a custom-built machine (W. Klement GmbH, Austria) operated at RT and the pressure of 5 GPa; the angular anvil velocity was 0.2 rad/sec; the number of anvil rotations was set to 10.

The phase composition, microstructure, spatial element distribution, residual porosity and microhardness were studied in cross sections of both the initial and deformed samples. X-ray diffraction (XRD) was measured in the Bragg–Brentano geometry using SIEMENS D 500 diffractometer with Cu-Kα1 radiation. The Pseudo-Voigt function was used for fitting of XRD peak profiles. Lattice parameters were determined by the PowderCell software [13] using a Rietveld-like full profile refinement. Transmission electron microscopy (TEM) observations and elemental mapping have been measured using TITAN 80–300 transmission electron microscope. The specimens for TEM investigations were cut from HPT discs at a 3 mm distance from the disc center on FEI Strata 400S dual beam facility.

In the as-sintered state (before the deformation), the alloy consists of a single bcc β-phase. The diffractogram shows the presence of several shoulders, which is an indication of a variation of the lattice parameter, caused for example by concentration inhomogeneities in the as-sintered alloy. The diffractogram of the sample after the HPT deformation shows broadening of the peaks, indicating grain refinement. The peaks are symmetrical, so we can conclude that the deformed samples are chemically homogeneous.

The grain size after sintering is of about 100 mm and the residual porosity of the material after the sintering is clearly visible. The presence of substantial residual porosity in the chemically homogeneous samples indicates that the diffusion processes leading to chemical homogenization are substantially faster than the processes leading to sintering and densification of the powders. The pores have irregular shapes, far from spherical, and relatively large sizes (up to 50-80 μm), which complicates further densification even after 4 hours at 1250°C. The residual porosity is estimated from the SEM image ~7.2%. A significant contribution to the porosity might originate from the accumulation of vacancies during the diffusion driven chemical homogenization of the sample with a significant difference of the diffusion coefficients of the participating elements Nb, Ti and Zr, leading to Kirkendall's porosity.