Evaluation of Write Field and Media Response for Shingled Magnetic Recording

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An evaluation of the shingled magnetic recording performance is presented based on combined analysis of the magnetic write field and medium responses. The writer structure is featured with the asymmetrically shielded main pole having a slot between the trailing shield and the side shield at the shingled writing edge. In order to account for the angle dependence of the magnetization reversal behavior, the effective write field profile is studied on the basis of micromagnetic modeling of the medium characteristics solving Landau-Lifshitz-Gilbert equation. In particular, the effective field gradients are examined at various critical locations of the write field contour. It is found that the aforementioned slot may be used to modulate the effective field gradient near the shingled writing corner and the combined analysis can be efficiently applied to perform analyses of the medium noise and erase band width.

***Index Terms*—Magnetic heads, Micromagnetics, Nanostructured materials, Perpendicular magnetic recording.**

I. Introduction

In recent years, new approaches are proposed to assure continued capacity growth for magnetic recording disk drives. One of the seemingly successful techniques is the shingled magnetic recording (SMR) scheme [1], [2] which does not require fundamental reengineering of the magnetic recording system when compared to other technical alternatives. In SMR scheme, the write field at the corner (on the trailing side) and partly the side of write head are contributing to the recording process as oppose to the conventional recording schemes in which only the write field at the trailing edge is primarily responsible [3]. In order for SMR to fully realize its potential, a more refined analysis of both write head and recording media is both important and challenging. On one hand, the evaluation of the write head performance involves precise modeling of the relatively complicated geometry features and material properties [4]. As a result, the write field may be subjected to a relatively complicated field angle distribution. On the other hand, it is desirable to take the media characteristics into consideration due to increasing complexity of the micro-structure of the recording medium which is often featured with nanoscale multilayered magnetic grains [5], [6]. In this paper, the performance of SMR schemes is evaluated based on combined analysis of magnetic write field and medium response. The write head is asymmetrically shielded, similar to that studied in [3] and [7]. It is however includes a slot in the wrap-around shield opposite to the corner of the shingled writing edge of the main pole as suggested in [4]. The magnetic write field is first analyzed using the finite element method. Then the effective write field is evaluated taking into account of the angle dependent switching behavior obtained using micromagnetic modeling of the nano-granular media. In particular, the sensitivity of the gradients of the effective fields at various locations of the write field contour, including the pole corner and the track edge, is obtained based on the combined analysis. It is found that the aforementioned slot may be used to modulate the effective field gradient near the shingled writing corner. The combined analysis can be efficiently applied to perform analyses of the erase band width.

II. Write Head modeling

The utilization of the asymmetrically shielded SMR write head is believed to be helpful to achieve higher effective write field while keeps good field gradient, and to reduce the leakage flux to the adjacent bits which is crucial for ultra-high density recording systems [7]. In this study, the magnetic write fields are analyzed using a finite element method, and a schematic view of the write head structure from air bearing surface (ABS) is shown in Fig. 1. In this figure, the key parameters that are to be considered in the following investigation are indicated as follows: X1, trailing shield gap, X2, shingle writing side shield gap, X3, base angle of the main pole on the shingle writing side, X4, length of the slot, X5, leading shield gap and X6, the shield gap on the free side.

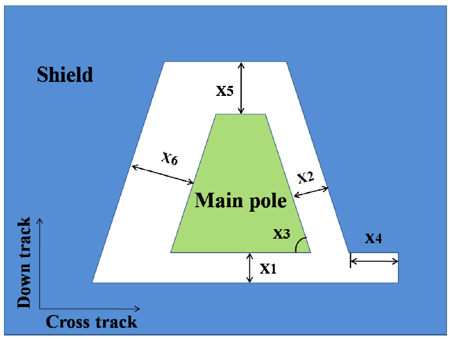

Fig. 1. An asymmetry write head views at ABS plane.

Figs. 2 (a) and (b) illustrate the write field magnitude and field angle distribution in media center plane, respectively. The influence of the slot between the trailing and side shields on the write field around the corner on the shingled writing side is clearly observable. It is worthwhile to explore such modulation effect as the write field contour in the region is of critical importance to the recording performance.

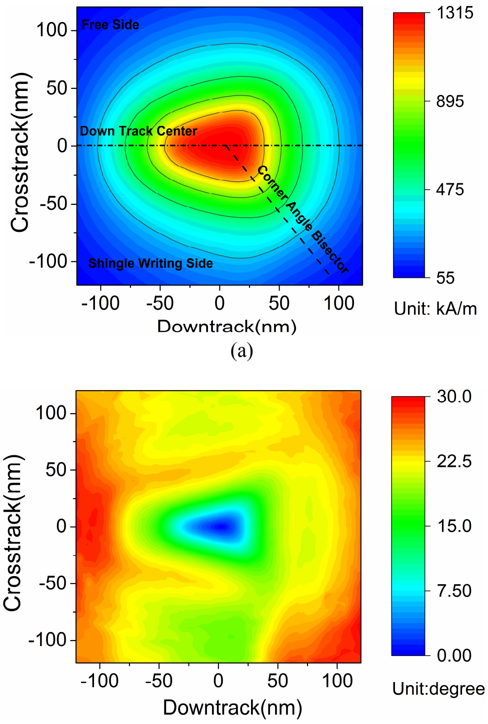

Fig. 2. Asymmetrical write field (a) magnitude and (b) angle distribution in center plane of media

III. Effective Write Field Evaluation and Recording Performance Analysis

The magnetization reversal dynamics shows clear dependence on the field angle for perpendicular recording media [8]. In the following analysis, the switching field angle dependence is evaluated based on micromagnetic modeling of media responses which provides more reliable information than that based on estimation using the Stoner-Wohlfarth model as reported in some previous research works [9]. Fig. 3 plots the switching field as a function of the applied field angle for media with different anisotropy energy density K_u.

One of the major concerns for the recording quality in shingled writing is that there is a tendency of effective field spreading around the corner of the write pole. Therefore the effective field gradient needs to be evaluated around the write contour in the directions normal to the contour. Fig. 4 shows the field profile calculated along the dash line across beneath the effective field profile as compared with the perpendicular and in-plane components of the write field along the corner bisector line indicated in Fig. 2(a). Fig. 5 shows the shingled recorded bits with a length of 20nm, the track pitch is 60nm, the grain diameter is 7nm.

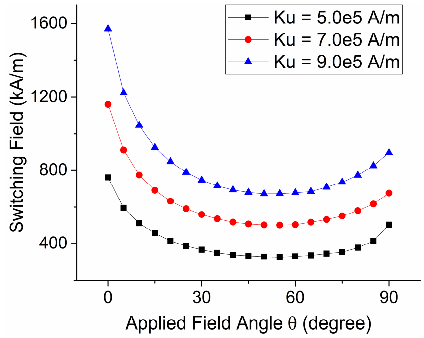

Fig. 3. Switching field vs. applied field angle for media with different anisotropy fields.

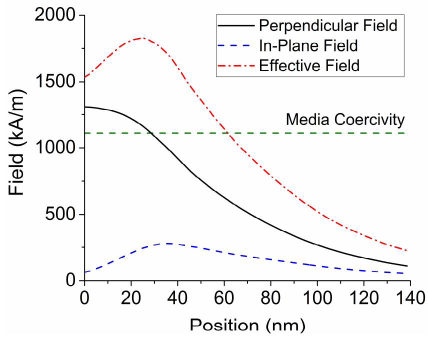

Fig. 4. Effective field profile as compared with perpendicular and in-plane components of write field along corner bisector line.

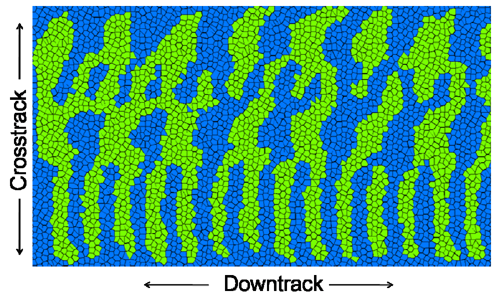

Fig. 5. Strings of bits recorded with SMR scheme

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