High-speed rewritable DVD

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ABSTRACT

Indium antimony (InSb) phase-change material with high antimony content is studied to apply to a recording layer for 12x rewritable digital versatile disc (DVD). To develop such a high-speed rewritable optical disc with sufficient thermal stability of the recorded signal, not only the Sb content and the crystal structure of InSb but also write pulse conditions are discussed. As the result, EFM+ jitter values after 10 times direct overwrite on InSb recording layer are obtained by less than 9% at the wide write speed condition ranging from 3.3x to 12x.

Keywords: Optical disc, Indium antimony, phase-change, rewritable disc, DVD.

INTRODUCTION

The annual market for rewritable media in 2005 is expected by 550 million discs. Its growth rate is around 15%. In 2006, market demand forecast for rewritable media will achieve to 600 million discs. From Fig.1, it can be seen that rewritable DVD products are pushing the market growth nevertheless CD-RW demand decreases. To keep this growth, new high-performance media should be continuously introduced into the market. In order to realize the new high-performance media, one of the directions is development of high-speed rewritable media towards the ultimate recording speed such as 16x. The other one is development of dual layer rewritable DVD. In this paper we focus on the new technologies for high-speed DVD.

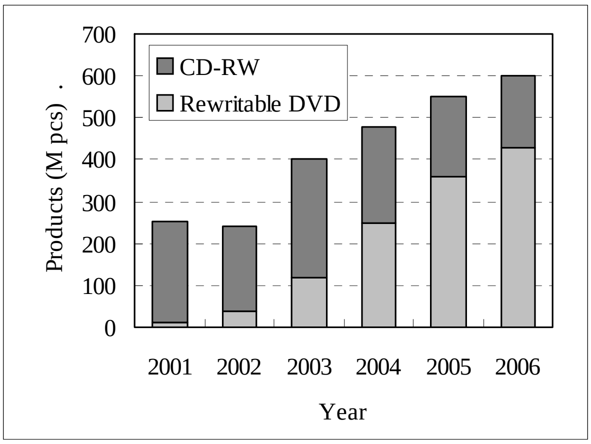


Fig.1 DVD R/RW disc demand forecast

This year we have introduced 8x DVD+RW into the market as the highest rewritable DVD which can be written at 3.3 to 8x. However it means this 8x media doesn't have backward compatibility with the legacy 1-2.4x and 1-4x DVD+RW media. The users who are using 4x drive cannot use 8x media in their drive. It may restrict the market growth. From user convenience point of view, when we develop the next high-speed media, it should keep the backward compatibility with 8x media at least. In order to satisfy this request, although several technologies are developed to maintain ultimate rewritable DVD, but the development of the new technologies for wide-speed rewritable will be very important.
In this paper we discuss on the design of a high-speed rewritable media with InSb phase-change material and the technologies for write strategy to assist the wide-speed recording.

INDIUM ANTIMONY PHASE-CHANGE MATERIAL FOR HIGH-SPEED RECORDING

We are investigating several Sb-based materials for high-speed recording.[1), 2), 3)] At the eutectic composition, the crystal structures of GaSb and GeSb (Ga12Sb88, Ge15Sb85) are assigned as hexagonal structure which is same as the structure of Sb. On the contrary the crystal structure of InSb (In32Sb68) is a simple cubic. Figure 2 shows X-ray diffraction patterns at the Sb content around 80 atomic % for each Sb-based materials measured by using well-monochromated synchrotron radiation at SPring-8. The crystal structure is cubic for InSb and hexagonal for GaSb and GeSb. The crystal structure is still cubic for InSb under Sb-rich content.

As for the crystallization speed of these Sb-based material, it is known that these materials have higher crystallization speed than that of conventional AgInSbTe which is using for CD-RW and 1-4x rewritable DVD.[1)]

Fig. 3 shows the maximum erase velocity for GaSb, GeSb, and InSb dependency on Sb contents. It is determined by a DC-erasability experiment in which 10 times rewriting 14T carriers could be reduced at -25 dB. This clearly shows that InSb had the highest crystallization speed of these materials when the Sb content is same.

From the results of our previous study of crystallization speed for Sb-based material, the structure of GaSb and GeSb becomes closer to the Sb structure and the crystallization speed becomes higher when the Sb content increases. The relationship between crystal structure and crystallization speed in this GaSb and GeSb case is easy to understand because crystallization speed of Sb is very high. Prof. Okuda also reported the excess Sb effect for the dynamics of rapid crystallization in PCOS 2002.[4)]

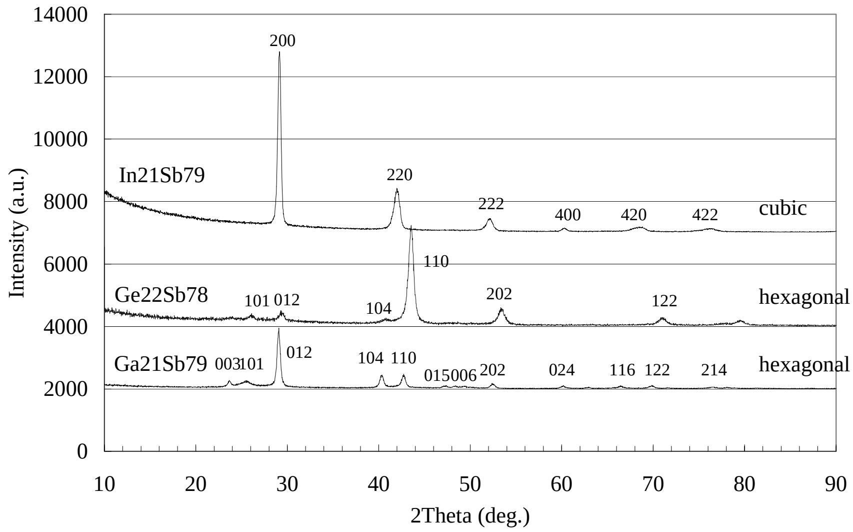


Fig. 2 X-ray diffraction pattern of Sb-based materials, GaSb, GeSb, and InSb with the Sb content around 80%[3)]

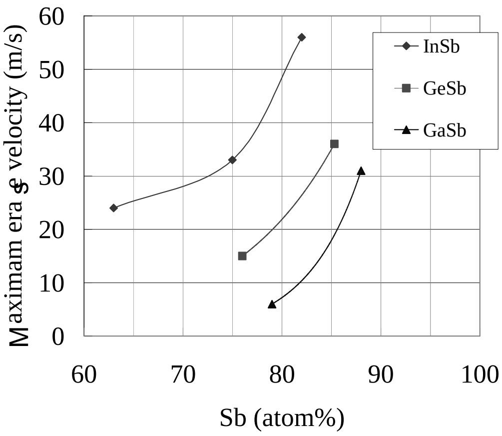
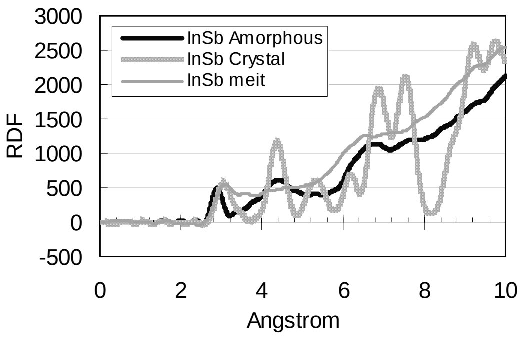
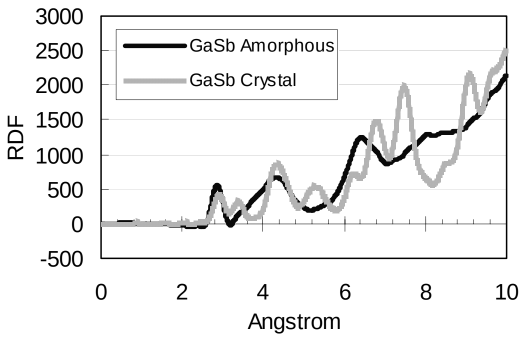


Fig. 3 Maximum erasable velocity for each Sb based materials[2), 3)]



(a)



(b)

Fig. 4 Radial distribution function (RDF) of amorphous and crystal states of (a) $In_{21}Sb_{79}$ and (b) $Ga_{22}Sb_{78}$ measured by using X-ray scattering

However, while crystallization speed of InSb is higher than the other Sb-based materials, InSb keeps the cubic structure. To analysis this different relationship between crystal structure and crystallization speed among GaSb, GeSb and InSb, we measured the medium-range structure for InSb and GaSb by X-ray scattering. This measurement was carried out by using synchrotron radiation at BL19B2 in SPring-8. For InSb, high-temperature X-ray scattering is also carried out at 1000K. At this thermal condition the material is melt that is confirmed by in-situ video monitoring.

With respect to the RDF pattern of the melt described in Fig.4 (a), the first peak is clear and the other peaks are broad. Furthermore this first peak of the melt is almost same position as that of InSb measured at room temperature. This suggests that crystallization of InSb from the melt is rapidly running, because it assumed that the nearest neighbor atoms move not so for a long distance at the crystallization process. On the other hand the first peak of RDF of GaSb with hexagonal structure splits into two peaks. It may require the nearest neighbor atoms to form two types of bonds with different bond length. The high-temperature X-ray scattering is not measured yet but the first RDF peak of GaSb melt will be one peak and the peak position will be an average of first and second peaks of GaSb. At forming these bonds, it assumed that the atoms have to move a certain distance and takes much longer time than that for the InSb bonds forming.

DESIGN OF HIGH-SPEED REWRITABLE DVD

At the development of 8x rewritable DVD, it is known that certain write strategy condition causes a high BER (Byte Error Rate) at the intermediate velocities.[5] Fig. 5 is TEM photograph of high BER 3T mark which is written at 6x condition on 8x rewritable DVD. A rapid crystal growth accidentally occurred at the tail of a written mark. In our experience, when the crystallization speed of phase-change material becomes high, it makes probability of this accidental crystal growth at the written mark increases.

To prevent this BER, in this work, InSb content and write strategy (WS) are optimized.

In our previous paper, $In_{18}Sb_{82}$ is feasible phase-change material for 16x rewritable media. However to solve this BER problem the maximum erasable velocity of InSb material has to be reduced to maintain an acceptable BER by optimizing Sb content and additional elements.

Fig.6 shows the RDF for amorphous phase and crystal phase of optimized InSb material. Although the maximum erasable

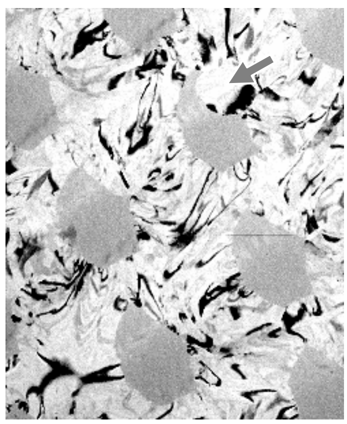


Fig. 5 TEM photograph of high BER 3T mark

velocity is reduced but the geometry of the first RDF peak after optimization is not so different from the RDF pattern in Fig. 4 (a).

On the other hand to prevent this BER with keeping good jitter of the written mark, WS study is very important for designing a high-speed rewritable media system. In order to maintain low BER at high-speed recording condition, no or short cooling gap WS depicted in the middle of Fig. 7 is effective which is also reported in ISOM/ODS 2005.

Furthermore when we use the conventional type multi-pulse WS with cooling gap depicted in upper part of Fig. 7 for low-speed recording we must carefully adjust the cooling gap length to maintain low BER.[5)]

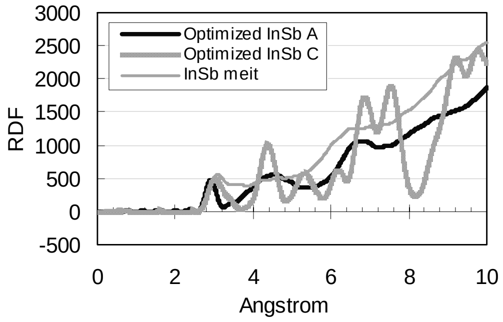


Fig. 6 RDF pattern of optimized InSb phase-change material

Simultaneously at the optimization of WS for high-speed recording, write power condition has to be studied. When recording speed becomes higher than 10x, the WS with low Pe and high Pw parameters will be preferable to keep low jitter. Indeed the Pe/Pw ratio is around 0.25 for 8x rewritable DVD instead of 0.5 for 2.4 or 4x rewritable DVD. In such low Pe/Pw condition as seen in 8x rewritable DVD, erasability of the written mark will be reduced. In generally the effective laser spot size of Pe for erasing is considerably smaller than amorphous mark width. From this estimation the amorphous mark width should be reduced at high-speed recording.

The first trial of our WS study for high-speed recording is high-Pb condition applying to 2T WS with no cooling gap depicted in the middle of Fig.7. In generally, at forming amorphous marks, a rapid cooling condition such as low Pb case makes mark width larger because re-crystallization from melt edge is suppressed. In high Pb condition the amorphous mark width is expected to form narrower than that of low Pb case.

As the result, we can successfully reduced the amorphous mark width at over 10x recording speed conditions and direct over write can be realized up to 16x. However from the pulse waveform observation, raise and fall time of the actual write pulses were critical at over 10x recording speed conditions.

The second step of our trial is applying block type WS depicted in bottom of Fig. 7 for the high-speed recording. This type WS is already applied to 16x recordable DVD, so called Castle WS. The problem of raise and fall time of the write pulse as seen in multi-pulse WS is not critical to use this type WS.

Fig. 8 shows the modulation dependency on WS. Castle WS effect for the written amorphous mark width reduction is calculated by around 10% compare with 2T WS at 12x.

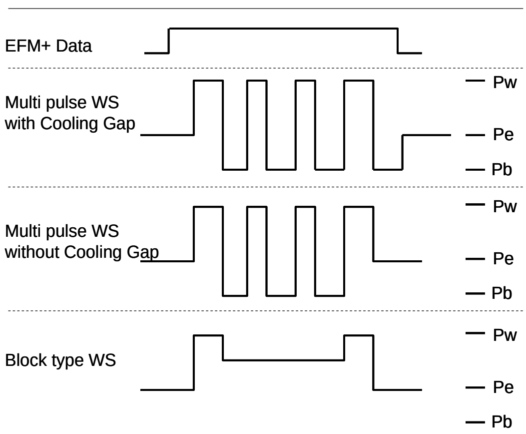


Fig. 7 Schematics of WS type for rewritable media

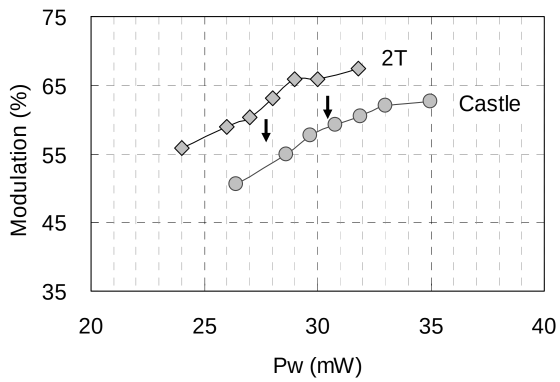


Fig. 8 Modulation dependency on WS at 12x write

HIGH-SPEED REWRITABLE DVD

To confirm our approach to maintain high-speed rewritable DVD discussed in the previous section, we prepare the test disc with optimized InSb material and do the rewrite test by using Castle WS combined with 2T WS.
The write pickup conditions used in this test are; wavelength is 659nm, lens NA is .065. 2T WS is used for the write speed ranging from 3.3 to 8x condition and Castle WS is used for 12x and 16x write conditions. The parameters of each WS are optimized at each write speed condition individually.

Fig. 9 shows the test result, the bottom jitter at direct overwrite 10times is plotted as function of the each recording speed and compared with the result from 8x rewritable DVD with GaSb-based material. The melting point of InSb is 490^{o}C which is 90 degrees lower than GaSb and GeSb. The write power at 8x for the test disc is around 35mW which is almost same as that for 8x rewritable DVD. This is one of the effective characteristics of InSb material to keep the compatibility with 8x rewritable DVD. Furthermore we confirmed that the castle WS improves the over write performance at over 10x recording. These results suggest that InSb material will be suitable material to apply to a 12x rewritable DVD.

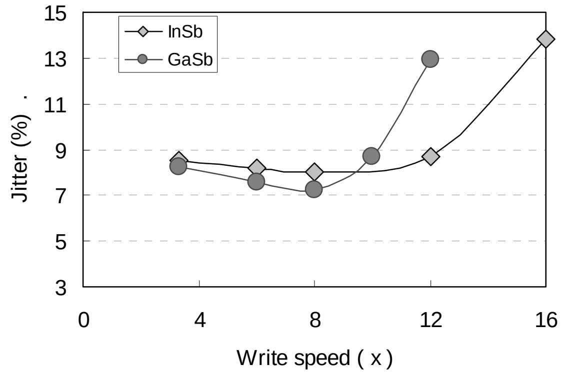


Fig. 9 DOW 10 jitter dependency on each write speed conditions

CONCLUSION

Indium antimony (InSb) phase-change material with high antimony content is optimized and applied to a recording layer for 12x rewritable DVD. Simultaneously Castle WS combined with 2T WS is applied for the high-speed and wide-speed recording. As the result, it is confirmed that optimized InSb combined new WS is suitable technology to realize 12x rewritable DVD with backward compatibility with 8x rewritable DVD.

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