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High-resolution magnetic force microscopy study of high-density transitions in perpendicular recording media

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Abstract

High-resolution magnetic force microscopy (hrMFM) has been used to investigate the write characteristics of forward and reverse flying heads on perpendicular recording media with soft underlayers. hrMFM has the advantage that it provides much better resolution than the read element of a head, particularly in the cross-track direction. Using a quantitative analysis method, many parameters, such as transition position jitter, transition width and signal-to-noise ratio are estimated from the hrMFM image. Furthermore, these parameters, which can also be measured using a spinstand, are compared to the micromagnetic properties of the transitions, such as track curvature, transition width and the local noise associated with transitions. The results give insights into the recording physics and, in particular, in the write process of shielded and un-shielded write heads in perpendicular recording.

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1. Introduction

Perpendicular magnetic recording [1] is widely accepted as a realistic option to further increase the areal density in magnetic disk drives beyond the limitations occurring in longitudinal recording [2]. When a new technology such as perpendicular recording is introduced, a major problem is that the recording physics is difficult to characterize until appropriately designed read heads are available. Moreover, the low cross-track resolution of available read heads renders it difficult to measure the micromagnetic structure of transitions, such as transition curvature, noise and amplitude profiles,

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and track edge effects. Extensive knowledge about the micromagnetic properties of transitions helps assess the potential and extendibility of the investigated recording system. In this paper, we quantitatively analyze high-resolution magnetic force microscopy (hrMFM) images of transitions written by forward and reverse flying longitudinal heads, to circumvent some of the discussed limitations, in particular, the resolution limit in the cross-track direction.

2. Experimental

The investigated dual layer perpendicular recording medium consists of a 13 nm thick CoPtCr-based alloy doped with SiO_x with a thick soft underlayer. The medium has an average grain diameter of approximately 7 nm. A series of tracks with transition densities ranging from 51 to 1016 kfci (kilo flux changes per inch) were written using two different magnetic recording heads (heads A and B). Both heads were longitudinal ring heads with 80 nm wide write gaps and 400 nm wide write poles. During the write process, head A was flown in the forward direction such that the transitions were written by the trailing edge of the write pole. In contrast, head B was flown in the reverse direction, such that the transitions were written by the edge of the write pole, which is directly at the write gap. In this configuration the return pole acts as a trailing shield, enhancing the write field gradient, similar to the head design suggested in [3–5]. The geometry during the write process is illustrated in Fig. 1 with the black arrows showing the direction of head motion.

During the write process, both heads were driven by the same write current. Head B is estimated to have a slightly higher flying height than head A. In spite of this disadvantage, spinstand measurements demonstrated that head B writes and reads back transitions at considerably higher linear densities than head A [6].

The written tracks were imaged by a hrMFM [7] to micromagnetically investigate the differences of the transitions written by heads A and B. Presently, the lateral resolution of commercial instruments is limited to 30–50 nm, which is much larger than the small magnetic features in modern recording media and are expected to be in the order of a grain diameter (7 nm). By operating the hrMFM in vacuum to enhance the sensitivity of the measurement to the sample stray field and using magnetic tips with an apex diameter < 10 nm, a very high lateral magnetic resolution is achieved. Furthermore, all hrMFM images were acquired using the same hrMFM tip at the same tip-to-sample distance. In all hrMFM images shown in this paper the motion of the head during the write process is from right to left, following the geometry described in Fig. 1. Thus the hrMFM images can be directly compared for evaluating the micromagnetic properties of the written transitions.

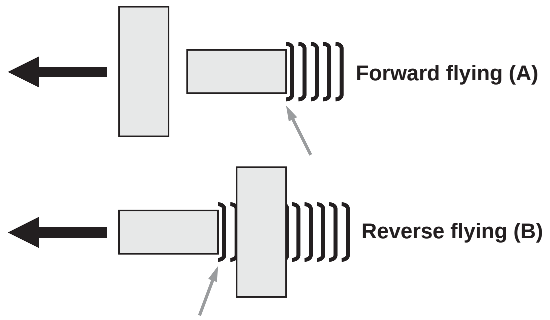

Fig. 1. Geometry of the experiments. The black arrows show the flying direction of the heads relative to the recording medium. The gray arrows show the recording position.

3. Results

Fig. 2 shows an overview image of the tracks written by head B. The areas between the tracks show the as-grown domain structure of the recording medium. The transitions written at 1016 kfci are closely investigated in Fig. 3, which shows hrMFM images (inset) as well as the cross-track averaged signals. The latter provides an estimate of the spinstand read-back signal based on the hrMFM images. Even a visual inspection exposes differences between head A and head B. Clearly, head B writes transitions with higher quality than head A. This result is in agreement with spinstand results of the same head–media combination [6]. The maximum achieved linear