SIDE READING IN SOFT BIAS STABILIZED READERS

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The reader in magnetic recording heads is built around a permeable layer, the Free Layer (FL), whose magnetization rotates when moved above written bits in the media. The FL needs to be stabilized by an external field in order to deliver stable and linear response. Hard magnets have been typically employed to produce this field (a.k.a. Hard Bias HB), but more recently, starting around 2011 [1,2], the industry has entirely switched to soft NiFe-based layers adjacent to each of the FL track edges (a.k.a. Soft Bias SB). These soft magnetic layers are well saturated by shape anisotropy and deliver a more controllable bias field than the granular hard magnets ever could. This has helped scaling the FL to smaller dimensions. In this paper, a micromagnetic model of the reader, SB, and shields is used to explore the side reading impact of the SB design and contrast it to that of the HB design. In addition to providing a bias field, the SB also act as side shields and narrow the magnetic read width. This is another advantage of this design, but is somewhat offset by an increase in the so called side lobes (undershoots), which worsens side reading.

The lobes are observed as one scans the reader across a written track. Fig.1 shows the cross-track response of a 24 nm wide reader over a 5 nm wide track (micro-track). The main side-lobe mechanism is common to both HB and SB but is illustrated here just for SB. In perpendicular recording there are poles from the magnetization in the micro-track at the top and bottom of the recording media layer. These poles are imaged in the Soft Under Layer (SUL). The net micro-track response can be conceptually understood as a superposition of the micro-track responses from the top of the media and the lower and wider micro-track response from the bottom. This superposition leads to low amplitude undershoots at the edges.

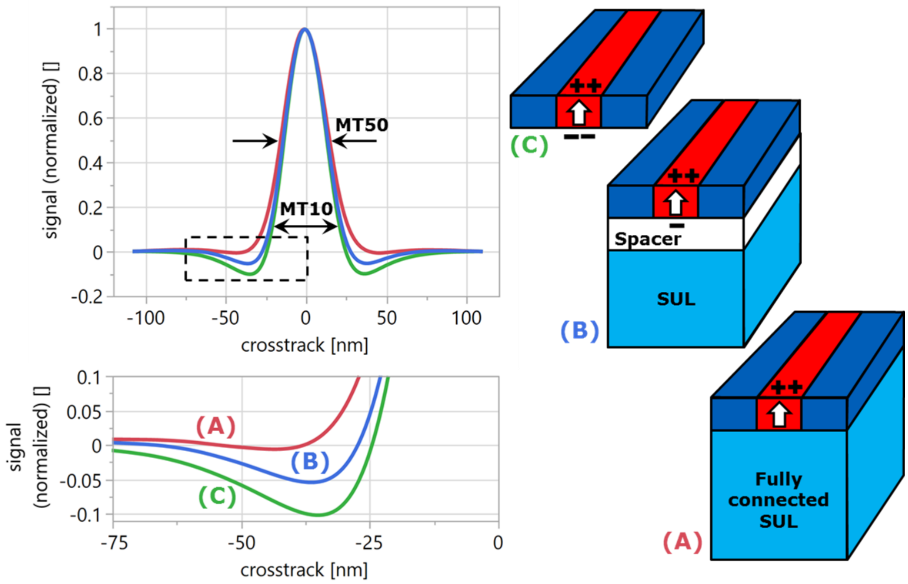

Fig. 1 Simulated micro-track profile of a SB reader (24 nm physical FL width) under 3 media configurations. (A) SUL in contact with the recording media layer (B) Typical product case with SUL separated by 19 nm from the media layer (C) No SUL case.

The 3 cases in Fig. 1 clearly illustrate the importance of the bottom charges. The smallest side lobes occur when the SUL (relative permeability 100) is in contact with the media layer, effectively canceling the bottom charges. Removing the SUL results in the largest side lobes because the bottom charges are unshielded. In actual media, where the SUL is separated from the media layer, the lobes are intermediate.

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Note that deeper side lobes have the effect of slimming the magnetic width measured at the 50% amplitude (MT50) but especially at 10% (MT10). This simulation was performed for a bit length of ~97 nm (8T at 2100 KFCI), much longer than the 24 nm read gap. The side lobes are much less pronounced at shorter bit lengths.

It is important to note that the side lobes do not disappear even when the bottom charges are fully erased Fig. 1(A). This is due to a new mechanism introduced by the SB design, which involves the upper charges. They can cause the SB magnetization to rotate, and it does, the SB stray fields cause an opposite rotation in the FL, hence the undershoot.

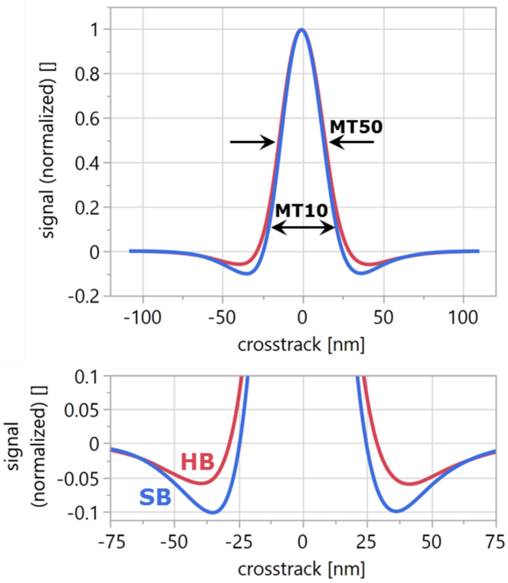

Fig. 2 Simulated micro-track profiles of SB and HB readers, for a media without SUL. HB has smaller undershoots and a wider net MT50 and MT10.

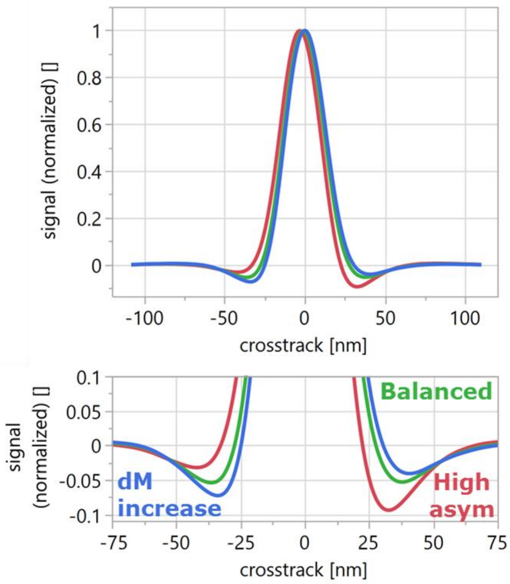

Fig. 3 Simulated micro-tracks for a balanced case (asymmetry = 6.6%, dM = -0.10 memu/cm^2) (Green). High positive asymmetry (15.6%) causes lobe imbalance (Red). Increasing the pinned layers moment difference to dM = 0.06 memu/cm^2 also causes lobe unbalance (Blue).

A direct comparison of the HB and SB micro-track for the no SUL case is shown in Fig. 2, again for an 8T bit at 2100 KFCI. The undershoots are much more pronounced for the SB than the HB, due to the fact that the SB is affected by both the top and bottom media charges, whereas the HB only by the bottom charges. This causes the MT50 to be 1.8 nm narrower for SB compared to HB, for the case of Fig. 2 of a media with a separated SUL at 8T.

Reader design parameters for Fig. 1 and Fig. 2 were chosen so as to produce equal lobes on each side of the track, but this is generally not the case and Fig. 3 highlights the two main mechanisms unbalancing the two lobes. One is asymmetry, and this is related to the magnetization angle of the FL away from the cross-track direction. This introduces a left to right imbalance because the micro-track stray field exerts different amounts of torque on the FL magnetization on the two sides. The second mechanism is more surprising and has to do with the moment difference in the SAF pinned layers (dM = P2 - P1). The model reveals that this is due to the PL rotation when the FL is off track center. The implications of side lobes imbalance for shingle magnetic recording will be discussed.

REFERENCES

1) T. Kagami, et al. “An Areal-Density Capability Study of SMR by using improved Write and Read Heads” Intermag Conference 2011, April 2011.
2) D. Mauri, et al. “Method and System for providing a Side Shielded Read Transducer” US Patent 8630068B1, 2014.