Journal of Alloys and Compounds 509 (2011) 2087–2093

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: www.elsevier.com/locate/jallcom

Non-isothermal crystallization kinetic study on $Ga_{15}Se_{85-x}Ag_x$ chalcogenide glasses by using differential scanning calorimetry

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ARTICLE INFO

Article history:
Received 28 August 2010
Received in revised form 12 October 2010
Accepted 27 October 2010
Available online 4 November 2010

PACS:
71.55.Jv
65.90.+i
67.80.Gb
73.61.Jc

Keywords:
Chalcogenides
Glass transition temperature
Non-isothermal process
Crystallization kinetics

ABSTRACT

At different heating rates, the glass transition temperature (T_g) and the crystallization temperature (T_c) are obtained from the non-isothermal differential scanning calorimetry (DSC) measurements of bulk $Ga_{15}Se_{85-x}Ag_x$ (x = 0, 2, 4, 6 and 8) chalcogenide glasses prepared by melt quenching technique. Their amorphous state was verified by using X-ray diffraction (XRD) and scanning electron microscopy (SEM). It was observed that the glass transition temperature and crystallization temperatures both increase with increasing heating rates and also by increasing Ag concentration in Ga–Se system. The activation energy of crystallization (E_c), activation energy of glass transition (E_g), crystallization enthalpy (ΔH_c) and the Avrami exponent (n) have been determined from the dependence of T_g and T_c on the heating rate (β). The obtained value of the n indicates that the volume nucleation with two dimensional growth is responsible for amorphous-crystallization phase transformation. On the basis of the obtained experimental data, the temperature difference ($T_g - T_c$) and the enthalpy released (ΔH_c) are found to be maximum and minimum, respectively, for $Ga_{15}Se_{77}Ag_8$ glass, which indicate that this glass is thermally most stable in the composition range under investigation. The crystallization kinetic study of $Ga_{15}Se_{85-x}Ag_x$ glass was studied by using the modified Kissinger and Ozawa equations.

1. Introduction

Amorphous semiconductors especially chalcogenide glasses have been investigated largely due to its important technological applications, such as switching, electrophotography, X-ray imaging, photonics, thermal imagining, ultra-high-density phase-change storage and memory, integrated fiber optics, infrared photo-detectors, photo-voltaic, biosensors [1–5]. The considerable interest of researchers in these glasses is due to the possibility of their various applications in different fields of electronics that based on the fact that they combine the characteristic features of the disordered systems and some properties of the crystalline semiconducting materials. Recently, chalcogenide glasses have been investigated as infrared transmitting materials to replace single-crystalline germanium for fabricating infrared optical lenses.

The differential thermal analysis (DTA) and differential scanning calorimetry (DSC) are extremely popular tools for studying the kinetics of non-isothermal transformation. The appeal of these methods is their simplicity and their flexibility in the selection of heating rates. Between these techniques, DSC is particularly important, since it is easy to be carried out and is quite sensitive [6]. In DSC two basic methods are used: isothermal and non-isothermal. In the isothermal method, the sample is brought quickly to a temperature above the glass transition temperature (T_g) and the heat evolved during the crystallization process is recorded as a function of time, whereas in non-isothermal method, the sample is heated at fixed rate and the heat evolved is recorded as a function of temperature or time. The isothermal experimental analysis techniques are more definite but on the other hand non-isothermal thermo-analytical techniques have several advantages. The rapidity with which non-isothermal experiments can be performed, makes these techniques more attractive. Further, this technique can be used to extend the temperature range of measurements for an advantage over the isothermal experiments. The non-isothermal measurements using a constant heating rate are more commonly used in the study of the crystallization of amorphous solids and possess several advantages such as the quick performance of these experiments. Many phase transformations occur too rapidly to be measured under isothermal conditions because of transitions inherently associated with the experimental apparatus. Industrial processes often depend on the kinetic behavior of systems undergoing phase transformation under non-isothermal conditions. In this respect, a definitive measurement of non-isothermal transformation kinetic is desirable. The DSC has widely been used to investigate the glass transformations in glassy materials. It is very quick and needs very small

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doi:10.1016/j.jallcom.2010.10.145