The Viability of Single Pass Three Level Recording in HAMR

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The atomic structure of a highly ordered FePt $L1_0$ grain provides the possibility for domain wall trapping sites within the grain. Near zero magnetic moment grains at recorded transition centers would yield a significant reduction of transition jitter noise, enabling high track density capability. This characteristic property would also enable single pass three level recording for which a zero magnetization state can be created with zero recording head field. The zero moment grains in the zero magnetization-level bit yields significant medium noise reduction and making the three-level recording potentially viable.

***Index Terms*—HAMR, Magnetic Recording, HDD, FePt, L10 grain, three-level recording.**

I. Introduction

FePt $L1_0$ granular thin film as the media for heat assisted magnetic recording (HAMR) has some very important characteristics [1]. In specific, an ordered $L1_0$ FePt grain consists of Fe and Pt atomic monolayers alternating along grain height perpendicular to the thin film plane. For a pure Pt monolayer, the exchange coupling between the two adjacent Fe monolayers would depend on the induced spin polarization of the Pt atoms. If the two Fe monolayers are magnetized in parallel, the Pt atoms would be spin polarized, consequently mediating ferromagnetic exchange coupling between the two Fe monolayers. If the two Fe monolayers happen to be oppositely magnetized, the Pt atoms in between would not be polarized, leading to zero exchange coupling between the Fe monolayers. In such case, the two oppositely magnetized Fe monolayers can be stable and the Pt layer effectively becomes a domain wall trapping site. If the order parameter of the FePt grain is not sufficiently high, a Pt monolayer could contain significant number of Fe atoms, yielding direct exchange coupling between the Fe monolayers. However, if the order parameter is a near unity, wall trapping site could form on a highly pure Pt monolayer.

The domain wall trapping sites within a FePt $L1_0$ grain in HAMR media can lead to formation of zero moment grains at recorded transition centers and the existence of zero moment grains at center of recorded transitions significantly reduces transition noise [2]. In this study, we investigate the viability of single-pass three-level recording for media with and without the wall trapping sites within the grains in FePt $L1_0$ HAMR media. With each bit-interval having three choices of magnetization levels $(+1, 0, -1)$, the linear density increases by 50%.

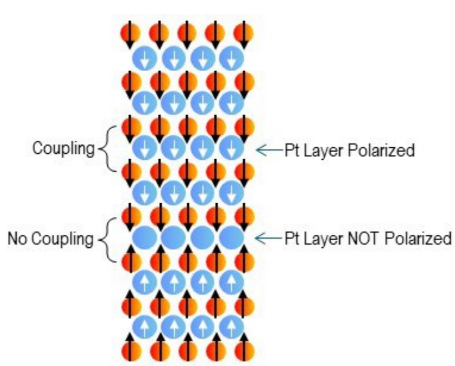

Fig. 1 Illustration of the proposed exchange coupling mechanism between adjacent Fe atomic monolayers in a perfectly L10 ordering with orange circles for Fe atoms and light blue for Pt atoms.

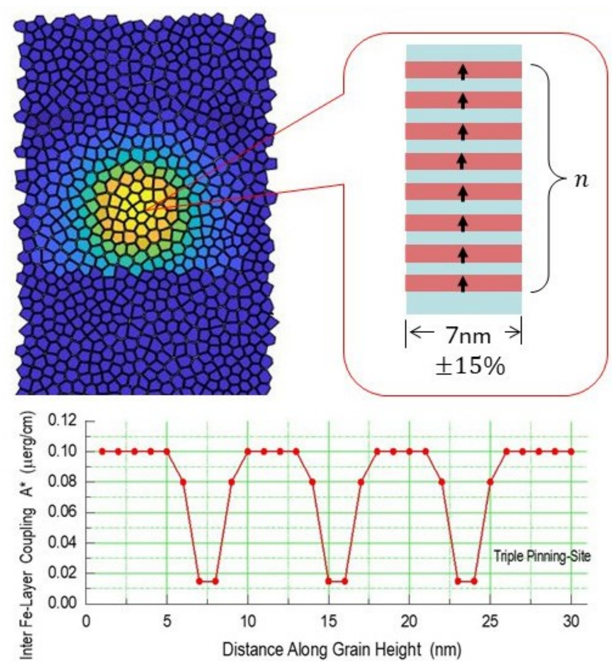

Fig. 2. Micromagnetic model setup for simulating heat-assisted magnetic recording process. A grain comprises of 32 Fe monolayers, with each monolayer represented by a macro-spin. A reduction of interlayer exchange coupling models a possible domain wall trapping site.

II. Modeling of $L1_0$ FePt Granular Media

The detailed recording model has been introduced in previous publications [2][3]. For the work presented here in specific, grain size follows a gaussian distribution of $\sigma = 15\%$ and mean $\bar{D} = 7nm$. Grain Curie temperature distribution has a of $\sigma = 15\%$ and a mean $\overline{T_C} = 660\,K$. Recording processes are simulated using a generic NFT with peak temperature of the recording thermal profile is $T_{peak} = 780K$ and resulting curved transitions are studied. In addition, a straight cross-track front thermal profile is also created by extend the track center temperature uniformly across recording track for noise analysis.

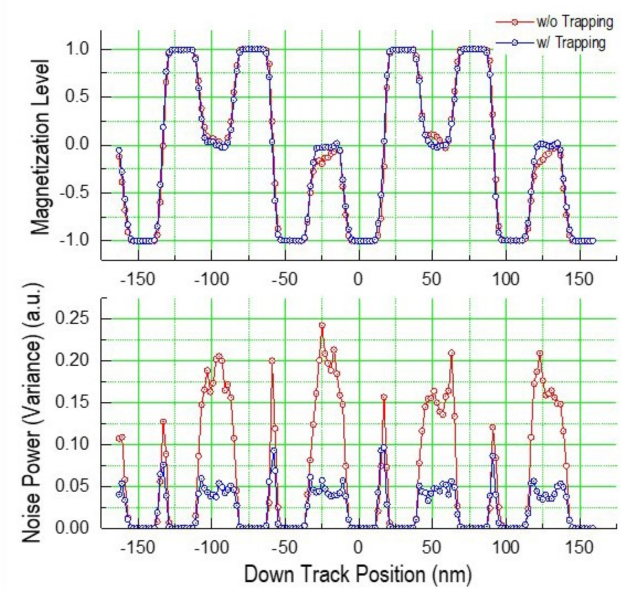

Fig. 3. Calculated three-level recording transition proffile mean (upper) and variance (lower) for media grains with (blue) and without (red) wall trapping sites within each grain. Straight cross-track thermal profile is assumed. 100 recording processes on different granular realizations are used for the statistics.

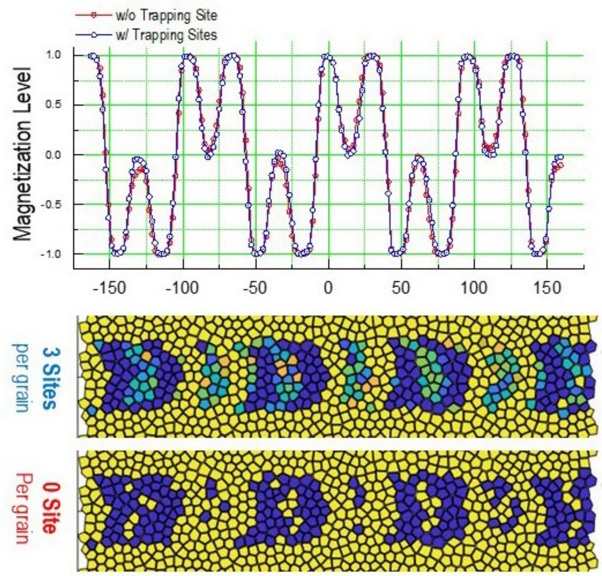

Fig 5. Three-level recording simulation with bit length B=16nm and a thermal profile by a generic lollipop NFT which result in curved transition fronts. Two cases shown here: a medium of grains with wall trapping sites (blue) and that grains without wall trapping sites (red). The read track width is 20nm.

III. Results and Discussions

Single-pass three-level recording processes are simulated with zero-level state created by zero recording head field. Figure 3 shows three-level recording results at a bit-length of $B = 25nm$. The identical recording process is repeated 100 times on different realizations of the Voronoi granular structure. The upper graph in the figure shows the statistical mean of the transition profiles for media grains with (blue) and without (red) wall trapping centers. For the case of media grains with wall trapping centers, the mean magnetization level for the "zero" state in between the two "1"s is well defined, and the medium noise power (variance) is substantially lower than that of the case without wall trapping sites in the medium grains. Figure 4 shows the recorded magnetization patterns corresponding to the results shown in Fig. 3. For the medium of grains with wall trapping sites, the state of zero magnetization level is formed by zero moment grains (indicated by light blue color) whereas for the media of grains without wall trapping site, the zero magnetization state is formed by a combination of positive and negatively magnetized single domain grains in the perpendicular direction. The zero moment grains in the zero magnetization state created absent of head field is the key for the low medium noise level.

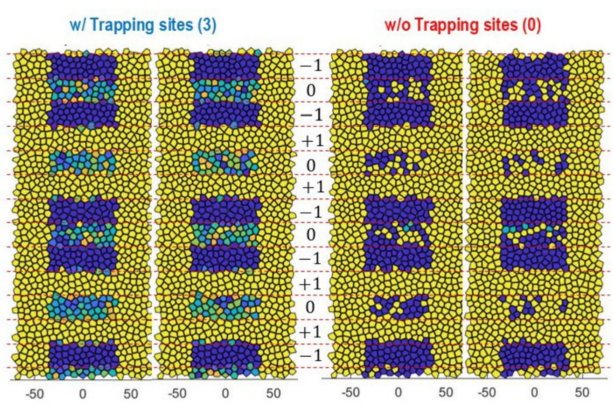

Fig. 4. Three-level recording granular magnetic momennt patterns for media grains with zero trapping site (left two) and three per grain (right two). The bit length is B=25nm.

Figure 5 shows the three-level recording with the thermal profile of a generic near field transducer (NFT) which results in curved transition fronts. The bit length is B=16nm. For the "0"-state, always sandwiched in between two "1"s in this case, the magnetization level is zero for the media of grains with trapping sites whereas magnetization deviates away from zero for the media without trapping site.

In conclusion, single-pass three-level recording should be viable if FePt grains can achieve sufficiently high $L1_0$ ordering so that wall trapping sites can be formed in FePt grains. It should be mentioned that trapping sites could also be artificially engineered [4][5].

References

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