Optical properties of post-annealed $Ge_2Sb_2Te_5$ films

Tamihiro Gotoh, Kenta Kawarai

Graduate School of Engineering, Gunma University, Maebashi 371-8510, Japan

Phase-change recording in chanlcogenide materials is particularly promising for use in digital storages, and further developments are intensively explored. Among several developing targets, the recording speed may be the most important, which is governed by crystallization rate. Crystallization rate depends on the thermal history of phase change materials, indicating that structural differences exist between amorphous states [1]. Despite many practical results presenting the relations between crystallization rate and structural disorder, little is known about amorphous structures of phase change materials. In order to obtain insights into amorphous structures of $Ge_2Sb_2Te_5$, we measured optical absorption spectra of as-prepared and thermal annealed $Ge_2Sb_2Te_5$ films using transmittance and photothermal spectroscopy.

Amorphous $Ge_2Sb_2Te_5$ films were grown on quartz substrates by dc sputtering. The film thicknesses were 140 and 800 nm respectively. The samples were annealed at several temperatures up to 180 °C in Ar gas. The optical band gap of as-prepared sample was deduced as 0.74 eV from Tauc's plot. At first, absorption edge shifted slightly to higher energy and then shifted to lower energy with increasing annealing temperature and large shift occurred at around crystallization temperature. X-ray diffraction results show that crystalline peaks appear after annealed over the crystallization temperature. We have also observed Urbach tail absorption using photothermal spectroscopy using individual cantilever [2].

The results suggest that structural differences exist between amorphous states. It is reported that as-prepared $Ge_2Sb_2Te_5$ films contain wrong bonds such as Ge-Ge bonds [3]. The structural change associated with the thermal relaxation process causes to change of the optical band edge. Furthermore, it has been reported that thermal annealing below the crystallization threshold increases nanoscale ordered region measured by transmission electron microscopy [4]. The nanoscale ordered regions act as the nuclei for crystallization and lead higher crystallization rate than as-prepared films.

[1] P. K. Khulbe, E. M. Wright, M. Mansuripur, J. Appl. Phys. 88, 3926 (2000).
[2] T. Gotoh, Rev. Sci. Instrum. 80, 074902 (2009).
[3] P. Jóvári, I. Kaban, J. Steiner, B. Beuneu, A. Schöps, and A. Webb, J. Phys., Condens. Matter 19, 335212 (2007).
[3] M. Naito, M. Ishimaru, Y. Hirotsu, M Takashima, J. Non-Cryst. Solids 345&346, 112 (2004).