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Observations of fractal patterns induced on surface of chalcogenide glass

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ABSTRACT

Properties of chalcogenide glasses were studied. After heat treatment, fractal patterns were found on surfaces of $Ge_{23}Se_{67}Sb_{10}$ and $Ge_{30}Se_{60}Sb_{10}$ glasses. According to box counting method, the fractal dimensions are determined as 1.58–1.61, which are similar to that of the fractal crystal $GeSe_2$. By analysis, the main factors for the formation of the fractal patterns are the glass structure and the weak interface energy anisotropy. Comparing the fractal pattern with compact seaweed pattern in undercooled Co-Sn melt, the growth mechanism of the fractal pattern in glass is similar to that in undercooled melt, i.e. the larger undercooling leads to the weaker of the interfacial energy anisotropy, which leads to the formation of fractal structure.

1. Introduction

The aggregation processes leading to fractal structures have been extensively studied by experiments and computer simulations. Many experiments on fractal aggregation have been reported, such as electrochemical deposition [1], viscous fingering [2], sputtering deposition [3] and ion-induced fractals in thin solid films [4]. The fractal growth had also been found in many amorphous materials. By annealed in air at successively increased temperatures from 140 °C up to 220 °C, Radnoczi et al. found the fractal crystals $GeSe_2$ in amorphous layers of GeSe [5]. The $GeSe_2$ phase resembles a forest with a typical tree size on the order of 10–30 μm, and it closely resemble shapes arising in two dimensional diffusion-limited aggregation(DLA) simulation introduced by Witten and Sander[6]. Cui et al. study the growth of fractal patterns in ZnO films doped with Fe, and found that the fractal aggregates were the result of cluster diffusion-limited aggregation (CDLA) of magnetic particles on the surface of the film[7].

Chalcogenide glass has drawn a great attention due to their electrical, optical and thermal properties [8]. However, the fragile of chalcogenide glass limited its application, thus it must suffer the heat treatment. In the heat treatment sample, the fractal can be found on the surface of the glass.

In this study, the fractal aggregates in the bulk Ge-Se-Sb glass surface are reported. Then the dimensionalities of the fractal in the Ge-Se-Sb glasses are calculated and discussed.

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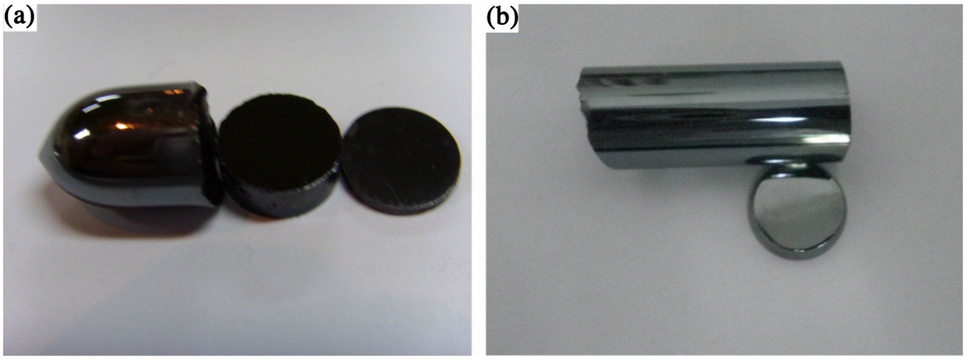

Fig. 1. As-prepared chalcogenide glasses: (a) $Ge_{23}Se_{67}Sb_{10}$, (b) $Ge_{30}Se_{60}Sb_{10}$.

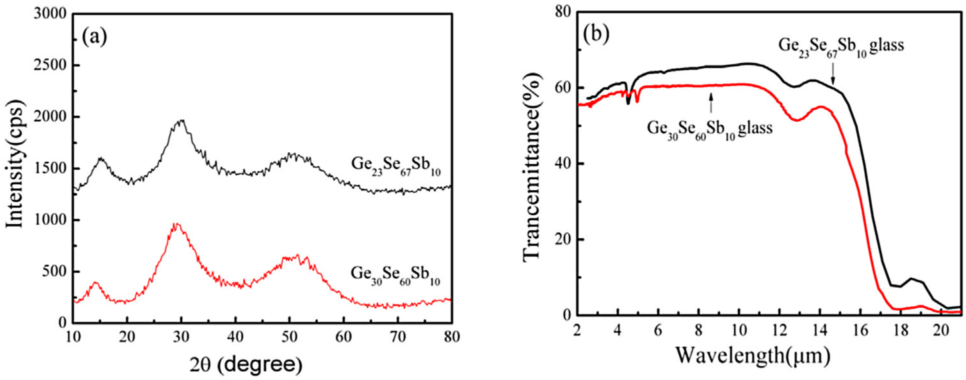

Fig. 2. XRD patterns (a) and infrared transmittances (b) for the as-prepared $Ge_{23}Se_{67}Sb_{10}$ and $Ge_{30}Se_{60}Sb_{10}$ glasses.

2. Experimental

The initial commercial Ge, Se and Sb (99. 999%) were specially purified to remove the impurities of oxygen, molecular water, carbon, silica and heavy metals, which can introduce the heterogeneous crystallization in chalcogenide glasses. And then the three materials were mixed and sealed in a quartz ampoule under vacuum of 2×10^{-3} Pa. The ampoule was placed in a resistance furnace and heated to 1223 K gradually. During heating, the furnace was frequently shacked to homogenize the melt. After holding 10 h, it is put in air. Thus the rod glass with diameter of 10 mm was obtained as shown in Fig. 1. The rod sample was cut into slices with size of $\Phi 10 \times 2$ mm using an inside diameter slicer for heat treatment. The structure of the sample was checked by using X-ray diffraction (XRD) analysis. Infrared transmittance was measured using a Fourier Transform Infrared Spectroscopy (FTIR) spectrometer. To observe the microstructure after heat treatment under scanning electronic microscope, polished discs were coated with a very thin gold film due to the electrically insulating character of the glass samples.

3. Result and discussion

3.1. Properties

The obtained samples of $Ge_{23}Se_{67}Sb_{10}$ and $Ge_{30}Se_{60}Sb_{10}$ glasses are shown in Fig. 1a and b, respectively. It can be seen that the sample surfaces are very bright and smooth. XRD patterns for the as-prepared samples are shown in Fig. 2a, where the amorphous structures of the samples are confirmed. The infrared transmittance of $Ge_{23}Se_{67}Sb_{10}$ and $Ge_{30}Se_{60}Sb_{10}$ glasses are shown in Fig. 2b. It can be seen that both the infrared transmittances of the two glasses reach to 60% at the range of 2–15 μm, particularly, behave strongly at the range of 6–15 μm, which can satisfy the requirements of infrared glasses. The infrared transmittance for $Ge_{23}Se_{67}Sb_{10}$ glass is higher than that for $Ge_{30}Se_{60}Sb_{10}$ glass, which may be attributed to the larger content of Ge for the latter glass. Generally, with increase of Ge content, the infrared reflectivity increases thus the infrared transmittance reduces.

Fig. 3 shows the DSC(differential scanning calorimetry) curves of $Ge_{23}Se_{67}Sb_{10}$ and $Ge_{30}Se_{60}Sb_{10}$ glasses with heating rate of 10 K min^{-1}. From the curves, the glass transition temperatures are measured as $T_g = 308\,^{\circ}$Cand $T_g = 293\,^{\circ}$C, and the initial crystallization temperatures are measured as $T_0 = 423\,^{\circ}$C and $T_0 = 429\,^{\circ}$C, for the two glasses respectively. Generally, the heat treatment temperatures are chosen between T_g and T_0.