W-6

# Effects of Soft Underlayer on Recording Properties in Double Layered Perpendicular Recording Media

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## 1. Introduction

Perpendicular magnetic recording is receiving much attention recently as a next generation recording technology because the present longitudinal recording is facing thermal stability problems [1]. Double layered perpendicular magnetic recording media composed of perpendicular recording layer and soft underlayer (SUL) are very attractive for increasing effective head write field, which is a crucial factor in high density recording [2]. However, magnetostatic interaction between recording layer and SUL contributes substantially on increase of noise in reproduction process. Therefore, the noise reduction in the double layered perpendicular recording medium became an important issue. Unlike a single layered perpendicular magnetic recording medium, it is reported that media noise power in double layered medium generally increase with increasing recording density.

In the present paper, to investigate the effect of SUL on noise, we have studied micromagnetic simulations of writing and reading process in a perpendicular system including a single pole head and a recording medium with SUL.

## 2. Micromagnetic Model

The recording layer was modeled as an array of 1500 grains of Voronoi cell of 7.1 nm average grain size with standard deviation of 0.55 nm. Saturation magnetization (Ms) of 400 emu/cm3, uniaxial anisotropy (Ku) of 3.5×106 erg/cm3 and exchange constant (A*) of zero were assumed. The SUL was modeled as an array of cubic cells with Ms of 800 emu/cm3, Ku of 104 erg/cm3, and A* of 10-6 erg/cm. Orientation of crystalline anisotropy easy axis of SUL was set to be the cross track direction. The unit cell of the SUL was 10 nm × 10 nm × 10 nm in dimension. Dimension of the SUL was 1200 nm × 1200 nm × 80 nm. Thickness of magnetic layer, SUL, exchange break layer (EBL) were 20 nm, 80 nm, and 5 nm, respectively. Head-medium velocity was 40 m/s and head-medium spacing was 5 nm. SNR was calculated by the reciprocity principle of a shielded magnetoresistive (MR) head. SNR (in dB) [3] is defined as the logarithmic ratio of the peak signal amplitude to the rms noise voltage, multiplied by 20. Trimmed single pole head dimension, head field and head field gradient is appeared in other paper [4].

## 3. Results and Discussion

Fig. 1 shows the simulated bit patterns. Ideal bits indicate the patterns written on a recording layer without SUL by ideally sharp head field in the linear density of 1058 kfci. Single layer patterns were obtained on the recording layer without SUL by the realistic head field calculated by micromagnetic simulation and double layer patterns were on the recording layer with SUL by the realistic head field. It was found that irregular bit was made in double layer and this is more prominent in the track edge region for both cases with track width of 60 nm and 160 nm. Irregularity is composed of bit size deviation and bit shape asymmetry.

Table 1 shows the calculated signal output, noise output and SNR for these three cases. When the SNR of the double layer and that of the single layer are compared, the double layer shows much lower value in spite of the similar signal output. This is due to the higher noise in the double layered medium. When the jitter in the transition region (are, is) considered the single layer bit pattern shows more irregular transition as shown in Fig. 1. However, in order to compare the transition position jitter by superimposing signal output in a graph as shown in Fig. 2, the transition position jitter is largest in the double layered medium. When the variations of zero output crossing regions are compared, 2.6 nm for the ideal bit, 4.2 nm for the single layer and 7.32 nm for the double layer: Therefore, we concluded the SUL in the double layered medium causes the increased transition noise. In order to understand the reason of this large transition position jitter we have studied on magnetization patterns in the soft underlayer as a function of time in 10 ps interval during writing process. The soft magnetization is changing greatly with time due to small damping constant.

The magnetization configuration in the SUL around the magnetic vortex varies with time to go an equilibrium states. The contribution of magnetic field gain from SUL on the write field changes from bit to bit. It was found that the asymmetry of Hy (head field component in cross track direction) makes bit shape asymmetry and the variation of Hx (in down track direction) makes bit size asymmetry. These two components are contributing transition position shift in the double layered media and are source of higher noise. For higher density recording the control of magnetic vortex near the top parts of SUL by the SUL modification is necessary to archive high SNR in the double layered medium.

## 4. Conclusion

We have compared a single layer medium and a double layered medium with SUL by the same writing head field. It was found that the transition position shift of the double layered perpendicular recording media is the most significant noise source at ultra high density recording region. The reason of the transition position shift in the recording layer is associated with a vortex formation in the SUL under a single pole head and its propagation during writing process.

## 5. References

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[2] R. Wood, IEEE Trans. Magn., 36 (2000) 36-42

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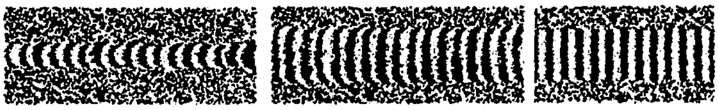

(i) ideal bit
(ii) single layer
(iii) double layer

Fig. 1 Written bit pattern of three different cases (i) ideal bit in single layer, (ii) realistic bit in single layer without SUL, and (iii) realistic bit in double layer with SUL. Left hand is for the track width of 60 nm and right hand for 160nm.

| | ideal bit | single | double |
|---|---|---|---|
| S(A.U.) | 1.65025 | 1.29335 | 1.23298 |
| N(A.U.) | 0.01771 | 0.02701 | 0.11904 |
| SNR(dB) | 19.69280 | 16.80129 | 10.15261 |

Table 1. Signal, noise, and SNR

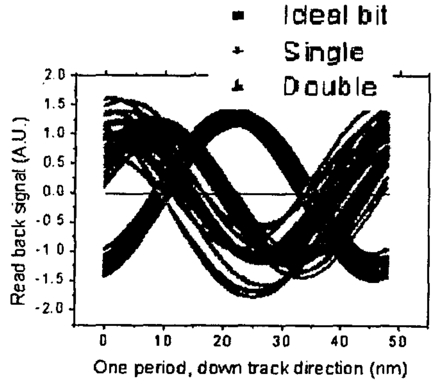

Fig. 2. Read back signal of three different bit pattern; (i) ideal bit in single layer, (ii) realistic bit in single layer, and (iii) realistic bit in double layer.