Abstract

The importance of amorphous chalcogenide materials can be judged from their wide utility in technological applications. These also represent a class of disordered materials and are important from basic physics point of view. Among the wide variety of technological applications that rely upon the physical properties of these materials two main applications are ‘phase change memories’ and ‘data communication’. These material exhibit anomalous behaviors in physical properties at two thresholds namely rigidity percolation threshold and chemical threshold with mean coordination number \(< r > = 2.4\) for the former and \(2.4 - 2.67\) for the latter respectively. Extensive studies have been made on effect of substitution/addition/alloying of non-chalcogen elements in chalcogenide materials on their properties. The effect of substitution of one chalcogen with another has not been studied much and thus in the present work, the effect of substitution of Se with Te has been studied for Sn\(_{10}\)Sb\(_{20}\)Se\(_{70-x}\)Te\(_x\) system at rigidity percolation threshold. Thermal, optical and electrical studies have been performed for Te- substituted Sn-Sb-Se system and is discussed for elaborating the system completely.

The bulk samples of compositions Sn\(_{10}\)Sb\(_{20}\)Se\(_{70-x}\)Te\(_x\) have been prepared by melt quenching technique. The bulk samples were found amorphous upto compositions \(X \leq 12\). Thermal parameters were evaluated from Differential scanning calorimetry (DSC) studies. Glass transition temperature \(T_g\) exhibited a sharp decrease with tellurium substitution upto 2 at\%, thereafter a monotonous increase is observed upto 10 at\% and afterwards again a decrease is observed. Apparent activation energy for glass transition was calculated using Kissinger equation and found to decrease with tellurium content in the sample. Activation energy for crystallization was calculated using modified Kissinger equation and Matusita equation and growth morphology was found to be three dimensional.

Thin films of compositions Sn\(_{10}\)Sb\(_{20}\)Se\(_{70-x}\)Te\(_x\) (0 \(\leq X \leq 14\)) were deposited onto well cleaned glass substrates by thermal evaporation technique using as-prepared bulk samples of each composition as source material for deposition. The surface morphology of the deposited thin films was studied by Scanning electron microscope (SEM) and Scanning probe microscopy (SPM). Films were found to be highly smooth with surface
roughness ~ 2nm and average grain size ~ 30nm. Compositional analysis was carried out with Energy dispersive x-ray spectroscopy (EDAX). Annealing of thin films were carried out at 130°C in vacuum ~ 10^{-5} mbar for one hour. Optical band gap $E_g$ was calculated from the absorption coefficient obtained using transmittance data. The optical gap showed a sharp decrease with initial substitution upto 2at% and afterwards exhibited a broad peak around X=4 composition. The width of tail states were calculated through the Urbach energy and that also showed a sharp decrease for initial substitution upto 2 at% and afterwards increased slowly upto X=8 composition and decreased for higher substitution. Results are explained on the basis of heteropolar bond formation and model given by Kastner (1972). Optical constants viz. refractive index n and extinction coefficient k were calculated by using the Swanepoel method and wavelength dispersion of refractive index was calculated by effective single oscillator model given by Wemple-DiDomenico fitting.

Electrical and photoelectrical studies for compositions X ≤ 8 showed the thermally activated conduction process with single activation energy for the studied temperature regime. The dc-activation energy for electrical conductivity showed a sharp decrease for initial substitution upto 2at% and thereafter it slowly increased upto X= 8 composition. High value of pre-exponential factor represented conduction through extended band states. No maximum was found in temperature dependent photoconductivity revealing that materials belong to type II photoconductor. Intensity dependent photoconductivity revealed predominant bimolecular recombination mechanism. Transient photoconductivity showed that rise and decay of photocurrent become slow with tellurium content in the samples. Decay process was found to be non-exponential and differential life time of the photo generated carrier was calculated for each composition that showed a decreasing trend for initial substitution upto X= 6 composition and afterwards increased for X= 8 sample. Activation energy for photoconduction was found to be smaller but close to dc-activation energy for dark conduction and might be responsible for observed low photosensitivity of these materials. The annealing effect on optical and electrical properties showed a decrease ~ 0.07- 0.14 eV in both optical band gap and dc-activation energy for annealed samples.

Thin film samples with high tellurium contents X= 10, 12 and 14 showed a sharp decrease in resistivity at particular temperature that might be related to amorphous-crystalline transition.