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Short communication

Bi–Ge–Sb–Sn–Te films for reversible phase-change optical recording

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Abstract

Bi–Ge–Sb–Sn–Te phase-change recording films (Films A–D) were prepared by the co-sputtering of $Bi_{30}Ge_{10}Te_{60}$, $Ge_{20}Sb_{80}$, Sb and Sn targets. The composition of the recording films was controlled by the dc power. The film composition, surface roughness and reflectivity were also closely related. Dynamic tests revealed that disks with Film C exhibited a low jitter value and a high modulation value after direct overwriting. Therefore, the composition of the recording film dominated the reversible recording properties of the phase-change optical disk.

Keywords: Bi–Ge–Sb–Sn–Te film; Optical disk; Surface roughness; Reflectivity; Reversible recording

1. Introduction

Phase-change optical disks contain digital data in the form of amorphous marks in a crystal matrix, utilizing the difference between the reflectance values of two phases [1]. In a phase-change disk, the rate of crystallization of the recording material determines the rate of recording. The rate of crystallization of the material is easily controlled by varying the recording film composition [2,3]. The choice of the recording film material can determine the recording characteristics [4]. The recording performance is most closely related to the structure and the material properties of the optical media [5,6].

Phase-change optical disks are developed with higher recording speed. New high-speed phase-change materials will be necessary to facilitate the development of media with increased recording speed. In this study, Bi–Ge–Sb–Sn–Te phase-change recording films are prepared by co-sputtering of $Bi_{30}Ge_{10}Te_{60}$, $Ge_{20}Sb_{80}$, Sb and Sn targets. The composition of the recording films was controlled by varying the dc powers. This work studies how the composition of recording films affects the recording characteristics of disks.

2. Experimental procedures

Fig. 1 shows the structure of a phase-change optical disk. The disk had a six-layer stack with a structure $ZnS–SiO_2$ (60 nm)/GeN_x (1.5 nm)/Bi–Ge–Sb–Sn–Te (16 nm)/GeN_x (7 nm)/$ZnS–SiO_2$ (0.5 nm)/Ag (150 nm), sputtered sequentially on a grooved polycarbonate (PC) substrate. The dielectric layers ($ZnS–SiO_2$) were deposited by RF magnetron sputtering in an atmosphere of Ar. The interface layers (GeN_x) were deposited by reactive RF magnetron sputtering in a mixed Ar–N_2 atmosphere. Two separate mass flow controllers (Hastings HFC-202) were applied to monitor the gas flow rates of argon and nitrogen. The phase-change recording films were prepared by co-sputtering of $Bi_{30}Ge_{10}Te_{60}$, $Ge_{20}Sb_{80}$, Sb and Sn targets in Ar atmosphere. The composition of recording films was controlled by four dc powers. The reflective layer (Ag) was deposited by dc magnetron sputtering in an atmosphere of Ar. In the deposition of a six-layer stack, the substrate was not heated. Table 1 lists all of the sputtering conditions of the six-layer stack in a phase-change optical disk. After sputtering, the disks were bonded with PC dummy substrates and initialized for the dynamic test.

The dynamic test was carried out using a dynamic tester (Pulstec DVD TESTER ODU-1000) with a laser diode of 650 nm wavelength and a numerical aperture (NA) of 0.6. The film thickness was measured using a surface profiler (Alpha-Step 500, TENCOR) and the field emission scanning electron microscope (XL-40FEG; FE-SEM). The elemental compositions were investigated by X-ray photoemission spectroscopy

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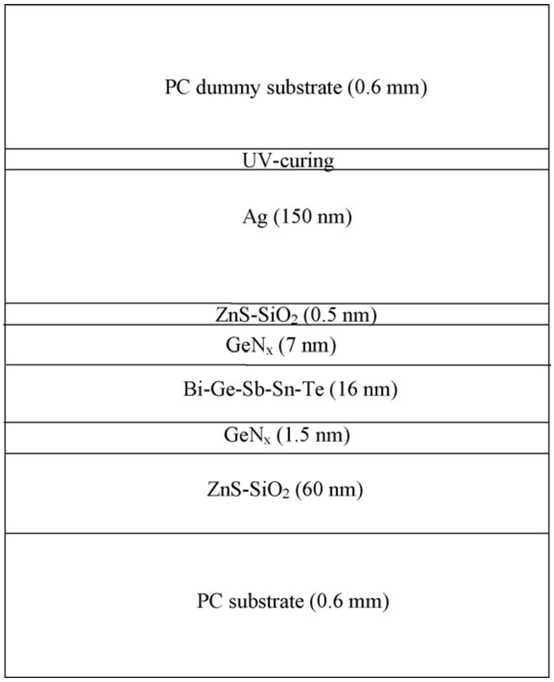

Fig. 1. The structure of a phase-change optical disk.

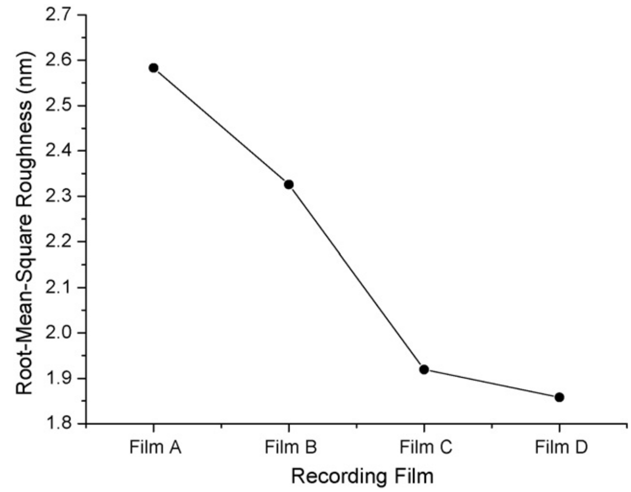

Fig. 2. The root-mean-square roughness of different Bi–Ge–Sb–Sn–Te phase-change recording films.

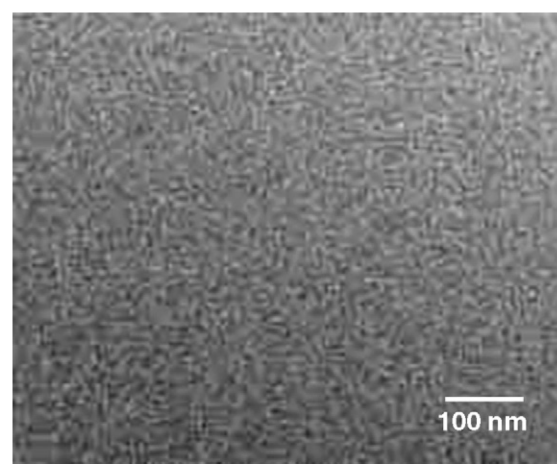

Fig. 3. The scanning electron micrograph of the surface of Film A.

(XPS; VG ESCA 210). The surface morphologies and surface roughness were investigated by atomic force microscopy (AFM; Digital Instruments Inc.). The reflectivity of the films was recorded using a spectrophotometer (ETA-ODT).

3. Results and discussion

Table 2 shows the elemental composition of Bi–Ge–Sb–Sn–Te recording films detected by XPS. The compositions of Bi–Ge–Sb–Sn–Te films (Films A–D) vary with dc power (P1, P2, P3 and P4) applied to the $Bi_{30}Ge_{10}Te_{60}$, $Ge_{20}Sb_{80}$, Sb and Sn targets. The Sb/Te atomic ratio of Film A was relatively high.

Fig. 2 shows the root-mean-square (RMS) roughness of different Bi–Ge–Sb–Sn–Te phase-change recording films. By comparison, the surface roughness of Film A was relatively

Table 1
Sputtering conditions of the six-layer stack in a phase-change optical disk

Film	ZnS–SiO$_2$	GeN$_x$	Bi–Ge–Sb–Sn–Te	GeN$_x$	ZnS–SiO$_2$	Ag
Target	ZnS–SiO$_2$	Ge	*a	Ge	ZnS–SiO$_2$	Ag
Sputter mode	RF	RF	dc	RF	RF	dc
Power (kW)	4.5	2	*b	2	0.5	4.5
Sputter gas and flow (sccm)	Ar, 12	Ar/N$_2$, 40/40	Ar, 10	Ar/N$_2$, 40/40	Ar, 30	Ar, 30
Pressure (mTorr)	6	6	6	6	6	6
Film thickness (nm)	60	1.5	16	7	0.5	150

*a Target	$Bi_{30}Ge_{10}Te_{60}$	$Ge_{20}Sb_{80}$	Sb	Sn
*b Power (kW)	P1	P2	P3	P4
Bi–Ge–Sb–Sn–Te				
Film A	0.15	0.6	0.6	0.08
Film B	0.15	0.5	0.6	0.07
Film C	0.16	0.6	0.6	0.08
Film D	0.16	0.6	0.5	0.07

Table 2
The elemental composition of Bi–Ge–Sb–Sn–Te recording films detected by XPS

Bi–Ge–Sb–Sn–Te films	Bi content (at.%)	Ge content (at.%)	Sb content (at.%)	Sn content (at.%)	Te content (at.%)	Sb/Te
Film A	5.38	8.42	69.74	5.68	10.78	6.47
Film B	5.75	7.80	69.66	5.30	11.49	6.06
Film C	5.28	8.44	68.91	5.51	11.86	5.81
Film D	6.05	7.83	68.78	5.23	12.11	5.68

high. The composition of the film generally affects the surface roughness of the films [7].

Fig. 3 shows the scanning electron micrograph of the surface of Film A. The surface was smooth because of equilibrium growth [8]. The surfaces of Films B–D were also investigated using SEM, and were similar to that in Fig. 3.

Fig. 4 shows the reflectivity at a wavelength of 650 nm for different Bi–Ge–Sb–Sn–Te phase-change recording films. Film A exhibits a relatively high reflectivity, probably because of the relatively high surface roughness, which can result in more light scattering [7,9,10]. This result was in agreement with the results of Fig. 2.

Fig. 5 shows the dependence of the jitter value on the recording speed for the different phase-change optical disks after 10 direct overwriting (DOW) cycles. The jitter values increased with the recording speed for the phase-change optical disks with Films A–D. The jitter values of the disk with Film A were relatively high at various recording speeds. However, the jitter values of the disk with Film C were relatively low, suggesting that the composition of the

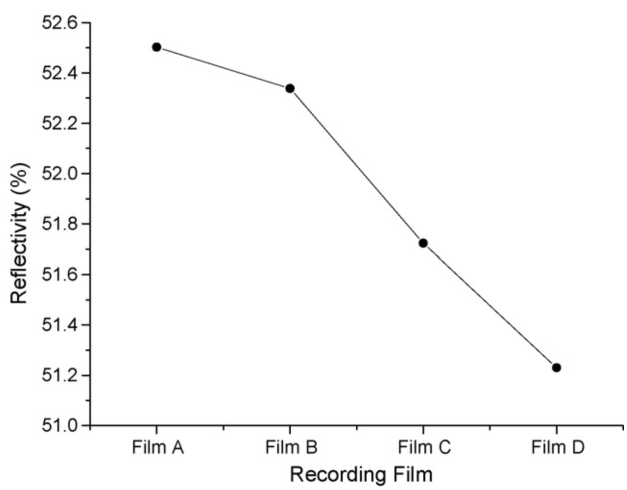

Fig. 4. The reflectivity at a wavelength of 650 nm for different Bi–Ge–Sb–Sn–Te phase-change recording films.

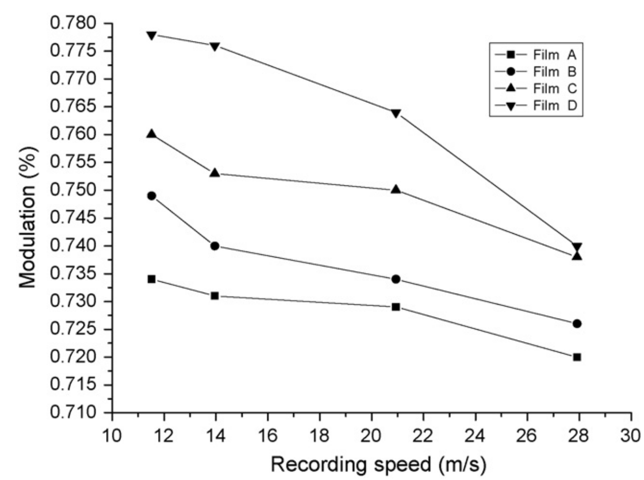

Fig. 6. The dependence of the modulation value on the recording speed for the different phase-change optical disks after 10 DOW cycles.

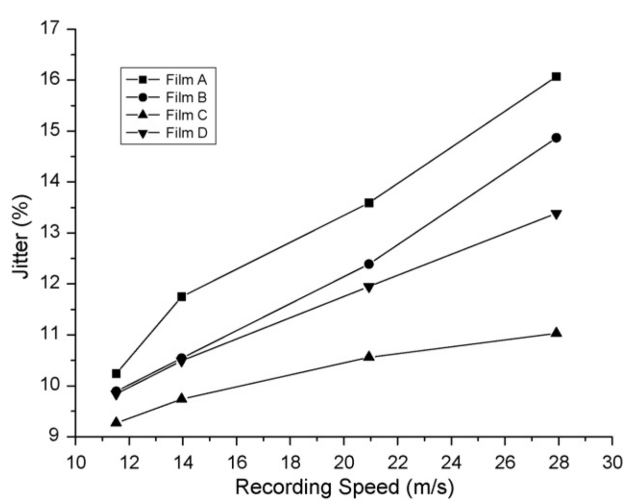

Fig. 5. The dependence of the jitter value on the recording speed for the different phase-change optical disks after 10 DOW cycles.

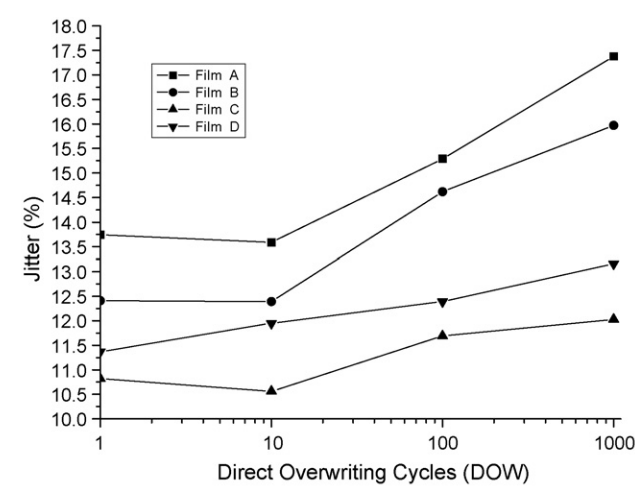

Fig. 7. The DOW performance of the different phase-change optical disks (6X DVD + RW).

film significantly affected the recording performance of disk. Additionally, Film C was better for high-speed recording.

Fig. 6 shows the dependence of the modulation value on the recording speed for the different phase-change optical disks after 10 DOW cycles. The modulation values decreased as the recording speed of the phase-change optical disks with Films A–D increased. The modulation values of the disk with Film D were relatively high at various recording speeds. However, the disk with Film A displayed relatively low modulation values at various recording speeds, suggesting that Film A did not improve the modulation value of the disk.

Fig. 7 shows the DOW performance of the different phase-change optical disks (6X DVD + RW). The jitter values of the disks with Films A and B increased for up to 1000 direct overwriting cycles. Additionally, the disk with Film C had a lower jitter value after 1000 DOW cycles, suggesting that the transfer rate between amorphous and crystalline states was faster for Film C.

4. Conclusions

Bi–Ge–Sb–Sn–Te recording films with different composition showed the different surface roughness and reflectivity. Film A showed relatively high reflectivity. It was probably due to the relatively high surface roughness, which could result in more light scattering. A dynamic test was used to investigate the recording properties of phase-change optical disks with different recording films. It could be found that the disk with Film C showed a low jitter value and a high modulation value after direct overwriting. The results suggested that the disk with Film C had the better reversible recording properties.

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