Journal of Magnetism and Magnetic Materials 320 (2008) 2854–2859

Contents lists available at ScienceDirect

Journal of Magnetism and Magnetic Materials

journal homepage: www.elsevier.com/locate/jmmm

Shielded planar write head

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ARTICLE INFO

Available online 23 August 2008

Keywords:
Shielded planar head
Tapered pole
Recording head
Perpendicular recording

ABSTRACT

Field calculation with a finite-element method was performed for optimization of the shielded planar head composed of a tapered pole in both down and cross track directions and a wrap-around shield. Especially, effect of the taper angle of the main pole and the gap length and the height of the shield on head field was investigated to obtain a strong head field with a sharp distribution. In order to explore potential of the planar head, comparison with a conventional head with a normal main pole with a short throat was made and feasibility of 1 Tbit/in^2 recording with patterned media was discussed in terms of magnetization reversals of aimed track and thermal stability of magnetization on adjacent tracks.

1. Introduction

Continuing growth of recording density will require using media with increasing anisotropy energy to maintain thermal stability of recorded bits consisting of reduced-sized grains. To alleviate writability problem for such increased anisotropy media, introduction of controlled inter-granular exchange coupling and hard/soft stacked layer design with inter-layer exchange coupling have been considered for granular media. Discrete track media may have an advantage in writability because wider track width of write heads than that of heads combined with continuous media can be used. Furthermore, bit patterned media that have large switching volume and consequently reduced switching field are considered as promising candidates for future high density recording media. As for writing heads, pole structures with a trailing shield and a side shield [1] have been developed for realizing a sharp field distribution. Recently, tapered pole structure [2] is expected to produce large head field exceeding the material limitation of saturation magnetization for main poles. We proposed a multi-charged-surface (MCS) main-pole design that has two types of structure as shown in Fig. 1: the stepped type and the tapered type [3]. The main-pole tip is composed of two stepped flat surfaces in the former type, while oblique surfaces in the latter type. The tapered MCS head can generate larger field than the stepped one. To realize the tapered MCS head, we have proposed a shielded-planar single-pole head (abbreviated as a planar head hereafter) and its fabrication method [4]. In this paper, simulation design of the planar head with a tapered main pole by field calculation using a finite-element method (FEM) is described.

2. Field calculation model

Schematic structure of the planar head used for the field calculation is illustrated in Fig. 2. The figure shows the cross section of the planar head in the cross track direction, which is the same as that in the down track direction except for the pole tip dimensions. The oblique angle of the tapered main pole, which is referred to as taper angle, is the same in both the down track and the cross track directions, and the bevel angle of the shield end is the same as that of the main pole. The head model is combined with a soft under layer (SUL) of a double-layered perpendicular medium. Typical parameters for the calculation are listed in Table 1. Field calculation was performed by a commercial 3D-FEM software, Maxwell.

3. Field calculation for head design

As shown in Fig. 2, the planar head is composed of a tapered main pole, a frame shaped shield plate which wraps around the main-pole tip, a horizontally wound coil and a return yoke. The structure is fundamentally an open magnetic circuit. If it is changed to a closed magnetic circuit such that the side ends of the return yoke reach near the surface of the medium, the head efficiency can be improved. However, it provides almost 10 times larger return yoke field and also increased fringing field of the main pole. Therefore, the flat return yoke at a distance from the medium surface has been employed, as shown in Fig. 2. In this planar head, key design parameters to obtain a strong and sharp field distribution are regarded as the throat height of the pole tip, the taper angle, and shield dimensions including the shield gap length and the shield height, which are described below.

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doi:10.1016/j.jmmm.2008.07.045

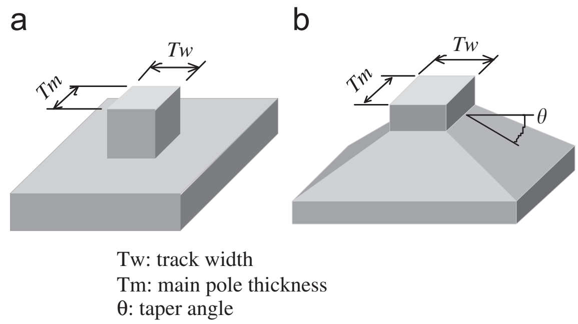

Fig. 1. Schematic illustration of multi-charged-surface (MCS) main pole: (a) stepped type, (b) tapered type.

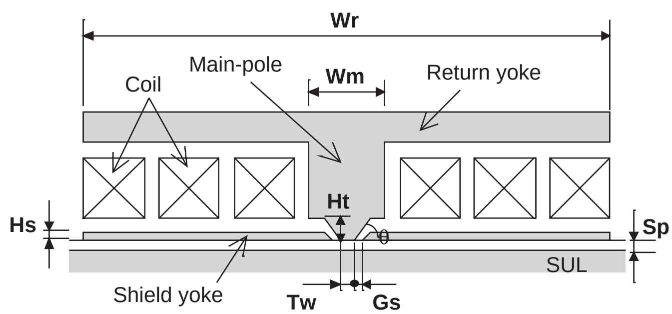

Fig. 2. Schematic illustration of shielded planar head with soft under layer of medium.

Table 1
Typical parameters of planar head for field calculation

Parameter	Value
Main pole	
Material	Bs2.4T, µ1000
Track width, Tw	14 nm
Thickness, Tm	45 nm
Taper height, Ht	100 nm
Taper angle, θ	55°
Core width, Wm	600 nm
Return yoke	
Material	Bs2.4T, µ1000
Core width, Wr	6.1 µm
Thickness	500 nm
Shield yoke	
Material	Bs2.4T, µ1000
Shield gap length, Gs	12 nm
Shield height, Hs	15 nm
Soft under layer	
Material	Bs2.4T, µ200
Thickness	100 nm
MP separation, Sp	12 nm
Number of coil turns	3

3.1. Full-tapered main-pole tip

Tapered poles combined with throat structure such as the one shown in Fig. 1b has been reported so far [5,6]. In the throat region of the pole, the pole width in the cross track direction, which corresponds to the track width, is constant throughout the throat height. Therefore, it is easy to obtain manufacturing accuracy in defining the track width. Effect of throat height on the head field is calculated as shown in Fig. 3 for the head with a cross section of the throat of 20×50 nm. It was found that the field dramatically

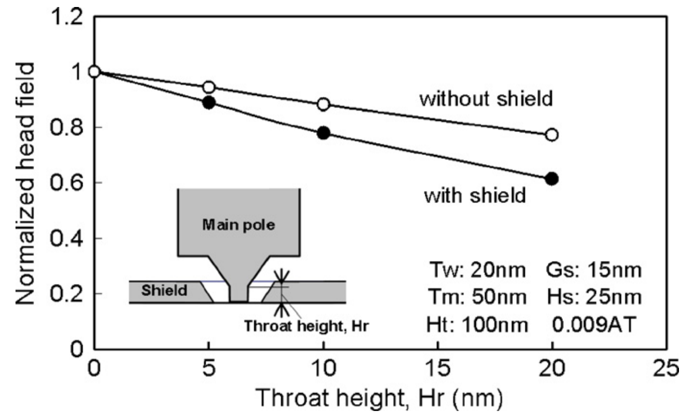

Fig. 3. Throat height dependence of normalized head field for track width of 20 nm and main-pole thickness of 50 nm.

decreased with increasing throat height. For example, when the throat height increased from 0 to 20 nm, which corresponds to the track width, the field strength decreased by about 40%. The field gradient in down track direction of the head with the throat of 10 nm was compared with that of the head with zero throat on the premise that the field strengths for these heads were the same by adjusting the shield heights which were 10 nm for the 10 nm-throat head and 25 nm for the zero-throat head. These heads exhibited almost the same field strength of 15 kOe. The maximum field gradient of the 10 nm-throat head was 416 Oe/nm, while 517 Oe/nm for the zero-throat head. It was found that zero throat was preferable for obtaining high field gradient to realize high linear density.

Next, cross track field profile of a head with the throat of 10 nm was compared with that of the zero-throat head. The head with throat had tapered structure of the main pole only in the down track direction in order to increase field strength [6,7]. Therefore, the difference in pole structure is the structure in the cross track direction, namely, cross track-throat structure and cross track-tapered structure. The maximum field strengths of these heads were set at almost the same values of 15 kOe by adjusting the shield heights, which are 15 nm for the cross track-throat head and 25 nm for the cross track-tapered head. Comparison of field distribution in the cross track direction is shown in Fig. 4. It was found that the cross track-throat head not necessarily showed smaller fringing field compared with the cross track-tapered head. This is because of poorer shielding effect due to lower shield height of the cross track-throat head.

From the above results, it is suggested that the main pole without throat, which is referred to as full-tapered main pole, is the most suitable design for future high density recording in terms of both linear density and track density. Consequently, this full-tapered pole structure has been adopted for the planar head.

3.2. Taper angle effect

In the MCS structure, the magnetic field from the charge on the tapered surfaces is superimposed on the field from the charge on the pole air bearing surface (ABS). This is the reason for the large head field of the planar head. Therefore, the taper angle, which is defined as the angle shown in Fig. 2, is regarded to be one of the major parameters of the head design.

Effect of taper angle on the field of the planar head is shown in Fig. 5 for various magneto-motive forces. In the figure, the case for the pole structure without the shield is also plotted. The track width and the taper height were 40 and 200 nm, respectively. The bevel angle of the shield end was changed in accordance with the