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Development of low-to-high Blu-ray recordable (BDR) disc

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ABSTRACT

Suitable compositions of antimony–indium–tin (Sb–In–Sn) and ceramic materials (ZnS–SiO_2), (($Sb_{100-x-y}$ $Sn_xIn_y)_P$(ZnS–$SiO_2)_Q$) are found possible candidates as phase change materials for high density optical data storage formats based on 405 nm laser for Write Once Read Many (WORM) application. In this work, we have developed a Blu-ray recordable, low-to-high (BDR L2H) disc that exhibits superior quality and meets most of relevant book specifications.

1. Introduction

Over last two decades, Optical media has become the most widely used storage and distribution medium for music, multimedia, movies, computer operating and application software, and other data. In today's world, the need for information is ever increasing as the business applications are getting more complex. Multimedia computer applications strive for increased reality with high quality video, 3D animation and multi-lingual hi-fi audio. The most recent development is the advent of Hi Definition (HD) digital transmission that is gaining ground the world across. Storage of 2 h of HD transmission data requires about 25 GB of storage space. The resulting demand for additional storage capacity has led to the development of higher density Blu-ray (BD) formats wherein the available capacity is orders of magnitude higher than 4.7 GB of single layer DVD (25 GB on BD single layer format) [1,2].

Rewritable BD disc, commonly abbreviated as BDRE, consists of a thin film multilayer stack in which the phase change film is sandwiched between two dielectric films of different thicknesses followed by a thick metallic film. A continuous laser wave with a large spot size (≈60–80 μm) is first used to crystallize the phase change film [3] by heating it to its crystallization temperature (T_C). The crystallized film is then irradiated with a focused laser beam of spot size ≈800 nm (wavelength 405 nm) for 10–30 ns, which subsequently heats the phase change layer to its melting point (T_M). After the laser passes this spot, the molten spot cools rapidly because of the large temperature gradient leading to the formation of an amorphous mark on the crystalline background.

Within the WROM recording, many physical mechanisms have been developed. Organic dye is most widely used as recording layer incase of CDR and DVDR. However, this mechanism suffers from one draw back, that is its strong dependence on the wavelength of the recording light. For example, the optical head used in the DVD devices operating at 650 nm, cannot read or write CDR discs that operate at 780 nm. Besides, dye based recording medium requires more laser power for recording and hence may have difficulties in recording at higher speeds. However, in the recordable Blu-ray disc, when the dye is used to record information, the unique push pull parameter show unambiguously higher order of magnitude and the formation of the smaller marks like 2T becomes difficult even after controlling the leveling ratio (dye on land versus dye on groove).

A more desirable approach on BDR technology is the use of inorganic phase change materials that have so far been the basis for the DVD rewritable technology. It has been established by earlier workers [4] that by properly selecting the composition, the phase-change materials can be made suitable for WORM application as well.

In BDR technology, depending on the phase change materials, two types of recording conditions, namely low-to-high (L2H) and high-to-low (H2L) are possible. The L2H refers to transition of reflectivity from low-to-high, whereas H2L refers to reflectivity transition from high-to-low upon formation of the recording marks. For the formation and detection of appropriate record-

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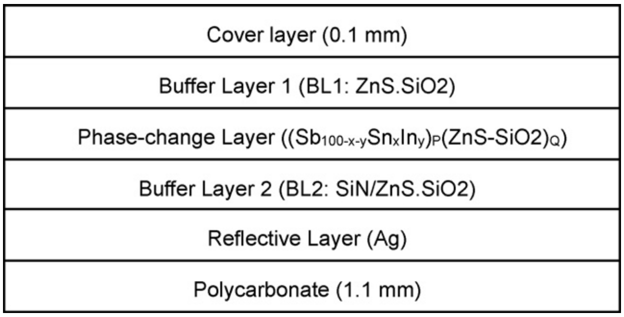

Fig. 1. Thin film layer stack configuration of BDR L2H optical media.

ing marks, it is necessary to have materials, which can transform either from amorphous to crystalline phase or vice-versa with sufficient difference in reflectivity between these two states when exposed to laser pulses of suitable power. Materials that have been developed over the years for BDR applications are Cu/Si [5,7], SbSnIn, InSb and BiFeO [6]. We have established that inorganic $Sb_{100-x-y}Sn_xIn_y$ material when doped with certain percentage of ceramics $ZnS–SiO_2$, could be used as the suitable material as phase change layer for the development of BDR L2H media. The following composition provides the best mark formation

$$(Sb_{100-x-y}Sn_xIn_y)_P+(ZnS–SiO_2)_Q, P = 95–98\% \text{and} Q = 2–5\%, x{:}y \sim 5$$

In the present work, we have made an attempt to use this material as the phase change layer and develop BDR L2H disc. We have optimized the layer stack design to achieve basic disc characteristics. The writing strategy was fine tuned in order to improve upon the 1X write power and 2X jitter. We have also attempted to develop a new phase change target material with reduced grain sizes of the ceramics in order to improve upon the 2X jitter.

2. Experimental

Multilayer stack of BDR was deposited on to a 1.1 mm grooved polycarbonate substrate using Unaxis multi chamber sputtering unit. Fig. 1 depicts the typical layer stack design. High purity sputtering targets of dielectric ($SiN/ZnS + SiO_2$), phase change and silver materials were used for sputtering various layers with argon as sputtering gas. Thicknesses of barrier layer 1 (BL1), barrier layer 2 (BL2), phase change and silver layers were optimized for better electrical performance. The dielectric BL1 and BL2 layers protect the phase change layer from environmental influences, whereas the silver metallic layer works as a heat sink medium apart from its reflectance characteristics. Thicknesses of films were optimized to obtain considerably higher contrast between the crystalline and amorphous state of the phase-change material. The BL1, dielectric layer in between the phase change and the cover layer are relatively thick in order to protect the cover layer from thermal damages during writing. Contrary to this, BL2, dielectric layer between the phase-change and the reflective layer is made thin, so that sufficient heat can reach to the metallic layer in order to make quenching possible. As the metallic layer acts as a heat sink during the quenching process, it is made sufficiently thicker. This optimization of various layer thicknesses is also very important from the point of view of lifetime of the discs.

The reflectance of the sputtered discs at 405 nm, before bonding, was measured using ETA-RT (Model: Steag Eta-optik). A 100 μm thick polycarbonate film was bonded with sputtered disc with pressure sensitive adhesive using vacuum bonding equipment. The electrical parameters of finished BDR disc, namely Jitter & ISI pattern were evaluated on ODU (Model: Pulsetec, ODU 1000).

3. Result and discussions

3.1. Optimization of the layer stack design and development of a suitable writing strategy

In order to get an optimized layer stack design, we developed a model where BDR L2H discs were produced through multiple experimentations with varying thicknesses of phase change layer, BL1 and BL2. Reflectivity was measured. From these measurements, we derived the optimized layer stack parameters, which are displayed in Table 1.

Table 1
Optimized layer stack parameters.

	Factors	Thickness (nm)
1	Reflective layer	200–230
2	Buffer layer 1	53–57
3	Buffer layer 2	2–6
4	Phase-change layer	10–15

We developed BDR L2H discs with this optimized layer stack design and measured all electrical parameters. The values of various parameters are tabulated in Table 2. It is evident that the BDR L2H disc using the optimized layer stack design and phase change composition shows excellent characteristics and meet most of the desired specifications. However, recording power at 1X and jitter at 2X requires improvement in order to obtain a BDR L2H discs that comply with the drives that have already been launched in the market based on other media types that require high recording power. Although, discs that require less write power, in general, are better from the perspective of drive design. Besides, this also means that our media is more sensitive making it more suitable for the development of high speed applications. We worked on to develop new writing strategy in order to improve upon these issues. It could be inferred from Fig. 2 that depicts power margin test where jitter is measured as a function of varying recording power at 1X with old and new writing strategies, that we could achieve significant improvement in the recording power at 1X with the new optimized writing strategy. Despite, we could not achieve the desired improvements in recording power at 1X or Jitter at 2X and hence worked on improving the stoichiometry of the phase change film by reducing the particle size of the dopant material.

3.2. Development of new phase change target material with reduced grain sizes of the ceramics in order to improve upon the 2X jitter

A new target was developed with the same composition as $(Sb_{100-x-y}Sn_xIn_y)_P + (ZnS–SiO_2)_Q$, $P = 95–98\%$ and $Q = 2–5\%$ but with smaller grain sizes of ceramics, as our earlier work on rewritable formats did indicate that this helps a lot in improving the mark formation. Figs. 3 and 4 display the SEM micrograph of the phase change materials with larger (5–15 μm) and smaller (<5 μm) grain size ceramic materials respectively.

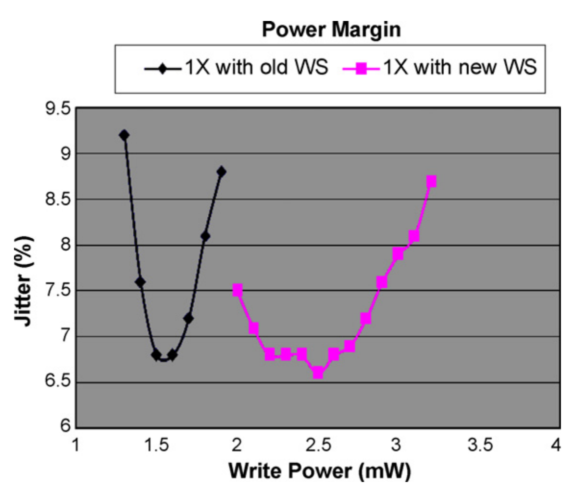

Fig. 2. Power margin plot for BDR L2H media at 1X recording speed.

Table 2
Recording characteristics of BDR L2H on ODU; measurement A: with optimized layer stack design, measurement B: with optimized writing strategy; measurement C: with finer grain phase change material.

Item	Unit	Specs	Measurement A	Measurement B	Measurement C	Specs	Measurement A	Measurement B	Measurement C
Write speed				1X				2X	
Measurement speed				1X				1X	
	WS->			N1				N1	
LEQ-gain	dB			7				7	
Radius for measurement	mm		26–27	26–27	26–27		30–31	30–31	30–31
Pwo	mW	3.0–6.0	1.7	2.6	3	3.0–7.0	3.1	3.2	3.1
Pbwo	mW	0.1–4.0	0.1	0.2	0.4	0.1–7.0	0.2	0.3	0.2
Pso	mW	0.3–4.0	0.4	0.9	0.9	0.3–5.4	0.8	0.95	1
Pco	mW	0.1–4.0	0.1	0.2	0.4	0.1–5.4	0.2	0.3	0.2
R8H		16–35	29.2	28.8	24.4	11–24	29.2	28.8	23.7
I8/I8H		≥0.4	0.42	0.43	0.43	≥0.4	0.42	0.42	0.42
I2/I8		≥0.040	0.2575	0.2672	0.052	≥0.040	0.2084	0.2106	0.053
R8H*I2		≥0.0036	0.012	0.011	0.0055	≥0.0036	0.012	0.014	0.0054
Asymmetry		−0.1 to +0.15	−0.017	−0.023	−0.015	−0.1 to +0.15	−0.05	−0.042	−0.023
Jitter (initial value)	%{leading}	≤7	6.8	6.6	6.6	≤7	7.7	7.4	6.8
	%{leading}	≤7	6.9	6.8	6.7	≤7	7.5	7.6	6.8
Jitter (initial value) at Pwo*0.90	%{leading}	≤7	6.9	6.8	6.9		7.3	7.3	6.9
	%{leading}	≤7	6.7	6.9	7		7.4	7.4	7.0
Jitter after 10E−6 times read at 1X and Pr = 0.4 mW (DC)	%{leading}		7	6.9					
	%{leading}		6.6	6.7					
Jitter after 10E times read at 1X and Pr-0.3 mW (HFM)	%{leading}		7.1	7					
			6.9	6.8					

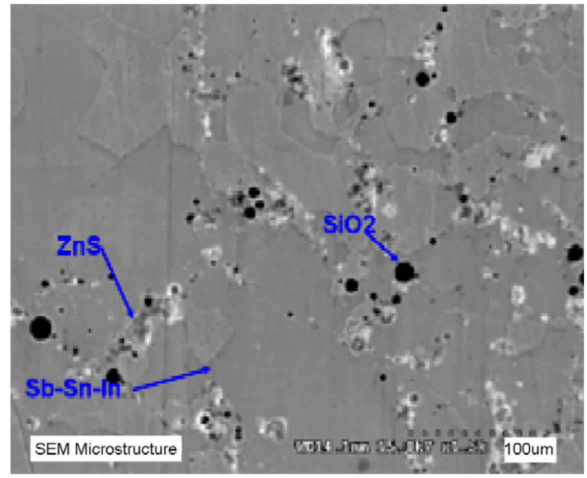

Fig. 3. SEM micrograph of phase change material doped with ceramics ZnS–SiO_2 (particle size between 5 and 15 μm).

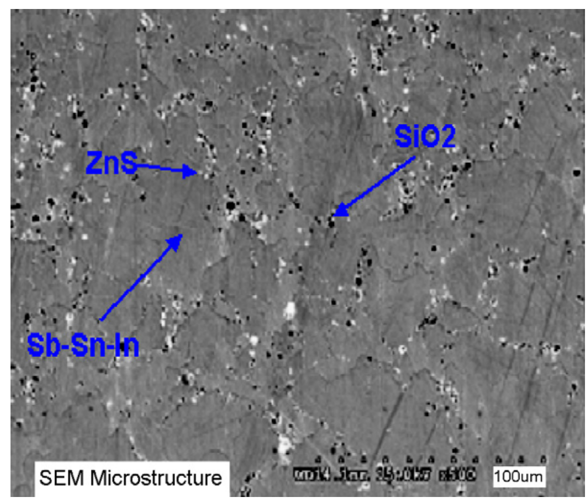

Fig. 4. SEM micrograph of phase change material doped with ceramics ZnS–SiO_2 (particle size <5 μm).

Samples of BDR L2H were prepared once again with this new material as phase change target and optimized stack layer. The discs were recorded using the optimized writing strategy as developed above. All electrical parameters were measured and are tabulated in Table 2. This time we succeeded in increasing the recording power at 1X and also decreasing the Jitter at 2X recording and all the parameters were meeting the book specifications.

4. Conclusion

The results as displayed in Table 2 clearly show that BDR L2H discs made with our phase change composition and the optimized layer stack configuration show improved electrical and optical performance when recorded with the optimized writing strategy and meet book specifications. To the best of our knowledge, we have demonstrated the process of obtaining a commercial BDR L2H disc by discovering an innovative phase change material, layer stack design and writing strategy.

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