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The effect of thickness on the Bi–Ge–Sb–Te films for reversible phase-change optical recording

Su-Shia Lin *

Institute of Mechatronoptic Systems, Chienkuo Technology University, Changhua, Taiwan 500, ROC

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Abstract

The Bi–Ge–Sb–Te phase-change recording films were prepared by the dc magnetron sputtering of a $Bi_5Ge_9Sb_{68}Te_{18}$ target in an atmosphere of Ar. The surface of the Bi–Ge–Sb–Te films grew in the form of needles as the film thickness increased. There was the close relation among the film thickness, surface roughness, and optical properties. The Bi–Ge–Sb–Te film with a thickness of 16 nm had the lowest jitter value and the highest modulation value. As the results, the film thickness affected the Bi–Ge–Sb–Te film for phase-change optical recording significantly.

Keywords: Bi–Ge–Sb–Te film; dc Magnetron sputtering; Thickness; Optical recording

1. Introduction

In the past decade, phase-change optical recording has evolved into a mature technology that is adopted in rewritable (RW) optical data storage systems such as compact disks (CD) and digital versatile disks (DVD) [1]. Phase-change optical recording of information is based on the writing and erasing of amorphous marks in a crystalline phase-change material. The difference between the optical properties of crystalline and amorphous states enables information to be read as a change in the reflectance [2]. The rate of crystallization of the recording material determines the recording speed [3]. Different recording materials have different recording characteristics [4]. Good overwriting characteristics have been obtained using recording materials that exhibit rapid crystallization, such as GeSbTe, InSeTl and InSbTe [5–9].

The optimization of the phase-change recorded film is essential to high-speed recording [1]. The preparation conditions such as working pressure, substrate temperature, type of substrates and the thickness of the films affect the characteristics of the films [10]. Among these factors, the influence of thickness on the characteristics of Bi–Ge–Sb–Te recording films is underreported. In this study, Bi–Ge–Sb–Te phase-change recording films were prepared by the dc magnetron sputtering of a $Bi_5Ge_9Sb_{68}Te_{18}$ target in an atmosphere of Ar. The direct effects of film thickness on the morphologic, optical and recording properties of Bi–Ge–Sb–Te films were studied in this investigation. The advantages of the use of $Bi_5Ge_9Sb_{68}Te_{18}$ film as a recording film have been described in the previous studies [11,12].

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–Te (10–20 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 Bi–Ge–Sb–Te phase-change recording films were prepared by the dc magnetron sputtering of $Bi_5Ge_9Sb_{68}Te_{18}$ target in an atmosphere of Ar. 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.

* Tel.: +886 4 7111111x2413; fax: +886 4 7111144.
E-mail address: sushialin@sina.com.tw.

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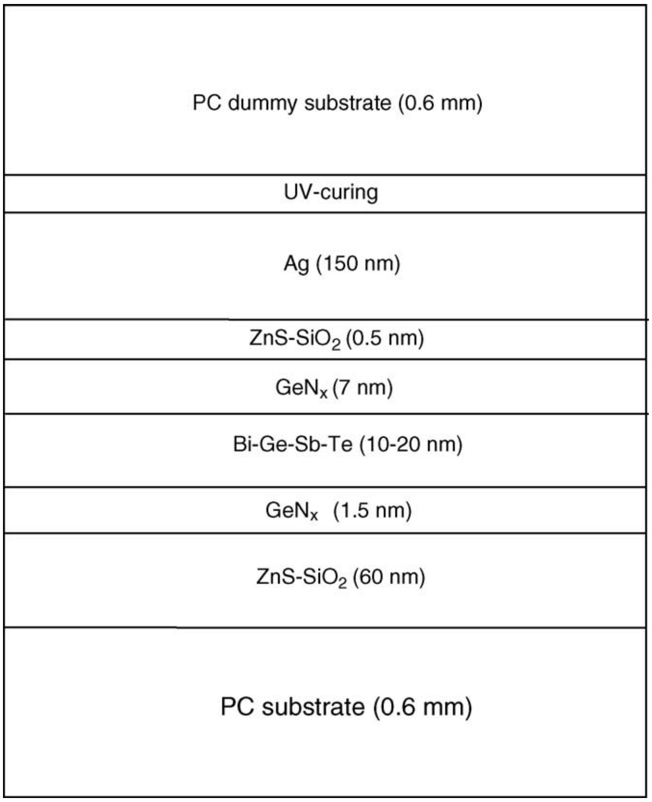

Fig. 1. The structure of a phase-change optical disk.

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 FE-SEM (XL-40FEG field emission scanning electron microscope). The surface morphologies and surface roughness were investigated by atomic force microscopy (AFM, Digital Instruments Inc.). The optical properties of the films and disks were recorded using a spectrophotometer (ETA-ODT) and by CATS, respectively.

3. Results and discussion

3.1. Surface studies

Fig. 2 shows the morphologies of Bi–Ge–Sb–Te films with thickness of (a) 10 nm and (b) 20 nm. The surface of the Bi–Ge–Sb–Te films grew in the form of needles as the film thickness increased. Ohring [13] considered electromigration, and found that local mass flux diverges throughout the film, because the grains are of various sizes and orientations. If more atoms enter than leave a region, such as a grain junction, then mass pileup or growth can be expected [13]. Therefore, the Bi–Ge–Sb–Te film nucleated as islands and formed needles in Fig. 2a. In Fig. 2b, more needles are observed.

Fig. 3 shows the root-mean-square (RMS) roughness of Bi–Ge–Sb–Te films of various thicknesses. The surface roughness increased with the thickness of Bi–Ge–Sb–Te films. Laukaitis et al. [14] reported that the roughness was strongly related to the morphologies of the growing films, which fact probably explains why Bi–Ge–Sb–Te films with a thickness of 20 nm were the roughest.

3.2. Optical properties

The optical properties of the recording film strongly affect both the writing sensitivity and the readout signal strength [15]. Fig. 4 shows the reflectivity of Bi–Ge–Sb–Te films of different thicknesses at a wavelength of 650 nm. The reflectivity increased with the thickness of the film, probably because the surface

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

Film	ZnS–SiO$_2$	GeN$_x$	Bi–Ge–Sb–Te	GeN$_x$	ZnS–SiO$_2$	Ag
Target	ZnS–SiO$_2$	Ge	$Bi_5Ge_9Sb_{68}Te_{18}$	Ge	ZnS–SiO$_2$	Ag
Sputter mode	RF	RF	DC	RF	RF	DC
Power (kW)	4.5	2	0.5	2	0.5	4.5
Sputter gas and flow (sccm)	Ar, 12	Ar/N$_2$, 40/40	Ar, 60	Ar/N$_2$, 40/40	Ar, 30	Ar, 40
Pressure (mTorr)	6	6	6	6	6	6
Film thickness (nm)	60	1.5	10–20	7	0.5	150

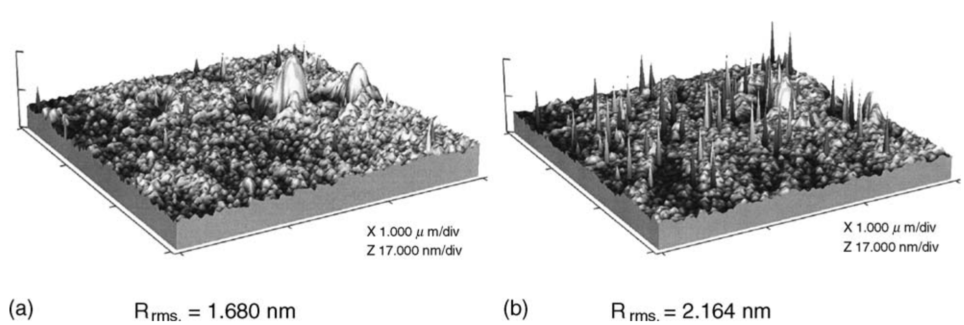

Fig. 2. The morphologies of Bi–Ge–Sb–Te films with thickness of (a) 10 nm and (b) 20 nm.