

## ABSTRACT

The density of sputtered  $\text{Ge}_2\text{Sb}_{2.04}\text{Te}_{4.74}$  thin films upon annealing has been precisely determined by x-ray reflection and compared to the values determined from x-ray diffraction (XRD) data. The film density increases in two steps around 130 and 280 °C upon annealing up to 400 °C. These increases are consequences of phase transitions from amorphous to NaCl type and from NaCl type to hexagonal structure, respectively, as revealed by XRD. Average density values of  $5.87 \pm 0.02$ ,  $6.27 \pm 0.02$ , and  $6.39 \pm 0.02$  g/cm<sup>3</sup> were measured for the amorphous, NaCl-type, and hexagonal phases, respectively. This corresponds to density changes upon crystallization of  $6.8 \pm 0.2\%$  and  $8.8 \pm 0.2\%$  for NaCl-type and hexagonal phases, respectively. The accompanying film thickness reductions were determined to be  $6.5 \pm 0.2\%$  and  $8.2 \pm 0.2\%$ , which compares very well with the density changes. The corresponding XRD values are determined to be 6.43–6.48 and 6.48 g/cm<sup>3</sup> for NaCl-type and the hexagonal phases, respectively. This shows that nearly void-free films are formed.