Phase-Change Material for High-Speed ReWritable Media

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1. Introduction

AgInSbTe-system was first reported in 1991 as completely erasable phase-change material[1)]. Since then, this material is widely used as recording material in phase-change media such as CD-RW and DVD+RW [2) 3)]. By these days, 1 to 4X DVD media with AgInSbTe-system have been developed[4)]. It is easy to get higher data transfer rate media using this material because the crystallization speed of AgInSbTe could rise by increasing the Sb concentration[5)]. However the Sb concentration becomes high, the thermal stability of amorphous marks becomes worse. To achieve further high-speed media, several Sb-based phase-change materials are investigated. Recording characteristics of GaSb media are evaluated as one example for Sb-based material.

2. Crystal structure and crystallization temperature

To compare SbTe-system with other Sb-based material, crystal structure and crystallization temperature were studied. Crystal structure was analyzed by powder X-ray diffraction. The conventional phase change disks with $Sb_{78}Te_{22}$, $Sb_{88}Te_{12}$ and AgInSbTe were crystallized by laser irradiation. After substrate, reflective layer and coating layer were removed, powder samples were created. These powders were put into 0.2 mm-diameter capillary tube and measured with well-monochromated, ultra-bright synchrotron radiation. The wavelength was 0.419 Å. Sb powder was also measured for comparison. Fig. 1 shows results of powder X-ray diffraction. The spectrum pattern of $Sb_{78}Te_{22}$ and AgInSbTe were identified as distorted NaCl structure. On the other hand, $Sb_{88}Te_{12}$ was almost same as that of Sb powder. Those were identified as hexagonal structure. To compare with Sb structure, lattice constants are calculated as hexagonal structure that is shown in Fig.2. In order to study thermal stability, crystallization temperature (Tc) was measured by using differential scanning calorimetry (DSC220: Seiko Instruments Inc.), in which amorphous materials are heated at a constant heating rate of 10 °C/min. Lattice constant and Tc of SbTe are listed in table 1. The dependence of Tc on lattice constant *a* is shown in Fig.3. Tc falls down as lattice constant *a* get close to that of Sb by increasing Sb concentration of SbTe. When Sb is increased for high-speed, a recorded mark becomes unstable.

To achieve further high-speed media with stable amorphous mark, new Sb-based materials are investigated. As pure Sb has 80m/s high crystallization speed[6)], it is expected that we can get new materials by choosing added element to Sb that have both high-speed crystallization and thermal stability of amorphous marks. Fig. 4 shows powder X-ray diffraction of GeSb, GaSb and InSb. The spectrum of InSb was identified as cubic structure. The spectra of GaSb and GeSb were identified as hexagonal structure. Lattice constant calculated as hexagonal structure and Tc are listed in table 2. Fig. 5 shows the dependence of Tc on lattice constant a of Sb-based material. Tc of GaSb and GeSb is higher than that of SbTe-system. It suggests that the material having short lattice constant such as GaSb and GeSb has high thermal stability.

3. Crystallization speed

For further investigation of Sb-based material, characteristics of the phase-change media with GaSb material were evaluated. Fig.6 shows the schematic diagram of the static tester. For monitoring real time phase-change, it has two beams optical path. One is for writing the other is for monitoring reflectivity of the test disc. Fig.7 shows static test results for GaSb and SbTe. Crystallization speed was calculated from erasure time of a recorded mark which diameter is same as beam spot size. Mark size was determined by measuring the reflectivity dependence on write power. Crystallization speed of $Ga_{9.6}Sb_{90.4}$, $Ga_{12}Sb_{88}$ and $Sb_{75}Te_{25}$ were measured as 38.3, 23.3 and 9 m/s, respectively. Crystallization speed of GaSb is higher than that of $Sb_{75}Te_{25}$.

4. GaSb recording characteristics

To confirm the performance of GaSb material, recording characteristics of GaSb media are studied. Figs. 8 and 9 show the dependence of erasability and carrier to noise (C/N) ratio on recording velocity, respectively. Write strategy is optimized at every write speed condition. Erasability less than -30 dB is obtained at linear velocity range of 14-27.9 m/s (DVD 4 to 8X). C/N ratio more than 45 dB is obtained at linear velocity range of 14-35 m/s. Fig.10 shows jitter variation of $Ga_{12}Sb_{88}$ media under accelerated 80ºC85%RH circumstance. The amorphous marks were written at 27.9 m/s. Little change of jitter value through 300 hours indicates $Ga_{12}Sb_{88}$ media have good archival stability.

5. Conclusion

High thermal stability of Sb-based phase change material such as GaSb and GeSb is due to the short lattice constant. In particular, GaSb material has possibility to obtain high-speed rewritable media since it has good archival stability and erasability in the range of DVD 4 to 8X linear velocities.

References

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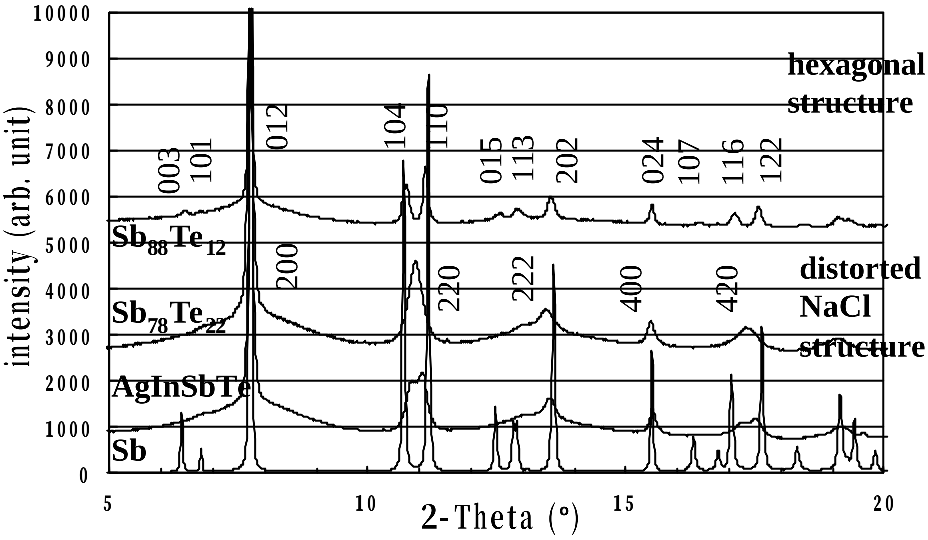

Fig.1 Powder X-ray diffraction of SbTe, AgInSbTe and Sb

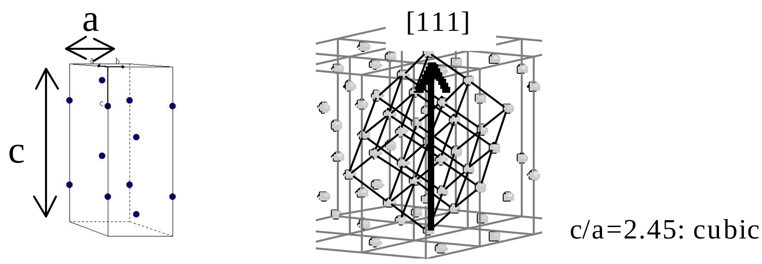

Fig.2 Unit cell of hexagonal structure ($R\bar{3}m$)

Table.1 Lattice constant, Tc of Sb and SbTe

composition	a(Å)	c(Å)	c/a	Tc (℃)
Sb78Te22	4.402	10.766	2.445	120.5
Sb88Te12	4.327	11.116	2.576	79.5
Sb	4.300	11.273	2.622	room temperature

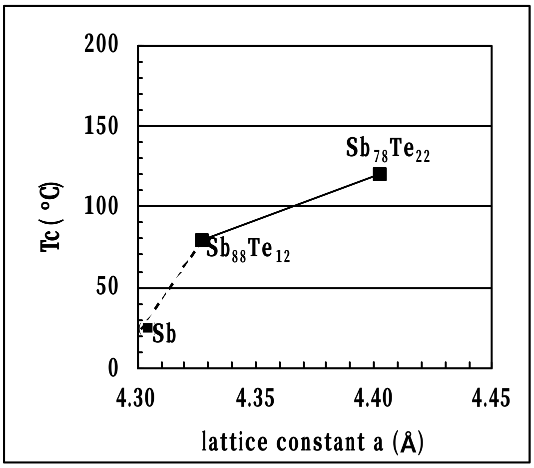

Fig.3 Dependence of Tc on lattice constant a of SbTe

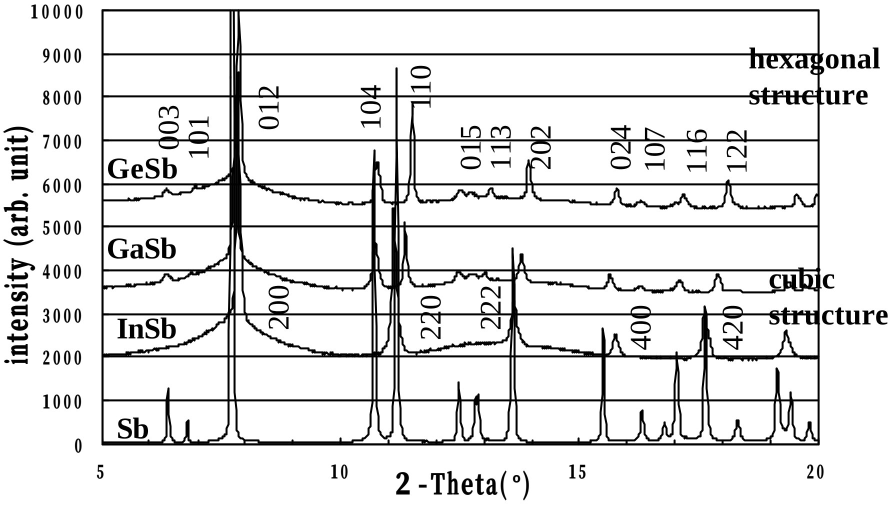

Fig.4 Powder X-ray diffraction of GeSb, GaSb, InSb and Sb

Table.2 Lattice constant, Tc of Sb-based material

composition	a(Å)	c(Å)	c/a	Tc (℃)
Sb	4.300	11.273	2.622	room temperature
Ga12Sb88	4.240	11.307	2.667	194.5
Ge16.7Sb83.3	4.185	11.320	2.705	255.5
In31.7Sb68.3	4.323	10.618	2.456	114.1

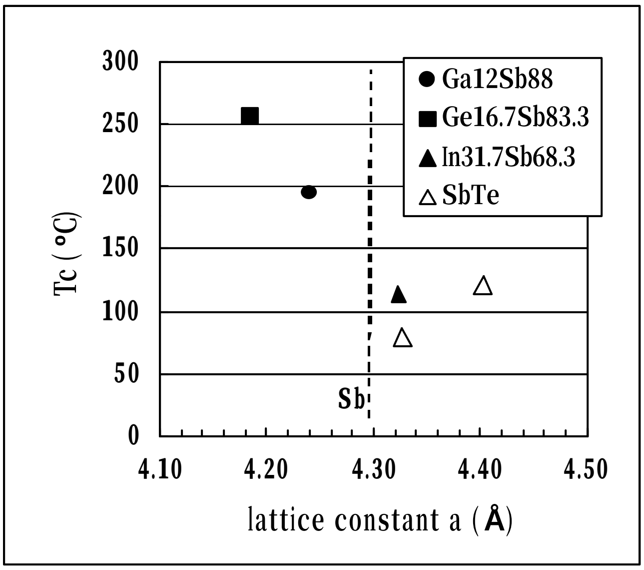

Fig.5 Dependence of Tc on lattice constant a of Sb-based material

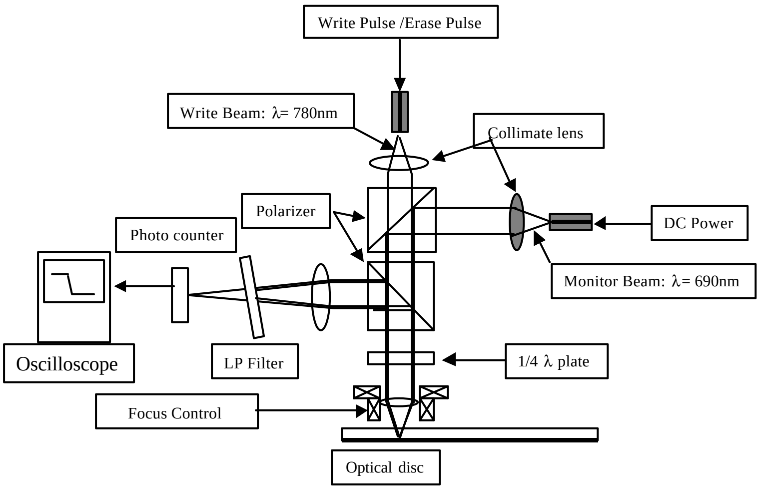

Fig.6 Schematic diagram of the static tester

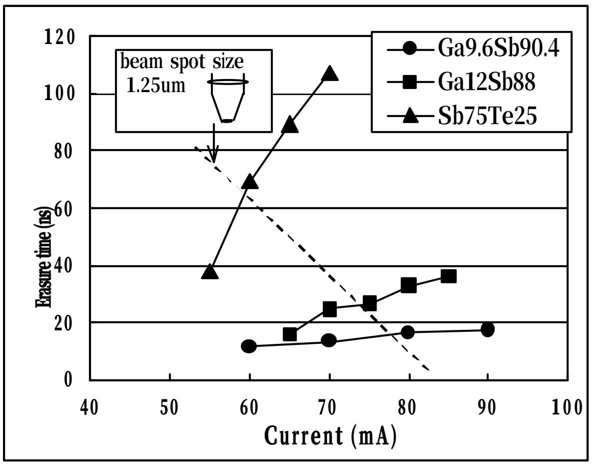

Fig.7 Erasure time of GaSb and SbTe media

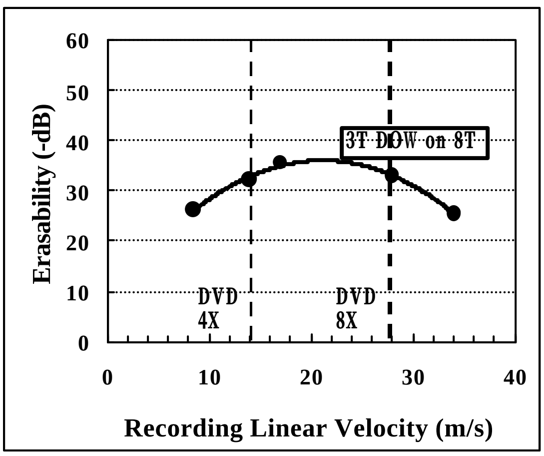

Fig.8 Dependence of erasbility on recording linear velocity

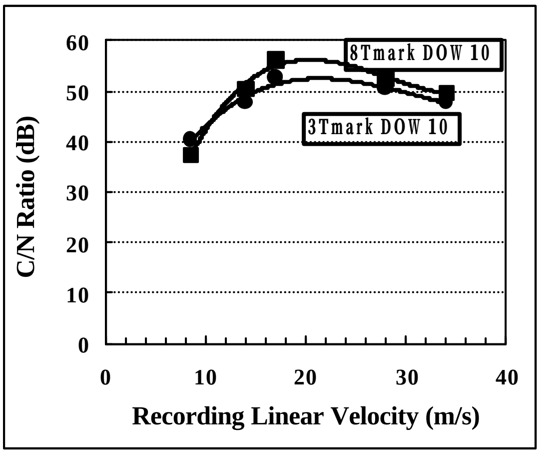

Fig.9 Dependence of C/N ratio on recording linear velocity

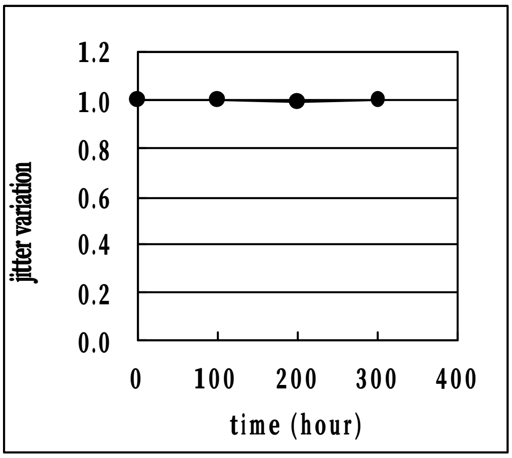

Fig.10 Jitter variation under accelerated 80ºC85%RH circumstance