New Material for a Super Resolution Disc

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Abstract

Using metal/Si materials as a recording layer, we have achieved good results for a SR disc (super resolution disc). Mainly by controlling metal composition and the ratio of metal to Si of recording layer, signal qualities were greatly enhanced. At the mark length of 75nm, the best CNR (Carrier to Noise Ratio) was about 45dB. Write power was reduced down to about 6.5mW. LFN (Low Frequency Noise) could also be reduced down to 14dB. Single tone pattern jitters for every mark whose length is from 2T through 8T were achieved to be below 10%. The readout signal was stable sustaining CNR>40dB during about 15,000 times reading. The so-called "3T-problem" could be avoided.

Key Words : SR disc, super-RENS, jitter, CNR, LFN, 3T problem

1. Introduction

Until recently the next generation optical memory technologies to store huge capacity of information over 25GB (Blu-ray disc) or 15GB (HD-DVD) have been studied very actively. Especially since J. Tominaga[1] invented "super-RENS" technology in 1998, super-RENS technology has been taken much attention. It deserves to store huge capacity information from over 100GB to 1TB, and moreover it has been known to have a lot of merits as well compared to NFR (Near Field Recording technology) or multilayered discs technology.

However up to now the super-RENS research has been focused on the discs which use PtO_x as the recording layer[2-4]. The recording mechanism for PtO_x is known like this. When the recording laser beam falls on the PtO_x recording layer, if the temperature beneath the beam rises locally up to a critical point, PtO_x recording layer is decomposed into Pt nano particles and oxygen. And it finally makes bubble like pits. Using this material the signal quality of CNR (Carrier to Noise Ratio) has been achieved over 40dB successfully and moreover achieved bER < 10^{-5} (bit Error Rate) using some additional pre-Equalizers and "Decision Feedback PRML (Partial Response Maximum Likelihood)" method[5]. The research to improve the signal quality is still going on.

The most important materials for the super-RENS disc would be those for the recording layer and readout layer. In this paper we report the new recording layer materials for SR disc (Super Resolution disc) based on metal/Si as a recording layer. The essential factors that the recording layer materials should have would be: 1) good readout stability, 2) reasonable modulation, and 3) low recording power. In order to satisfy the necessary properties for the recording layer materials, we tested some of metal/Si materials which are considered to have stable structure against repeated readout of recorded marks. We thought that the criterion for counterpart materials of silicon to make a silicide should have: 1) appropriate thermal conductivity to help to control the shape of written marks, 2) high readout stability after recording, and 3) low melting temperature to make the recording power low. So we selected a noble metal which has rather lower melting temperature. Furthermore to increase the signal quality with fine tuning, TCI (Thermal Control Ingredient) was chosen because recording power is still high even though its signal properties are excellent. These TCI materials should have the property of: 1) lower melting temperature and 2) lower thermal conductivity than the given noble metal. So we chose metals having low melting point as a TCI materials of the metal/Si recording layer.

Through this material composition control and film structure optimization, we obtained the following results: At the mark length of 75nm, the best CNR was about 45dB. And in the condition that CNR was over 40dB,

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write power was reduced down to about 6.5mW, LFN (Low Frequency Noise) was also reduced to about 14dB, and single jitters for every length mark from 2T through 8T were achieved below 10%. The readout signal was stable sustaining CNR>40dB during about 15,000 times reading. The so-called “3T-problem” could be avoided.

2. Experiment

2.1 Basic super resolution film design

In our experiment, the film structure was constructed as polycarbonate-substrate/reflective-layer/ZnS-SiO_2/metal/Si/ZnS-SiO_2/readout-layer/ZnS-SiO_2/cover-layer. We selected the recording layer as (metal/Si). The metal layer was composed of noble metal only or its alloy with other additive metals. When the recording layer is exposed to the laser light, the recording layer which consists of metal/Si was designed to be mixed-up or to be alloyed into marks which would have different refractive index from the original state.

In order to reduce the readout power, the readout layer was designed to be located in the opposite side of reflective layer to recording layer. Furthermore the silicon layer was put into the laser incident side to keep the recording power loss from higher thermal conductivity of metal layer (Fig. 1). The structure of Samsung is (readout-layer)/(recording-layer)/(readout-layer). And that of TDK is (recording-layer)/(readout-layer)/ (reflective-layer).

The various recording layer structures and material compositions were tested. The noble metal alloys were made by co-sputtering as the ratio was varied. And the thickness ratio of the silicon layer to metal layer was also varied.

2.2 Recording laser power reduction

High recording power can cause media damage, bad readout stability, high LFN, and so on. And for drive design (especially, pick-up) and for better high speed disc margin, low recording laser power is very important.

First, we checked the recording power as changing the composition ratio of TCI to noble-metal and could find the proper window in which CNR was over 40dB. As you can see in the Fig. 2, the recording power was reduced as TCI was added from the left upper (noble metal only) to the right lower (TCI only), and finally got from 12mW to 6.5mW. Next we checked the reflectance and modulation according to the composition ratio of TCI to noble metal and thickness ratio of the metal layer to the silicon layer. We targeted the reflectance over 10% and the modulation over 40%. The reflectance was between 9.5% and 13.6%. The modulation was from 35.2% to 49%.

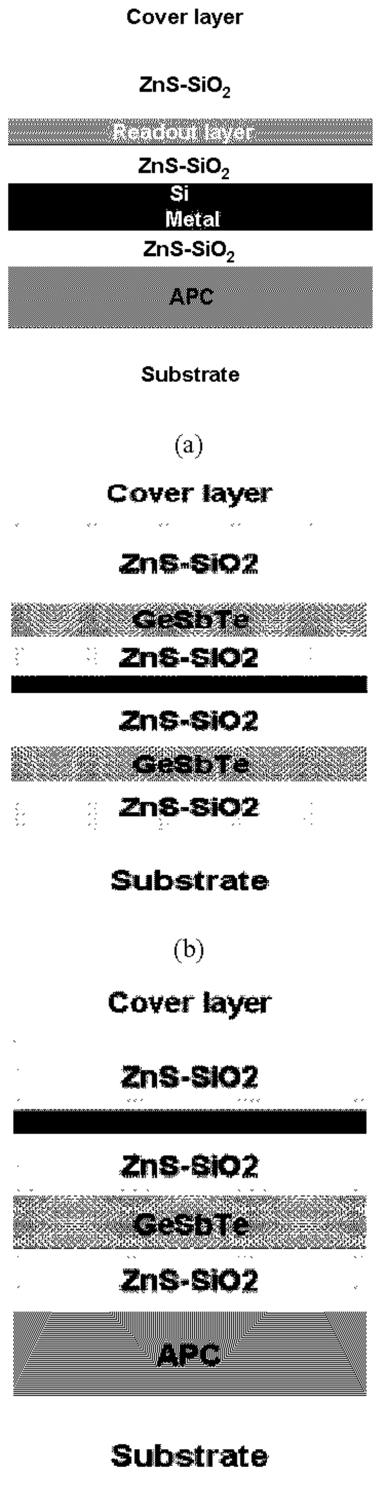

Fig. 1 Typical super resolution layer structures of (a) LGE, (b) Samsung, and (c) TDK. We used metal/Si for recording layer material. PtO_x was used as recording layer by Samsung and TDK.

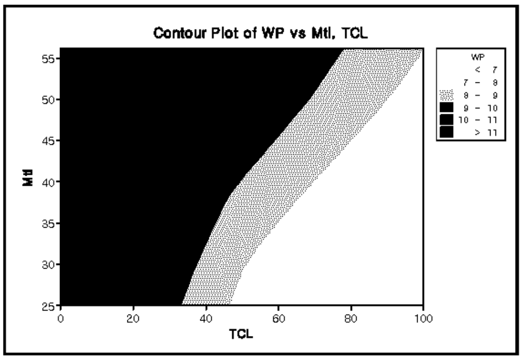

Fig. 2 Write Power vs. composition ratio of TCI to noble metal(x-axis) and thickness ratio of the metal layer to the silicon layer(y-axis). The CNR within this window is over 40dB.

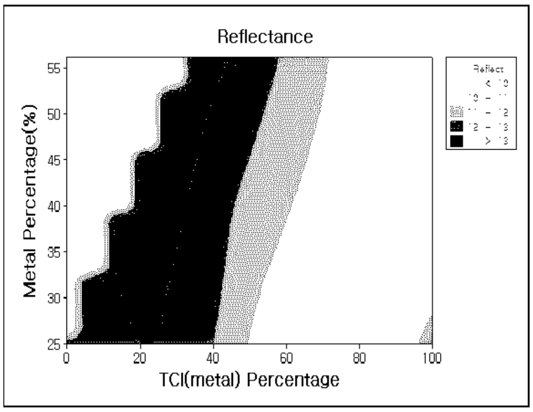

Fig. 3 Reflectance vs. composition ratio of TCI to noble metal and thickness ratio of the metal layer to the silicon layer(y-axis). The CNR within this window is over 40dB.

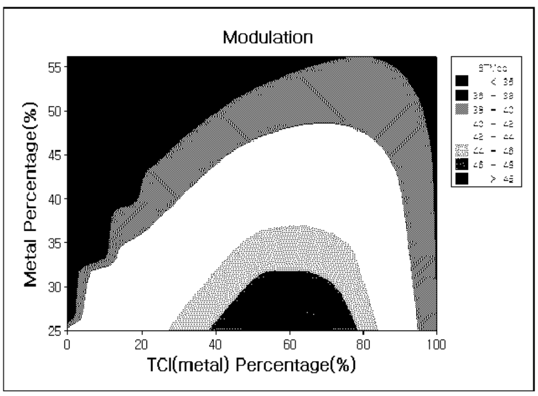

Fig. 4 Modulation vs. composition ratio of TCI to noble metal(x-axis) and thickness ratio of the metal layer to the silicon layer(y-axis). The CNR within this window is over 40dB.

Comparing to Blu-ray specification book, we could have obtained the reasonable results. We can see the result in the Fig. 3 and Fig. 4.

The Pulstec's ODU1000 was used to evaluate samples. The track pitch of discs was 320nm. The rotation speed of the disc was fixed at 2.4m/s or 4.9m/s. The wavelength of the laser was 405nm and NA was 0.85.

3. Results and discussion

3.1 Low frequency noise

In SR disc, LFN problem has been known crucial. Even though CNR is high, if LFN is not low enough, the readout signal can not be properly resolved from the noisy signal in which the low frequency fluctuating noise is merged into the signal. Comparing to CD/DVD/BD or HD-DVD, the much smaller signal amplitude with LFN of SR disc may cause much problem.

We measured LFN as the ratio of noble metal and TCI to silicon. We could reduce LFN down to about 14dB (Fig. 5). We also found that the LFN has writing power dependency as you can see in the Fig. 6. The better result was obtained in the case of low writing power.

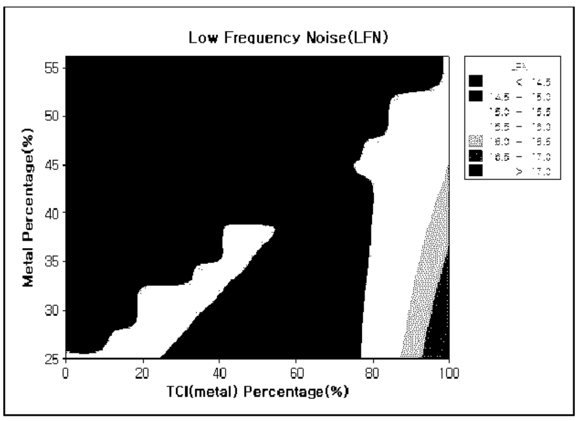

Fig. 5 Low frequency noise vs. composition ratio of TCI to noble metal(x-axis) and thickness ratio of the metal layer to the silicon layer(y-axis). The CNR within this window is over 40dB.

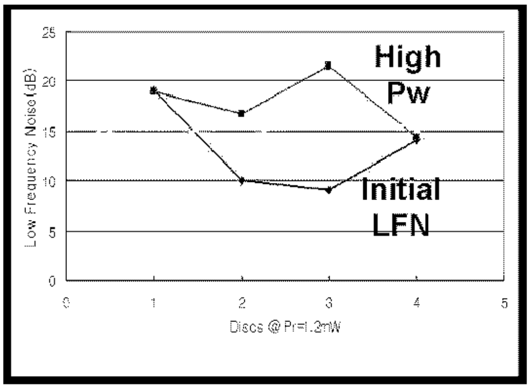

Fig. 6 Writing power dependency of LFN: Readout power was 1.2mW. Initial LFN means the LFN before writing marks. The second disc has the lowest LFN when the marks were written by low writing power.

3.2 Single tone pattern jitter

The jitter fro single tone pattern marks (Fig. 7) was also evaluated for the 2T though 8T length marks. And all the jitter values were obtained under 10%. And even the jitter values for over 5T marks were obtained down to 5.6%.

3.3 So-called 3T-problem

Furthermore the so called "3T-Problem" which is known as the near-diffraction-limit problem is also crucial for super resolution technology. If any, even though the jitter values are good enough, the jitter for 3T mark is very high. The reason is not clearly revealed yet. However it could be avoided in this material system as you can see in Fig. 7. The reason is not fully understood, but we think that the film structure and material composition might be main cause.

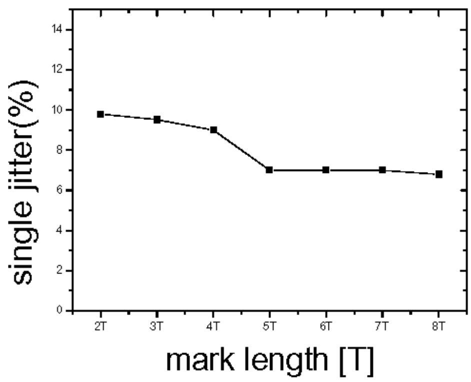

Fig. 7 Single tone patterned marks jitters: 2T ~ 8T. All jitter values are bellow 10%.

3.4 Readout signal quality

Fig. 8(a)-(d) show 2T readout signals waveform. It shows very clear and stable wave form and the PLL clock (phase locked loop; time recovery system) signal is shown well locked.

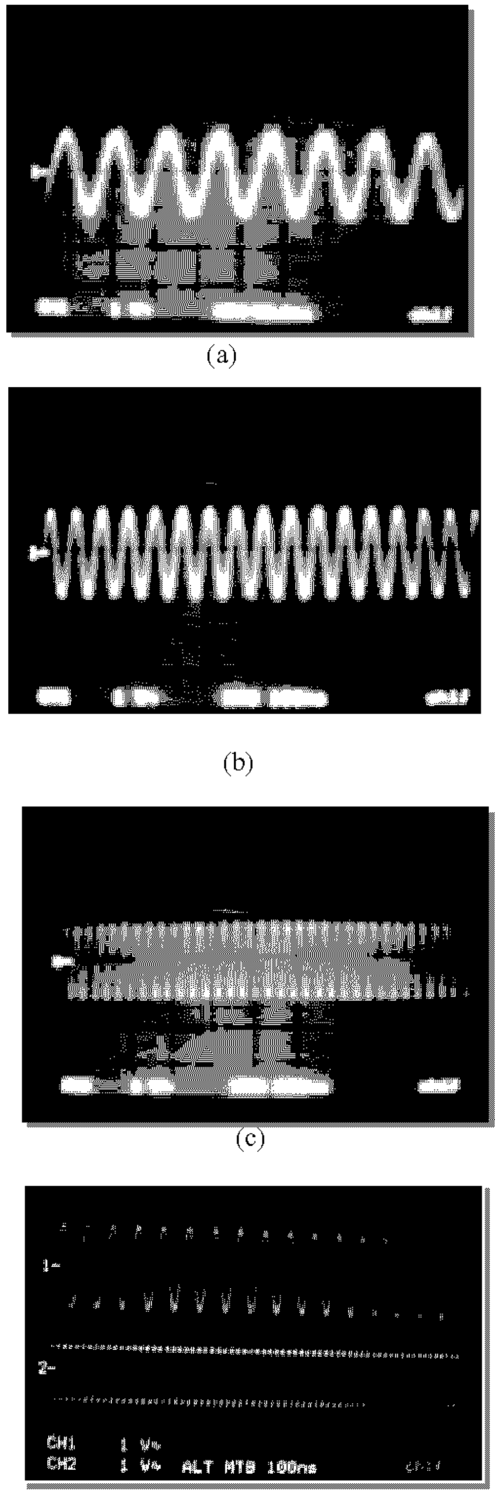

Fig. 8 2T readout signal waveform after equalizer (a), (b), (c), and PLL clock signal (d)

4. Conclusion

Using metal/Si materials as a recording layer, we have achieved good results for a SR disc (super resolution disc). At the mark length of 75nm, the best CNR (Carrier to Noise Ratio) was about 45dB, write power was about 6.5mW, LFN (Low Frequency Noise) was about 14dB, and single jitters for every length mark from 2T through 8T were below 10%. The readout signal was stable sustaining CNR>40dB during about 15,000 times reading. The so-called "3T-problem" was not observed

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