Land/groove optical recording with GeTe/Sb₂Te₃ superlattice-like structure

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A superlattice-like (SLL) structure was applied to phase-change optical recording. The recording layer consisting of alternating thin layers of two different phase-change materials, GeTe and Sb₂Te₃, were grown by magnetron sputtering on polycarbonate substrates. Land/groove optical recording was adopted to suppress crosstalk and obtain a large track density. Dynamic properties of the SLL disc were investigated with the shortest 1T pulse duration of 8 ns. Clear eye pattern was observed after 10000 direct overwrite cycles. Erasability above 20 dB was achieved at a constant linear velocity of 19 m/s. Carrier-noise ratio (CNR) kept above 46 dB when the recording frequency reaches 21 MHz. The SLL phase change optical disc demonstrates a better recording performance than the Ge₁Sb₀.₅Te₄ and Ge₁Sb₀.₅Te₇ discs in terms of CNR, erasability, and overwrite jitter.


Research of phase-change recording materials dates back to more than three decades ago. In 1968, Ovshinsky discovered a new order-disorder memory phenomenon in chalcogenide film materials, later termed “Ovonic memory”. In addition to the electrical switching effect, these materials also exhibit laser optical memory effect. Since then, a number of great improvements have been made. In 1985, Chen et al. reported that the erase time of less than 30 ns could be achieved without compromising data stability by using a medium based on stoichiometric compounds, which greatly enhanced the practicality of a phase-change recording system. In the last decade, the development of high-density phase-change optical recording has drawn increasing attention for its unique features of large capacity, direct overwrite (DOW), low cost, and non-contact data retrieval. Data storage density and recording performance are the two mostly concerned aspects. The former is limited by the optical diffraction limit and crosstalk between adjacent tracks, whereas the latter is mostly related to structure and properties of the optical media. In order to improve the recording performance of high-density phase-change optical media, stoichiometric compounds of GeSbTe and AgInSbTe systems were widely applied in rewritable phase-change optical recording for their featuring characteristics of suitable crystallization and melting temperatures for laser induced phase changes and rapid transition in nanosecond range. On the other hand, more complicated disc structures were invented to improve the performance of the optical media, wherein additional layers were used, including a thermal balance layer, an optical compensation layer, and interface layers, etc. Recently, we proposed a novel superlattice-like (SLL) structure phase-change optical recording technology, in which a SLL structure of phase-change materials is introduced into the recording layer of the optical media to accelerate the crystallization process and enhance the structural stability of the recording layer.

In this letter, we report the latest progress of this new recording technology. The GeTe/Sb₂Te₃ SLL structure was applied to land/groove optical recording, which permits double track density. The dynamic recording performance of the SLL discs was investigated with the shortest 1T pulse duration of 8 ns and was compared with the typical conventional Ge₁Sb₀.₅Te₄ and Ge₁Sb₀.₅Te₇ discs, which were identified to have structural stability and fast recording speed, respectively.

Figure 1 depicts the structure of the SLL phase-change optical disc. Quadri-layer thin films are formed on the polycarbonate substrate: the lower dielectric layer with the thickness of 100 nm, the upper dielectric layer of 23 nm, and the reflective layer of 100 nm. The phase-change recording layer is sandwiched by the two dielectric protective layers of ZnS-SiO₂, and the reflective layer of Al alloy is attached. The phase-change layer was prepared by alternative sputtering of two different phase-change materials, GeTe and Sb₂Te₃, with thickness varying from 2 to 6 nm. Samples were prepared on 0.6-mm-thick polycarbonate substrates, with land/groove spiral type tracks. Discs with the recording layer of Ge₁Sb₀.₅Te₄ and Ge₁Sb₀.₅Te₇ with similar structure were prepared for comparison.

The sputtering system used in the experiment is Balzers cube system. It consists three target chambers, two direct current (DC) sputtering chambers and one radio frequency (RF) chamber, which enable alternative sputtering of GeTe and Sb₂Te₃ without exposure to the atmosphere. DC sputtering was used to deposit electrically

![Fig. 1. Cross-section view of SLL phase-change optical disc.](http://www.col.org.cn)
conducting materials GeTe, Sb₂Te₃, and Al alloy. RF sputtering was used to deposit non-conducting material ZnS-SiO₂. The background vacuum was at the level of 7×10⁻⁵ Pa. The work pressure was (4.5–5.5)×10⁻¹ Pa, while the processing gas was 15 sccm Ar.

The dynamic properties of writing, reading, and erasing were tested using a commercial dynamic tester (ShibaSoku DVD TESTER LM330A). In order to reduce the influence of thermal interference, multi-pulse recording method with pattern adaptive compensation function was adopted. Figure 2 shows a schematic diagram of write strategy used in this experiment. In the dynamic measurement, the power and wavelength of the laser were properly set to achieve the best performance of the disc. If the pulse width and power were not optimized, the amorphous marks from the previous recording cannot be completely erased. This will cause the distortion in the overwritten marks, and hence a high noise level.

Data marks of the universal disc format (UDF) were written on the discs, and were then examined using a Zeiss Optical Axioplan microscope. The image of mark spots observed at the magnification of 2000 times is shown in Fig. 3. The recording marks can be clearly identified with various mark lengths, which indicates high carrier-noise ratio (CNR) and low overwrite jitter.

A comparison is made between the SLL phase-change disc and the conventional four-layer discs of Ge₁₋₈Sb₂Te₄ and Ge₁₋₈Sb₂Te₇. The dependence of CNR on recording frequency is shown in Fig. 4, which was measured at a constant linear velocity (CLV) of 19 m/s with different signals from 3T to 14T (1T = 8 ns). The CNR of SLL disc keeps 51 to 46 dB from 4.5 to 20.8 MHz recording frequency, which corresponds to signals 14T to 3T, and mark length 3.14 to 0.67 μm. It is much higher than those of the Ge₁₋₈Sb₂Te₄ and Ge₁₋₈Sb₂Te₇ discs, and is enough for the information retrieving from the discs. The SLL disc has an erasability ranging from 31 to 22 dB, which is much higher (about 6 dB) than the Ge₁₋₈Sb₂Te₄ and Ge₁₋₈Sb₂Te₇ discs. This is vital for the disc to be directly overwritten.

As well known, data transfer rate of DOW discs are limited by the erasability. Figure 5 shows a comparison of the dependence of erasability on CLV between the SLL phase-change disc and the reference discs. Increasing the CLV from 6 to 19 m/s, the erasability value drops from 32 to 2 dB for the Ge₁₋₈Sb₂Te₄ disc and from 27 to 3 dB for the Ge₁₋₈Sb₂Te₇ disc, whereas it just drops from 35 to 20 dB for the SLL disc, which indicates that SLL structure is more suitable for high speed phase-change recording.

Figure 6 shows the dependence of jitter on overwrite cycle number when the discs were written by 3T – 14T random signals. The jitter of the SLL disc remains below 9% after 1000 times of DOW cycles. For the reference
optical disc and improve the overwrite properties. Figure 7 shows the eye patterns of repeatedly overwritten tracks after $10^4$ cycles. The eye patterns are clearly observable for the optical disc with SLL phase-change recording layer. The signals from $3T$ to $14T$ ($1T = 16$ ns) can be easily distinguished even after $10^4$ cycles. Although the eye patterns of Ge$_2$Sb$_2$Te$_4$ reference disc are fairly good after $10^4$ DOWs, it has a very low erasability (see Fig. 4). For the Ge$_2$Sb$_2$Te$_5$ disc, after $10^4$ cycles, the eye pattern becomes obscure and cannot be recognized.

In conclusion, we have deposited two phase-change materials, GeTe and Sb$_2$Te$_3$, alternatively on a polycarbonate substrate to form a SLL structure, which was sandwiched by two dielectric layers. Although neither GeTe nor Sb$_2$Te$_3$ could be used as a phase-change material for practical applications, present experimental results revealed that the phase-change optical disc with the SLL structure demonstrated an excellent dynamic recording property that could meet practical recording requirements. It was demonstrated that better CNR, erasability, overwrite property, and sensitivity could be achieved as compared with the Ge$_2$Sb$_2$Te$_4$ and Ge$_2$Sb$_2$Te$_5$ reference discs with a single recording layer. The SLL structure gives an alternative to increase the recording performance of the phase-change optical disc. Further work is required to investigate the mechanism and physics that lie behind the experimental results.

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References