A study to optimize Sb-Te layer preparation for super-resolution readout using PtOx recording layer

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ABSTRACT

Composition of Sb-Te alloy and its layer thickness were varied to study the condition for better super-resolution effect in a super-resolution near-field structure disc using PtOx recording layer. We have confirmed that Sb-Te composition should be adjusted to near a eutectic point ($Sb_{70}Te_{30}$) and optimized the layer thickness to 15 nm probably as a result of controlling the temperature increase by the readout-laser irradiation.

Key words: super-RENS, super-resolution readout, PtOx, Sb-Te, eutectic point, Raman scattering

1. INTRODUCTION

Super-resolution near-field structure (super-RENS) disc[1] has become one of the promising techniques for future high-capacity optical disc since the discovery of PtOx recording layer.[2] Sb-Te layer (that is sandwiched by $ZnS\text{-}SiO_2$ layers) plays a role in the super-resolution readout, and Hwang *et al.* have previously reported that it is important to adjust its composition to near a eutectic point.[3] We have confirmed their results, and further examined on the Sb-Te layer thickness optimization. We also prepared Sb/Te stacking layers replacing the Sb-Te layer, and compared the super-resolution readout properties.

2. EXPERIMENTS

All the samples were fabricated by RF magnetron sputtering, and Fig. 1 shows the super-RENS disc structure. The details concerning PtOx layer preparation are found in ref. 4. The disc properties were evaluated by an optical disc drive tester (DDU-1000, Pulstec Industrial Co.) with the laser wavelength (λ) and the numerical aperture (NA) of 635 nm and 0.60, respectively. Disc rotation speed was 4 m/s, and the duty ratio for recording was set at 50%. The resolution limit of our optics is 265 nm ($=\lambda/4NA$), and a 200-nm mark length was used for the evaluation of super-resolution effect. Sb/Te stacking layers prepared on SiO_2 substrate was annealed in Ar gas atmosphere using a heating stage (THMS600, Linkam Scientific Instruments). Raman scattering was measured in a backscattering geometry at room temperature using the 632.8 nm line of a He-Ne laser (Ramascope, Renishaw).

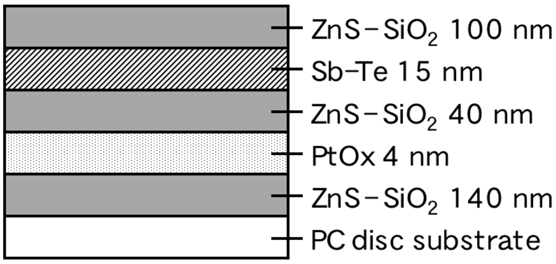

Fig.1 Super-RENS disc structure

3. RESULTS & DISCUSSION

Fig. 2 shows the carrier-to-noise ratio (CNR) properties of 200-nm mark trains as a function of the readout laser power for various Sb-Te compositions. A eutectic point of Sb-Te locates at around $Sb_{70}Te_{30}$,[5] and the results confirmed an advantage of selecting the composition to its vicinity for high-CNR super-resolution readout.[3, 6] CNRs of 46 dB and 49 dB were obtained using $Sb_{67}Te_{33}$ and $Sb_{80}Te_{20}$, respectively. When $Ag_{6.0}In_{4.4}Sb_{61.0}Te_{28.6}$ (AIST) is used replacing the Sb-Te in Fig. 1, the maximum CNR was 48 dB.[7] This CNR value for AIST was higher than our previous one (46 dB) using the layer thickness condition of 60 nm.[2] Our previous studies have demonstrated that the super-resolution readout is related to the temperature increase inside the readout layer (e.g., AIST layer).[8, 9] A rough temperature estimation of the AIST layer during the readout suggested that there is a temperature difference in its layer thickness direction as the layer becomes thick.[7] The layer thickness optimization to 15 nm (from 60 nm) is probably achieved since such temperature distribution is not preferable to obtain a good super-resolution effect. Although further thinning of the AIST layer should bring better super-resolution effect based on this idea, temperature increase, which is essential for the super-resolution readout, becomes difficult at less than 15 nm according to the estimation.

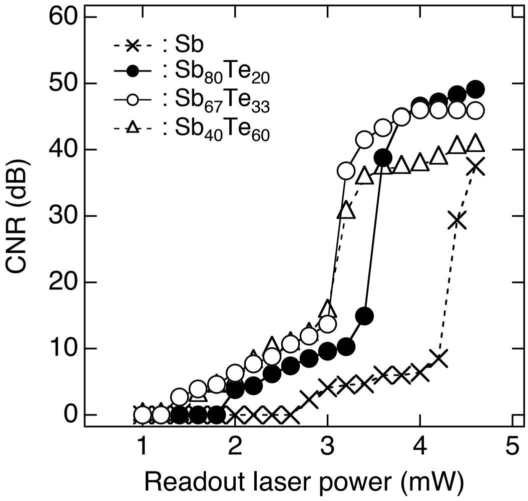

Fig.2 CNR properties of super-RENS discs with various Sb-Te compositions.
(Recording laser power: 12 mW)

As an attempt to combine two readout layers for better super-resolution readout, we have prepared Sb/Te stacking layers replacing the Sb-Te layer in Fig. 1. Since the temperature distribution that is supposed to form in the layer-thickness direction is not preferred for a good super-resolution effect, we have kept total thickness of the stacking layers to be 15 nm. We did not include any dielectric layers (e.g., $ZnS\text{-}SiO_2$) to separate each stacking layer because we considered that a complete separation is presumably difficult when the total thickness is only 15 nm. We have prepared three stacking-layer cases for this study, and they were Sb (5 nm)/ Te (5 nm)/ Sb (5 nm), Sb (10 nm)/ Te (5 nm) and Te (5 nm)/ Sb (10 nm). We kept the ratio of total Sb layer thickness to Te thickness to be 2 to 1. When one assumes the density of bulk materials (Sb: 6.68 g/cm^3, Te: 6.24 g/cm^3) in the stacking-layers, total Sb to Te (Sb:Te) ratio will be about 2.3 to 1.[10]

Fig. 3 shows the CNR properties of 200-mark trains as a function of the readout-laser power for the above three Sb/Te stacking-layer cases. Recording laser power was 12-13 mW. High CNRs of 44 dB were obtained in all three cases at an optimized readout power of about 4.0 mW. Both the CNR value and its readout-laser power dependence property were fairly similar to the ones of $Sb_{67}Te_{33}$ and $Sb_{80}Te_{20}$ in Fig. 2. We have also prepared Sb (5 nm)/ Te (5 nm)/ Sb (5 nm) that is sandwiched by $ZnS\text{-}SiO_2$ layers on read-only-memory (ROM) substrate,[11] and obtained a high CNR of

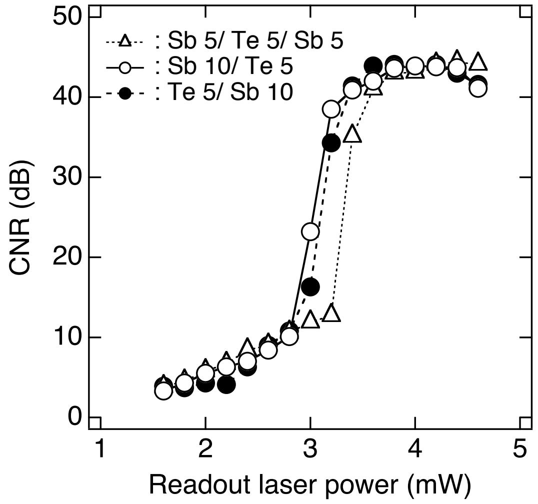

Fig.3 CNR properties of super-RENS discs with various Sb/Te stacking conditions. (Total Sb/Te layer-thickness ratio is fixed to 2. Recording laser power: 12-13 mW)

46 dB for 200-nm pit trains at a readout laser power of 2.8 mW. Since the pits are pre-recorded for the ROM case and both the PtOx write-once (as shown in Fig. 3) and the ROM cases showed high CNRs, the mark recording process probably did not play a major role in the super-resolution readout (that is achieved by the Sb/Te stacking layers). The CNR values of Sb/Te stacking (44 dB, in Fig. 3) were higher than the ones of pure Sb (37 dB, in Fig. 2) and pure Te (40 dB, not shown). Although the combination of two readout layers seemed to be successful, mixture of Sb and Te is the most likely reason for the high CNR since the Sb:Te ratio is adjusted to about 2.3:1 (near a eutectic point).

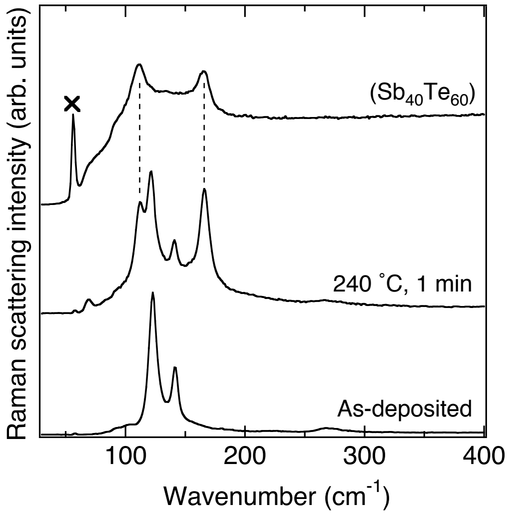

Fig.4 Raman scattering spectra of Sb (7 nm)/Te (8 nm) stacking layers. ($Sb_{40}Te_{60}$ spectrum is shown for comparison. A peak labeled “x” originates from the measurement setup.)

To study briefly on the Sb/Te mixture, we have performed Raman scattering measurements for as-deposited and annealed cases. We have modified the Sb:Te ratio to Te-rich side for the measurement since formation of $Sb_{40}Te_{60}$ is a good indication in Raman scattering. Fig. 4 shows the Raman scattering spectra for Sb (7 nm)/ Te (8 nm) stacking layers. In the figure also shows a spectrum of crystalline $Sb_{40}Te_{60}$ film for comparison. For the as-deposited stacking, two Raman peaks were observed at 123 cm^{-1} and 141 cm^{-1}, and they are originated from crystalline Te.[12] Raman peaks from Sb were missing in the spectrum presumably since it was amorphous[1] and/or the intensity was weak compared to the Te ones. When the stacking layers were annealed at 240°C for 1 min, additional Raman peaks appeared in the spectrum at 112 cm^{-1} and 166 cm^{-1}. The peak positions matches to the ones of $Sb_{40}Te_{60}$, and it indicates that at least part of the stacking layers is mixed and $Sb_{40}Te_{60}$ alloy is formed.

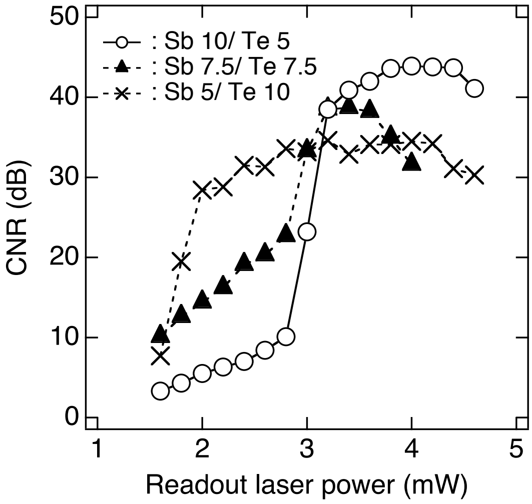

Fig.5 CNR properties of super-RENS discs with various Sb/Te stacking conditions.
(Sb/Te layer-thickness ratio is modified. Recording laser power: 12-14 mW)

Fig. 5 shows the CNR properties of 200-nm mark trains as a function of the readout laser power when Sb and Te layer thicknesses were modified while keeping the total to 15 nm. The result for Sb (10 nm)/ Te (5 nm) is a duplicate of the one shown in Fig. 3. The maximum CNR dropped as the Sb:Te ratio deviated from the condition in Fig. 3 near a eutectic point. Although there were some CNR-property differences between Figs. 2 and 5 when the Sb:Te ratio is off from the optimized condition, it was basically important in both layer-preparation cases controlling the Sb:Te ratio for better super-resolution effect.

We have previously estimated that the temperature of AIST layer during the super-resolution readout is above 350°C.[8, 9] If we can assume a similar temperature in the readout using Sb/Te stacking layers, it is probably enough for the Sb-Te alloy formation according to the Raman scattering results. Since the Sb:Te ratio of the stacking layers should be adjusted to near a eutectic point to generate high CNRs, (almost) all the stacking layers in the disc structure are presumably mixed and formed an Sb-Te alloy by the readout-laser irradiation.

Experimental results of the Sb/Te stacking layers suggest that how the super-resolution readout layer is prepared is not really an important point in the super-RENS. It is probably sufficient as far as the Sb:Te ratio and its layer thickness conditions are both properly adjusted. The readout laser increases the temperature in super-RENS, and it controls some of the film properties: chemical potential, Sb/Te configuration, and crystalline properties. Combination of two readout layers (for better super-resolution effect) should separate each layer not to combine, and locating thin readout layers (about 15 nm) at both side of the recording layer may be more appropriate to meet the requirements of super-RENS.[13]

4. CONCLUSION

We have studied on optimizing the Sb-Te layer preparation of a super-RENS disc using PtOx recording layer. We have first confirmed that composition of Sb-Te should be adjusted to near a eutectic point ($Sb_{70}Te_{30}$). Sb-Te layer thickness was optimized to 15 nm (from 60 nm), and it is probably achieved as a result of controlling the temperature and its distribution inside the layer when the readout laser is irradiated. As far as these two conditions (the composition and the layer thickness) are fulfilled, further preparation control was basically not necessary for super-RENS, and the layer can be replaced with Sb/Te stacking layers.

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Biography

Takayuki Shima received the B.E., M.E., and Dr. Eng. from Chiba University, Japan in 1992, 1994, and 1997, respectively. He was an Industrial Technology Researcher of New Energy and Industrial Technology Development Organization (NEDO), Japan during 1997-2000. He was a Domestic Research Fellow of Japan Science and Technology Corporation (JST) and Japan Society for the Promotion of Science (JSPS) during 2001-2003. He joined National Institute of Advanced Industrial Science and Technology, Japan in 2003. He is a member of Japan Society of Applied Physics (JSAP), Materials Research Society (MRS), and The Institute of Image Information and Television Engineers. His current research interests include development of materials for high-capacity optical data storage media.