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Journal of Magnetism and Magnetic Materials 287 (2005) 9–15

Journal of magnetism and magnetic materials

www.elsevier.com/locate/jmmm

Principal complementarity between perpendicular and longitudinal magnetic recording

Shun-ichi Iwasaki*

Tohoku Institute of Technology, 35-1 Yagiyama-Kasumi-cho, Taihaku-ku, Sendai 982-8577 Japan

Available online 30 October 2004

Abstract

Complementarity law between contrasting characteristics of longitudinal and perpendicular recording is described. The complementarity includes orthogonal field distributions of single-pole head and ring head due to the spatial configuration of pole structure. Significant dependence of recording resolution upon media parameters (δ, H_c, B_r) in longitudinal recording is indicated. In contrast, these parameters do not govern the resolution in perpendicular recoding. This intrinsic difference is caused by the opposite effects of demagnetization. Read/write characteristics in hard disk drives are found to obey these complementary relationships during prototyping.

Keywords: Perpendicular recording; Longitudinal recording; Metal particle tape; Complementarity

1. Introduction

Perpendicular magnetic recording was introduced by the discovery of the Co–Cr perpendicular anisotropy film and the single-pole head [1] based on the circular magnetization mode [2]. During the research process leading to the establishment of perpendicular recording, the head and media were investigated simultaneously. In order to clarify the recording principle, it was necessary to entirely re-examine recording theory because of the novelty of perpendicular recording. Besides, since the head and media were evaluated at the same time, the fundamental principles behind perpendicular recording had to be carefully considered. Therefore, the iteration approach was taken to deduce recording principles by going back and forth between experimental data and theory. The fundamental nature of longitudinal and perpendicular magnetization was found to be complementary in many phenomena. The complementarity principle was thus discovered, and became the principal guideline for development [3]. The word "complementarity" was used because it was expected that the physical understanding of the whole phenomena of magnetic recording and its technological application would be perfected with longitudinal and perpendicular magnetic recording by complementing each other. The hint for this

*Tel.: +81 22 229 1151; fax: +81 22 233 1641.
E-mail address: iwasaki@tohtech.ac.jp (S.-i. Iwasaki).

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doi:10.1016/j.jmmm.2004.10.003

was obtained from the optical phenomenon that two colors of light, for example red and green, bring about white or gray when they are mixed, i.e., they are complementary colors.

At present, perpendicular recording is expected to establish recording schemes and devices for ultra-high density recording beyond 1 Tbits/inch^2. The complementarity principle is a significant aid for this purpose.

2. Spatial complementarity

A fundamental rule is that an attracting force (enhancement) acts between neighboring opposite magnetizations in the perpendicular mode, whereas the force is repulsive (demagnetization) in the longitudinal mode. This means that perpendicular magnetization is the more magnetically stabilized than the longitudinal magnetization at higher densities. This contrasting nature of the forces indicates that the magneto-static energy and the demagnetizing field in the magnetization modes act in opposite ways. Therefore, in terms of the requirements for high-density media, the parameters of saturation magnetization, M_s, coercive force, H_c, recording layer thickness, δ, and recording bit density (bpi) affect performance in opposite ways in longitudinal and perpendicular recording.

Besides, the structure of two magnetic heads, the ring head for longitudinal recording and the (auxiliary-pole driven) single-pole head [1] for perpendicular recording, shows a spatial symmetry. Fig. 1 schematically indicates this relationship. The auxiliary pole of the single-pole head is in the magnetically same potential, or magnetically continuous, to the soft magnetic underlayer (SUL), therefore, the backside of the medium is filled with highly permeable material. This space is air in the longitudinal case. And, the main pole of the single-pole head corresponds to the gap of the ring head that is unity permeability. Thus, the highly permeable material in longitudinal mode is changed into the space of unity permeability. The two recording schemes could be referred to as a “spatial complementarity”.

As a result of this spatial complementarity and potential distribution, the fields of the ring head

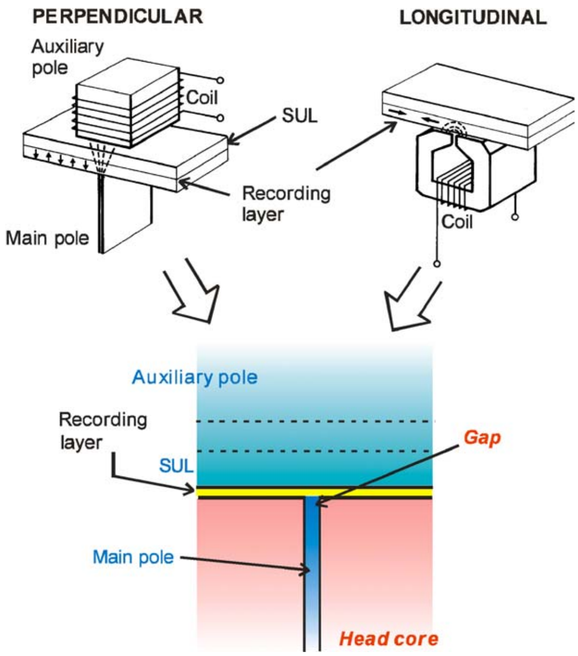

Fig. 1. Schematic explanation of the spatial complementarity between ring head and single-pole head.

and that of the single-pole head are orthogonal to each other. The horizontal component of the ring head, Hx_{ring}, is identical to the vertical component of the single-pole head, $Hy_{\mathrm{S.P.}}$, and vice versa.

$$Hx_{\mathrm{ring}} \equiv Hy_{\mathrm{S.P.}}, \quad Hy_{\mathrm{ring}} \equiv Hx_{\mathrm{S.P.}}.$$

In addition to this vector relationship, the well-known gap loss of the ring head, G_p, corresponds to the main-pole thickness loss, T_p [4] in readback process. It can be understood that the loss due to the thickness of non-magnetic material, or the length of the gap, in the ring head is equivalent to that by thickness of the soft-magnetic material in single-pole head, that is,

$$\text{Gap loss (ring)}, \ G_p \equiv \text{Main-pole thickness loss}, \ T_p.$$

3. Longitudinal magnetization mode

A remarkable motivating force to gain a fundamental understanding of perpendicular recording was the accumulated knowledge of