Phase Transition Characteristics in Ge_xSb_{100-x} Film for Optical Storage Media

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Key Words: optical recording, phase change, chalcogenide, optical properties, chemical binding

ABSTRACT

Rewritable optical memory devices such as an CD-RW and DVD+RW are data storage media, which take advantage of the different optical properties in the amorphous and crystalline states of phase change materials. The switching property, structural transformation, transformation kinetics and chemical bindings of $Ge_xSb_{100-x}(6 \leq x \leq 34)$ were studied to investigate the feasibility of applying Ge_xSb_{100-x} alloys in optical memory. The Ge_xSb_{100-x} thin film was deposited by RF magnetron co-sputtering system and phase change characteristics were investigated by X-ray diffraction (XRD), static tester, inductively coupled plasma atomic emission spectrometer (ICP-AES) and atomic force microscopy (AFM). Optimum film composition of Ge_xSb_{100-x} was studied and its minimum time for laser induced crystallization and optical contrast for phase transition was performed. These results might be correlated with the binding energies between Ge and Sb, and indicate that Ge_xSb_{100-x} have an potential for optical memory applications.

1. INTRODUCTION

Phase change materials have introduced data storage methods such as a rewritable optical disks and optical ram which take advantage of the different optical properties in the amorphous and crystalline state. Recently, the optimum recording materials in terms of data transfer rate, archival life and optical contrast were found to be $Ge_2Sb_2Te_5$ and AgInSbTe which used in DVD-RAM, CD-RW, DVD+RW. However optical storage device still requires the more effective phase change materials because of its fast and stable operation.(1)

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The $Ge_xSb_{100-x}(6 \leq x \leq 34)$ were studied to investigate the feasibility of Ge_xSb_{100-x} alloy in optical memory.

2. EXPERIMENTAL PROCEDURE

Ge_xSb_{100-x} thin films were prepared by RF magnetron sputter (SNTek, Korea) on to Si(100) wafers and slide glass. Ge (5N, RND KOREA, Korea) and Sb (5N, Kurt J. Lesker, USA) were sputtered by co-sputtering method. Differenct RF power was induced between 10~70 W on Ge target under 50 W RF power fixation on Sb target. Base pressure was 1 × 10^{-7} torr and working pressure was adjusted to 1 mtorr by flowing Ar (6N, Seoul gas, Korea) through mass flow controller). Targets were presputtered for 5 min in order to remove oxides and contaminations, and substrate holder was rotated with 20 RPM for homogeneous deposition.

Film thickness was measured by surface profiler (AS500, KLATencor, USA), and film composition was measured by ICP-AES (Elan 6100, Perkin

Elmer, USA). Surface roughness was observed by AFM (Auto-probe CP-R microscope, Digital instrument, USA). As doposited films were annealed at 100~400 °C in Ar atmosphere for 10 min with 5 K/min heating rate. The structure of the annealed film was analysed by Grazing incident X-ray diffractometer (Figaku D/MAX II A, Japan & Philips X'pert MRD, Philips, Netherlands) and X-ray diffractometer (PANalytical X'pert PRO, Philips, Netherlands). Phase transition kinetics and switching property was measured by static tester (Media test-I, Toptica photonics, Germany).

3. RESULT AND DISCUSSIONS

3.1 Basic properties of film.

Film thickness variations according to deposition time and RF power (10~70 W) are shown in fig. 1. Thickness of the film is linearly proportional upon time and RF power. Table 1 presents film compositions with different RF power. RMS roughness is very important in phase change optical disk, since protective layer and reflective layer are deposited on phase change film. Fig. 2 presents the surface of deposited film and RMS roughness of $Ge_{20}Sb_{80}$ film which is 2.8Å. Considering that the RMS roughness of bare Si wafer is 2.0Å, RF magneston co-sputtered Ge-Sb film has very smooth surface which is favorable for optical disk.

3.2 Structural analysis

Fig. 3 presents the XRD patterns and Miller indexes of as-deposited and annealed Ge-Sb films. As-deposited films are amorphous state and crystallization is observed at different temperature upon compositions. In case of Ge 6 at% Ge-Sb film, crystallization temperature is below 100 °C however as Ge portion increases, crystallization temperature rises up to above 300 °C. As a result, Sb has weak amorphous stability and which gives the expectation about fast crystallization property of

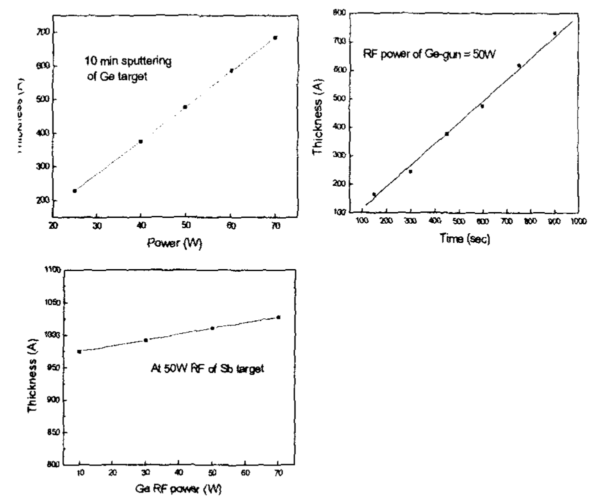

Fig. 1. Ge-Sb film thickness upon deposition time and RF power.

Table 1. Ge-Sb Film Compositions upon Induced Ge RF Power. (Sb RF power : 50W)

	10W	20W	30W	40W	50W	60W	70W
Ge	5.8	10.5	14.9	19.6	24.1	28.8	33.5
Sb	94.2	89.5	85.1	80.4	75.9	71.2	66.5

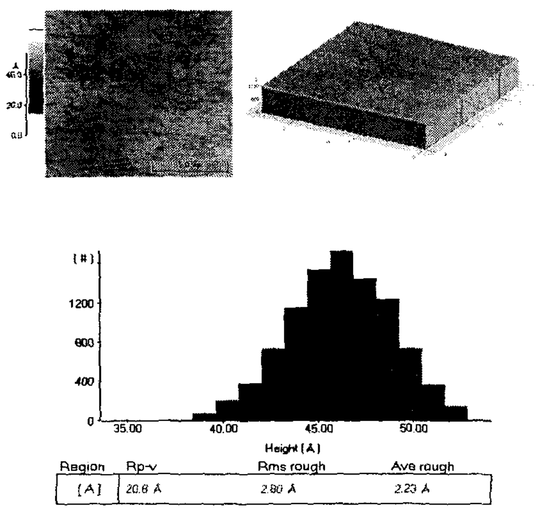

Fig. 2. AFM image and surface analysis of $Ge_{20}Sb_{80}$ film.

Sb-based compound. In addition, the larger amounts of Ge portion would give the amorphous stability since crystallization temperature was risen with adding Ge. This characteristics give solutions about data transfer rate and long term stability of optical storage media.

Crystallized Ge-Sb films' XRD patterns are very similar to Sb in terms of peak position and tendency. This result corresponds to other reports.[2] Each crystalline peak shows shifted 2Θ to the high angle direction compared with Sb, which means Ge added Sb has more closed packing structure. Considering the small electro negativity difference between Ge and Sb, the cause of this phenomena should be based on strong covalent bonding between Ge and Sb. In table 2, peak position and calculated lattice parameters are presented.

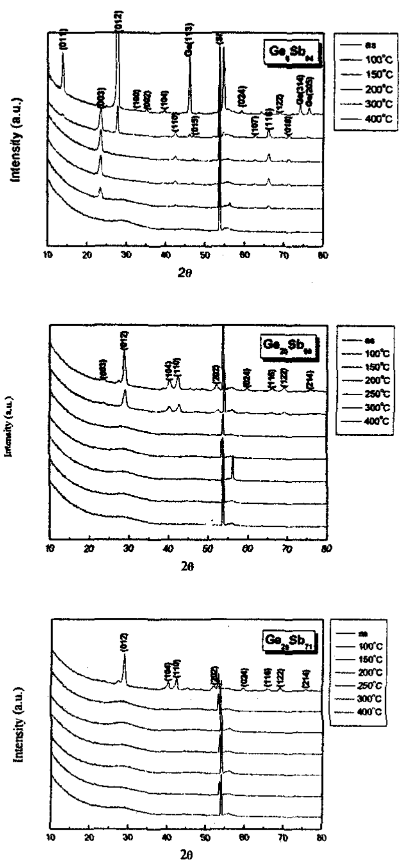

Fig. 3. XRD patterns of Ge-Sb film with different compositions and annealing temperature.

Table 2. Peak Positions and Calculated d-spacing of Ge-Sb Films

400°C annealed Ge_6Sb_{94}		
h k l	Position [¡Æ2Th.]	d-spacing [A]
0 0 3	23.52	3.782
1 0 1	25.34	3.515
0 1 2	27.13	3.287
1 0 4	40.09	2.249
1 1 0	42.34	2.135
0 1 5	46.98	1.934
0 0 6	49.06	1.857
1 0 7	62.54	1.485
1 1 6	65.98	1.416
1 2 2	69.20	1.358

400°C annealed $Ge_{20}Sb_{80}$		
h k l	Position [¡Æ2Th.]	d-spacing [A]
0 0 3	23.43	3.797
0 1 2	28.81	3.099
1 0 4	40.37	2.234
1 1 0	42.31	2.136
2 0 2	52.03	1.758
0 2 4	59.63	1.551
1 1 6	66.02	1.415
1 2 2	69.14	1.359
2 1 4	75.80	1.255

400°C annealed $Ge_{29}Sb_{71}$		
h k l	Position [¡Æ2Th.]	d-spacing [A]
0 1 2	28.82	3.09816
1 0 4	40.10	2.24867
1 1 0	42.36	2.13379
2 0 2	52.07	1.75644
0 2 4	59.62	1.55086
1 1 6	66.00	1.41548
1 2 2	69.14	1.35866
2 1 4	75.81	1.25492

3.3 Phase transition kinetics

Fig. 4 is PTE diagrams of Ge-Sb film by static tester. As induced laser power and time increased, the reflectivity increased because of crystallization.[3,4] From the result, Ge-Sb films shows fast phase transition property between 10ns and 30ns. This results should be based on weak amorphous stability of Sb. Therefore, Sb-based phase change material should be emphasised on phase stability rather than phase transition speed. However Ge-Sb film, contains more than Ge 20 at%, does not produce wide crystallization region by laser inducement.

Fig. 5 shows reflectivity switching phenomena of $Ge_{20}Sb_{80}$ during cyclic phase transition by laser inducement which performed with 19mW / 30ns and 27mW / 100ns for crystallization and amorphization. Although the $Ge_{20}Sb_{80}$ film does not show wide crystallization range, it has stable switching property up to 10,000 times

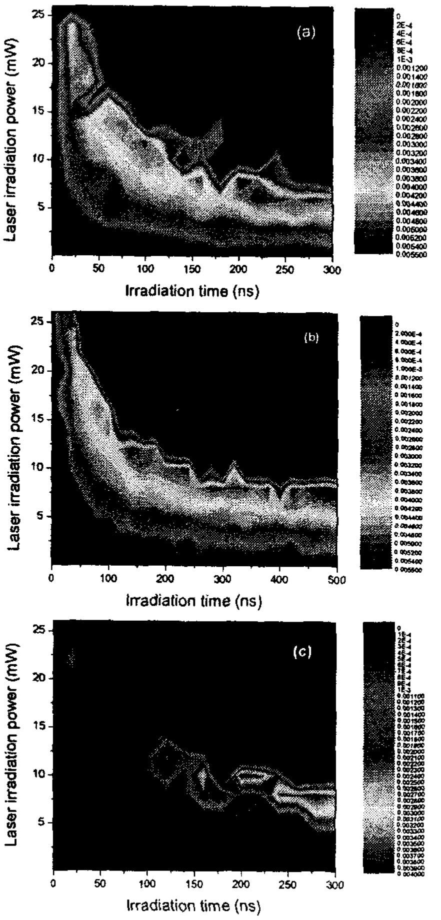

Fig. 4. PTE diagrams of (a) Ge_6Sb_{94}, (b) $Ge_{10}Sb_{90}$, and (c) $Ge_{15}Sb_{85}$ films.

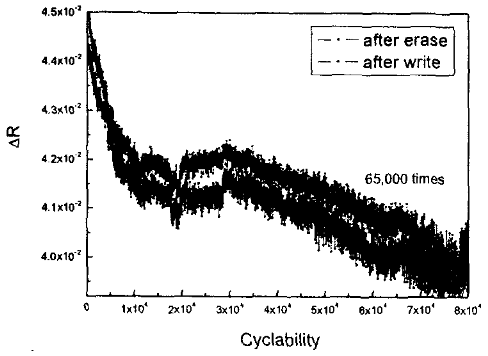

Fig. 5. Cyclic phase transition of $Ge_{20}Sb_{80}$ film by laser inducement of static tester.

4. CONCLUSION

The Ge-Sb alloy has fast crystallization property below 20ns, which would be based on amorphous un-stability of Sb. The Ge gives phase stability because of its strong covalent bonding with Sb, which results in closed structure and rising of crystallization temperature. $Ge_{20}Sb_{80}$ shows stable cyclic switching property relatively.

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Reference

(1) T.J Park, M.J Kang, and S.Y Choi, (2005), "Influence of Sn/Bi doping on the phase change characteristics of GST", Soc. of Information Storage Sys. Vol.1 No.1 (pp. 93-98).

(2) H Tashiro, M Harigaya, K Ito, M Shinkai, K Tani et al., (2004), "Characterization of Ultra-Fast Phase Change Optical Disk with GaSb Material", MRS Symposium Proc.Vol.803.

(3) M.H.R. Lankhorst, (2002), "Modelling glass transition temperatures of chalcogenide glasses. Applied to phase-change optical recording materials", Journal of Non-Crystalline Solids Vol.297 (pp. 210 - 219).

(4) H. Iwasaki, Y. Ide, M. Harigaya, Y. Kageyama and I. Fujimura, (1992), "Completely Erasable Phase Change Optical Disk", Jap. J. of App. Phys. Vol.31 No.461