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Fundamental Challenges Facing Perpendicular Magnetic Recording at Nanoscale Dimensions

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Perpendicular magnetic recording has attracted substantial amount of attention as a viable alternative to conventional recording schemes to be implemented in the next several generations of mass data storage solutions. While being technically the closest alternative to longitudinal recording, perpendicular recording is capable of deferring the superparamagnetic density limit beyond what is believed to be achievable with longitudinal recording. Some of the critical issues pertinent to the implementation of perpendicular recording at extremely high-density recording (1Terabit per square inch and above) are addressed in this work.

Magnetic recording is rapidly shifting into the realm of nanoscale technologies. At 1 Terabit per square inch, the size of a recording bit is 25nm x 25nm (assuming 1:1 bit aspect ratio.) To write such small magnetic features onto a recording medium, the dimensions of the write poles need to be shrunk drastically. The characteristic sizes of the smallest magnetic entities in a recording medium (typically crystalline grains) are pushed down to only a few nanometers.

Among the open questions to be discussed in this work is the ability of a write pole with dimensions in the nanoscale range to controllably conduct magnetic flux. The writability limits of a single-pole head (SPH) on a perpendicular medium with a soft underlayer (SUL) are discussed in lieu of the above. The implications of a finite magnetic spacing between a SPH and a SUL on both recording and playback processes are discussed. The necessity of the rigorous control of the recording field gradients is emphasized. Potential solutions in terms of both the geometrical tailoring of the write pole and the utilization of shielded write pole structures are outlined. It is shown that not only does the properly optimized shielded write pole enable sharper field gradients but it also facilitates flux conduction to the air-bearing surface; however, at the expense of marginal efficiency loss. The considerations for the optimized playback head design most suitable for the use in perpendicular recording are presented. It is demonstrated that differential reader configurations possess advantageous critical playback characteristics such as higher playback amplitude, improved spatial resolution, and reduced dependence on flight-height variations as compared to conventional shielded readers. Reciprocity principle is used as a powerful design tool to evaluate playback performance of various reader configurations. Modified design of differential readers with a single MR sensor is proposed to overcome the manufacturability issues associated with a conventional double-MR sensor differential reader.

The role of perpendicular recording in the long-term future of magnetic recording is speculated.