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Study of phase separation in amorphous Se–Te–Bi material

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ABSTRACT

We have prepared ternary $Se_{80}Te_{17}Bi_3$ and $Se_{80}Te_{14}Bi_6$ glasses using melt-quench technique and performed the non-isothermal kinetics by differential scanning calorimetry (DSC) at various heating rates (β). X-ray diffraction and FESEM have been used to identify the transformed phases. The change in glass transition temperature (T_g) and crystallization temperature (T_c) with heating rates have been used to calculate different crystallization parameters in $Se_{80}Te_{20-x}Bi_x$ chalcogenide glasses. We found that both T_g and T_c becomes larger with increasing β. Activation energies of glass transition (E_g) and crystallization (E_c), the crystallization enthalpy (H_c), thermal stability and glass forming ability (GFA) were determined from the dependency of T_g and T_c on heating rates. From our experimental data, the temperature difference ($T_c - T_g$) and H_c are largest and lowest, respectively, for $Se_{80}Te_{17}Bi_3$ glass, which shows that $Se_{80}Te_{17}Bi_3$ glass is more stable than $Se_{80}Te_{14}Bi_6$ glass.

1. Introduction

During the past few decade the systematic examination of amorphous to crystalline phase transformation in amorphous chalcogenide materials has been studied not only to enhance our understanding about the disorder system but also to be used in optical recording and other electronic devices. The characteristic structure relaxation in amorphous materials has indispensable interest to researchers in the field of material science and technology. These structural effects generally induce

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apparent modification in structural properties of amorphous alloys which contain the reduction in glass transition temperature (T_g) and to become greater in molar volumes. The observation of phase separation in glassy alloys is not easily accomplished if the changes in diffraction pattern are indinguishable. Amorphous glasses generally crystallize just above T_g at normal heating rate so T_g can be set to a minimum limit for the temperature of crystallization. The glass transition temperature is, therefore, seems to be a primary source parameter for the first order approximation of the stability of phase change amorphous material to be used in optical recording.

Recently, amorphous chalcogenide materials have aroused great importance in the field of material science mainly due to their broad applications such as ultrafast optical switches, electronic memories, and optical recording. The basic principle underlying these applications depends on the potentiality of the material that leads the phase change from amorphous to crystalline state. Because of this transformation there is an impetuous change in structural, electrical, thermal and optical properties. It has already been established that when we add Se to Te, the corrosion resistance become greatly improves [1]. So, Se–Te alloys are subjected to be an auspicious media and can be employed as phase change material. When Se–Te is used as a recording material in phase change technique it puts up some severe perplexity. The two prime concern are the finite reversibility and the low values of T_g and T_c [2,3]. These issues can easily be handled by doping another element which can be used as chemical modifier of Se–Te system. Several researchers have examined the phase separation on ternary chalcogenide glasses with variant compositions and elements like Se–Te–Sb, Se–Te–Ge, and Se–Te–In [4–6]. It is found that when binary glassy system is added by another element like Bi then the glass furnishes a larger thermal stability. A constant heating rate are frequently implemented to study the crystallization in amorphous materials under non-isothermal measurements. Differential scanning calorimetry is immensely favored method to examine the transformation kinetics. The fascinating hallmark of these techniques rests in their ease and flexibility in the choice of heating rates and other parameters.

In DSC measurements, the material being heated at a fixed rate first experiences structural change ahead of acquiring crystallization. This phenomenon is clearly visible from the presence of large exothermal crystallization peaks in the DSC traces. In chalcogenide glasses prior to crystallization, the appearance of endothermic peak which is known as glass transition peak, is also observed in the DSC trace. This glass transition is assumed to be due to the restructure in the amorphous material, that tends to thermodynamically stable state as the system temperature is raised [7–9]. Analysis of amorphous alloys using non-isothermal DSC approach has become progressively more striking. To determine the rank of glass constancy for the prepared glass, various easy and straightforward quantitative modes have been used in the present research work. All these modes are based on the evaluation of thermal parameters such as T_g, T_c and melting temperature (T_m). These thermal parameters during the heating processes of glassy samples are easily and precisely obtained by DSC measurements. Attempts have also been made experimentally and theoretically in understanding the crystallization kinetics and phase transformation in chalcogenide material. Among the several articles published few recent works deserve to be mentioned here. For instance, El-Oyoun [10,11] has examined the kinetics conversion mechanism of Ge–Te glasses using model fitting procedure and the results to add Ga on kinetics parameter of Ga–Se glass system. Using DSC, Zhu et al. [12] and Lu et al. [13] have examined the kinetics of $(Cu_{46}Zr_{47}Al_7)_{97}Ti_3$ and $(Zr_{46}Cu_{42}Al_7Y_5)_{95}Be_5$ respectively. Similarly, Wu et al. [14] and Zhang et al. [15] have studied kinetics of Cu–Zr–Ti–In and $(Fe_{0.8}Ni_{0.15}M_{0.05})_{78}Si_8B_{14}$ alloys. Further, Moharram et al. [16] have studied the crystallization kinetics of two overlapped phases in As–Te–In glass while Abdel-Rahim et al. [17] have examined the crystallization of Se–Te–Sn chalcogenide alloys. Rheingans et al. [18] have studied the phase transformation of Cu–Zr–Ag–Al glass. Besides, lots of extensive studies [19–25] on synthesis and characterization of phase change materials are available in the literature. Our present work is devoted to understand the phenomena during phase transformation in $Se_{80}Te_{20-x}Bi_x$ chalcogenide glasses.

2. Experimental

Employing the melt-quench technique, bulk glassy materials of $Se_{80}Te_{17}Bi_3$ and $Se_{80}Te_{14}Bi_6$ were prepared. Uncontaminated (99.999% pure) Se, Te and Bi in suitable proportions were potted in a