Super-Resolution ROM Disc with a Semi-Conductive InSb Active Layer

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ABSTRACT

The next generation optical memory technology to store high capacity information over 25 GB (Blu-ray) is studied actively. A novel emergent technique, the super-resolution, allows writing and/or reading information bits which are smaller than the resolution limit of the optical head without increasing the complexity of the detection system. So super-resolution is very attractive since this technology guarantees the compatibility with the already existing Blu-ray players/recorders.
We have developed a super-resolution ROM disc in a Blu-ray optical pick up. Our solution implies the use of a "super-resolving" structure made of a specific thin film stack. The nature and the microstructure of the "active" layer are mainly responsible for the appearance of the phenomenon of super-resolution.

Key words: super-resolution, ROM disk, InSb, bER, crystalline microstructure, optical storage

1. INTRODUCTION

The principle of super-resolution is very promising to overcome the optical diffraction limit and to achieve high capacity information while keeping conventional far field optics. For the ROM format the essential characteristics that the readout layer should have is a low readout power and a good stability. In this paper, we report the bER characteristics of ROM disc with 80 nm minimum pit length (2T signal) measured on a simple structure comprising an InSb active layer. We also highlight the strong influence of the crystalline microstructure (grains size) of the InSb film in the efficiency of the super-resolution process.

2. EXPERIMENTS

The ROM samples are deposited on the substrate with the $ZnS-SiO_2$ / InSb / $ZnS-SiO_2$ 3-layer using sputtering method (figure 1). The ROM stamper was fabricated by electron beam lithography (fabrication: Sony), it contains random pattern (1,7 RLL code) including 2T (80 nm), 3T (120 nm) marks under resolution limit (120 nm). The 80 nm minimum pit length corresponds to 46 GB capacity (figure 2). The track pitch is 320 nm to ensure suitable push-pull tracking servo condition and compatibility with the blue optical system (λ=405 nm, NA=0.85). The signal error rate is evaluated thanks to an adaptive PRML technique developed by Ricoh.
Structural characterizations of the InSb layer are made thanks to TEM observations and x-ray diffraction measurements at the ESRF (European Synchrotron Radiation Facility: BM32 beamline).

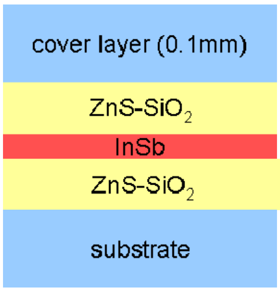
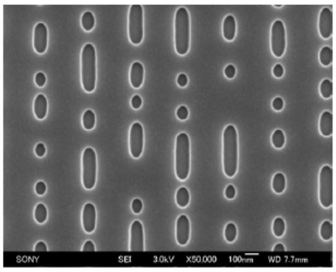


Figure 1: Standard layer structure of ROM disc



(1,7) RLL, 2T pit length=80nm

Figure 2: SEM image of the ROM stamper

3. RESULTS & DISCUSSION

Stoechiometric InSb material is used for super-resolution readout. Figure 3 shows RF waveform. The 2T and 3T signals, which are pits length under resolution limit, are clearly detected without missing any signals as it is compared to NRZI (Non Return to Zero Inverted) source data.
The bER results are depicted figure 4 and 5. The bER is 2.10^{-3} level at the optimal readout conditions and at the optimal readout power (it should be noticed that, at low readout power, the bER is very poor, ($\sim 10^{-1}$) as same as CNR response on low readout power). bER was measured for about 29000 clocks (about 8200 marks).
The evaluation of the readout stability is made on the bER basis which is a more severe condition than C/N readout counts. We achieve a stability of about 10^4 cycles.

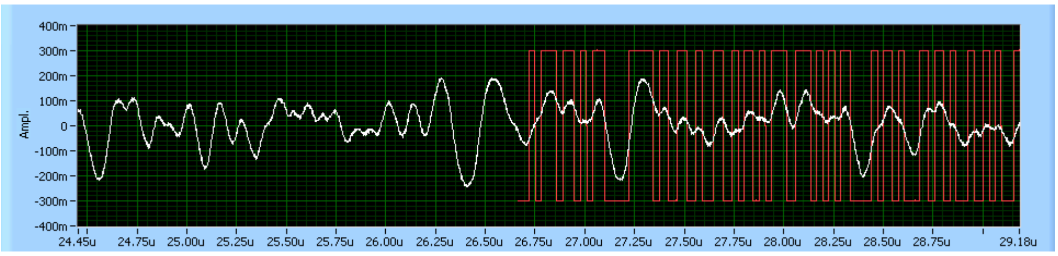


Figure 3: RF waveform of 46 GB random signal (in white) and corresponding NRZI source data (in red).

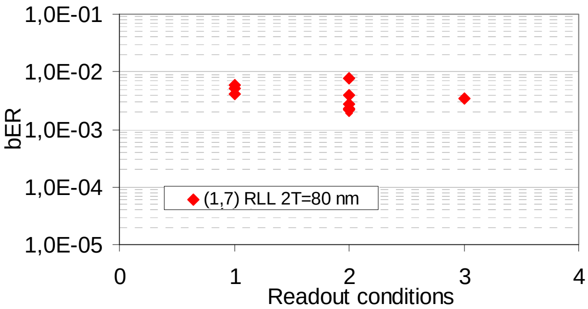


Figure 4: bER results as a function of the readout conditions (at the optimal readout power).

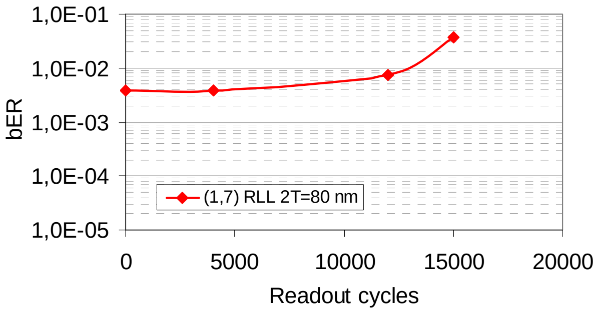


Figure 5: bER as a function of the readout cycles

We have already reported a model illustrating the super-resolution effect in the case of small band gap semi-conducting materials [10,11]. This model is based on the photogeneration of free carriers under the focused laser spot. The appearance of an electronic plasma seems to be responsible for a local increase in reflectivity and a reversible semiconductor/metal transition which allows the detection of marks smaller than the original diffraction limited spot. So, the super-resolution effect depends strongly of the diffusion area of the electrons. Under these assumptions, the crystalline microstructure seems to be a very crucial parameter since the electronic mobility value can be modified by the grain boundaries.

In order to investigate this point we have studied with more details two 3-layer structures with respectively a 20 nm-thick InSb layer and a 50 nm-thick InSb layer. Figure 6 shows the evolution of the C/N versus P_{read} for both structures. It appears that the C/N values are higher with a 20 nm layer. The evaluation of the bER on the random pattern confirms this behavior; a value of 2.10^{-3} is measured with a layer of 20 nm whereas a poor super-resolution effect appears with a layer of 50 nm.

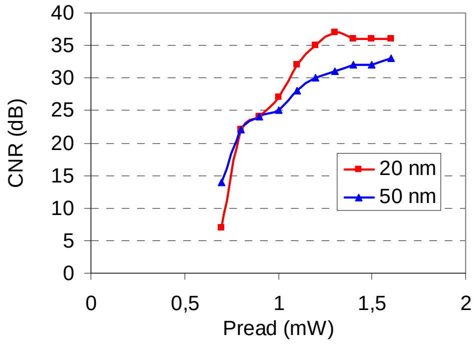


Figure 6: CNR vs Pread of the $ZnS\text{-}SiO_2$ / InSb / $ZnS\text{-}SiO_2$ structure. Red curve: 20 nm InSb. Blue curve: 50 nm InSb.

We have then investigated the microstructure of the InSb layers. Figure 7 shows the [111] diffraction peak of InSb measured on both stacks. According to the Scherrer's law it appears that the size of the crystalline grains (⊥ layer) is closely the thickness of the InSb layer. These measurements have been confirmed by TEM observations. Figure 7 shows a TEM image of the trilayer structure and figure 8 shows that the size of the crystalline grains is 20 nm for a 20 nm-thick InSb layer.

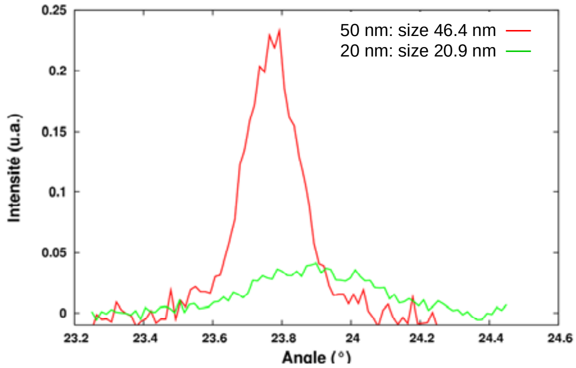


Figure 7: [111] diffraction peaks measured on a 20 nm-thick InSb layer (red curve) and on a 50 nm-thick InSb layer (green curve).

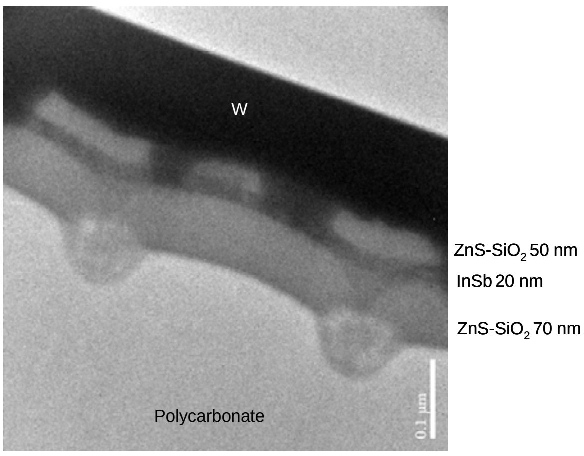


Figure 7: XS TEM image of the tri-layer structure

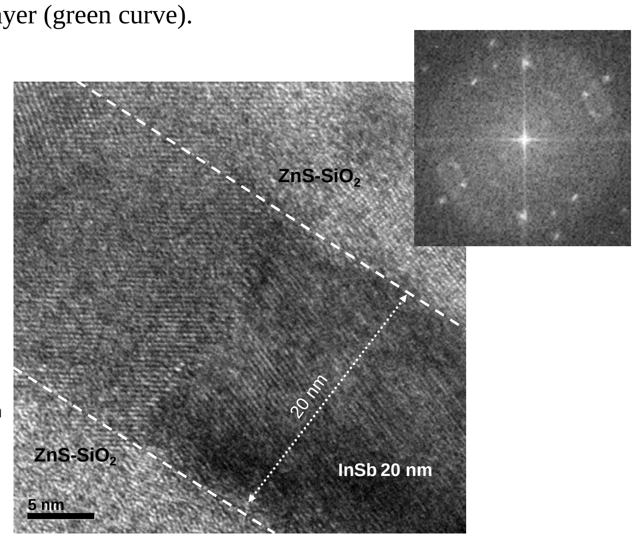


Figure 8: HR TEM image of the tri-layer structure ($ZnS\text{-}SiO_2$ / InSb 20 nm / $ZnS\text{-}SiO_2$)

According to these experimental results, figure 9 shows a schematic representation of the microstructure of a 20 nm-thick layer and the microstructure of a 50 nm thick layer when deposited on a periodic structure with 80 nm pits. It appears clearly that in the case of the 50 nm layer only a few 'big' grains are involved during the readout process of this 80 nm pit. So we think that the super-resolution effect is efficient when the crystallites have an optimal size comprised between 10 and 25 nm. This fine microstructure allows confining the electrons, limiting their spatial extension and ensuring an efficient optical transition area and consequently an optimal super-resolution effect.

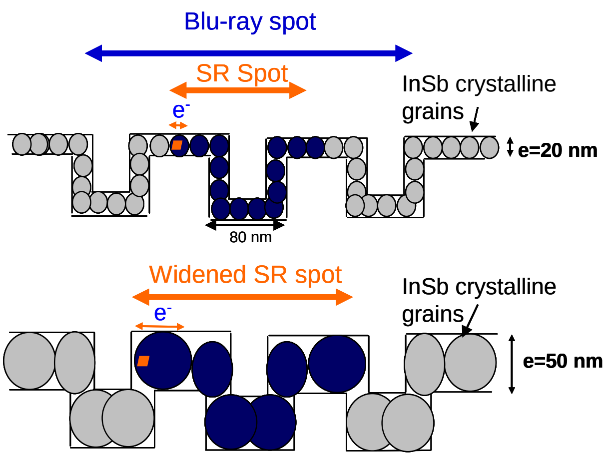


Figure 9: Microstructure (schematic representation) of a 20 nm-thick InSb layer (top figure) and a 50 nm-thick InSb layer (bottom figure) deposited on a periodic structure with 80 nm pits.

4. CONCLUSION

We have developed a super-resolution ROM disc in a BD optical pick up. We achieved bER of 2.10^{-3} for the random signal of 46 GB level capacity with a readout stability of 10^4 cycles. These results indicate a good potential of the InSb tri-layer structure and the feasibility of this technology for practical use. This paper tends to show the crucial role of the InSb crystalline microstructure in the super-resolution process.

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