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TITLE OF THE INVENTION

PERPENDICULAR MAGNETIC DISK APPARATUS

BACKGROUND OF THE INVENTION

One embodiment of the present invention relates
5 to a perpendicular magnetic disk apparatus capable of
suppressing degradation of recorded data.

Magnetic disk apparatuses are perpetually
demanded to improve recording densities, and thus the
recording scheme is being shifted to the perpendicular
10 recording system. Also in the perpendicular magnetic
disk apparatus, the bit size carrying information on
the recording medium is inevitably reduced in
accordance with the increase in recording density.
Consequently, there is a tendency that erroneous
15 erasure of data recorded on the medium may easily
occur, leading to degradation of recording stability.
One factor of erroneous erasure of data recorded on
the medium is a perpendicular magnetic field that is
generated based on magnetization remaining on the main
20 pole after recording operation.

Conventionally, there has been proposed a
perpendicular magnetic head whose residual
magnetization on the main pole can be reduced (Jpn.
Pat. Appln. KOKAI Publication No. 2004-86961). This
25 perpendicular magnetic head includes a write pole, a
supplemental pole and a coil. The write pole includes
a main pole and a yoke portion having a greater width

than the main pole in the cross-track direction. The magnetostriction constant of the main pole and the magnetostriction constant of the yoke portion have positive and negative signs, respectively.

5 According to research by the present inventor, however, it has been found that the problem of erroneous erasure of data cannot be solved by merely controlling the magnetostriction constants of the main pole and yoke portion.

10 BRIEF SUMMARY OF THE INVENTION

 According to an embodiment of the invention, there is provided a perpendicular magnetic disk apparatus comprising: a perpendicular recording medium including a soft underlayer and a perpendicular
15 recording layer; and a write head including a main pole, a return yoke and an exciting coil, wherein a product of a magnetostriction constant λ [E-6] of the main pole and a stress S [MPa] acting on the main pole, and a coercivity H_c [Oe] of the medium meet the
20 following formula:

$$\lambda \times S > 30,000,000/H_c.$$

 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

 A general architecture that implements the various feature of the invention will now be described
25 with reference to the drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the invention and not limit the scope

of the invention.

FIG. 1 is a perspective view of a perpendicular magnetic disk apparatus according to an embodiment of the present invention;

5 FIG. 2 is a perspective view of a perpendicular magnetic disk apparatus according to another embodiment of the invention;

FIG. 3 is a graph showing the relationship between a coercivity H_c of a medium and an occurrence
10 rate of recording instability when magnetic heads each including a main pole formed of different materials are used; and

FIG. 4 is a graph showing lower-limit conditions under which the occurrence rate of recording
15 instability becomes zero in a coordinate system of the coercivity H_c of the medium and the product of $\lambda \times S$.

DETAILED DESCRIPTION OF THE INVENTION

Various embodiments according to the invention will be described hereinafter with reference to the
20 accompanying drawings.

Whether erroneous erasure of data recorded on the medium occurs depends on the balance between magnitude of a perpendicular magnetic field by magnetization remaining on the main pole after recording operation
25 and stability of the recorded state in the medium. The inventor has found that, in order to solve the problem of erroneous erasure, it is necessary to take

the magnetostriction constant of the main pole, the stress acting on the main pole, and the coercivity of the medium into account. To be more specific, it is necessary that a product of a magnetostriction

5 constant λ [E-6] of the main pole and a stress S [MPa] acting on the main pole, and a coercivity H_c [Oe] of the medium meet the following formula (1):

$$\lambda \times S > 30,000,000/H_c \quad (1).$$

The stress S is induced when the main pole is
10 formed, and it uniformly acts in the film surface. The product of λ and S is electrostriction energy. In a perpendicular magnetic disk apparatus that satisfies the relationship of formula (1), data recorded on the medium is not erased by magnetization remaining on the
15 main pole after recording operation.

FIG. 1 is a perspective view of a perpendicular magnetic disk apparatus according to an embodiment of the present invention. A magnetic disk 10 shown in FIG. 1 includes a substrate 11, a soft underlayer 12
20 and a perpendicular recording layer 13 having magnetic anisotropy in the perpendicular direction to the film surface. Another layer such as a crystal orientation layer may be formed. Usually, a protective layer is formed on the perpendicular recording layer 13, and a
25 lubricant is coated on the protective layer. A magnetic head 20 shown in FIG. 1 is a separate-type magnetic head in which a write head and a read head

are separated. The write head includes a main pole 21, a return yoke 22 disposed on the leading side of the main pole 21, and an exciting coil 23. The main pole 21 is formed of a high-permeability material and generates a perpendicular magnetic field to the magnetic disk 10. A closed magnetic path is efficiently formed by the main pole 21, the soft underlayer 12 of magnetic disk 10, and the return yoke 22. The exciting coil 23 is wound around a back yoke that couples the main pole 21 and return yoke 22. The read head includes a magnetoresistive film (not shown in FIG. 1) and shield films 25 and 26 disposed on the trailing side and leading side of the magnetoresistive film.

FIG. 2 is a perspective view of a perpendicular magnetic disk apparatus according to another embodiment of the invention. This perpendicular magnetic disk apparatus has the same structure as the perpendicular magnetic disk apparatus shown in FIG. 1, except that the return yoke 22 is disposed on the trailing side of the main pole 21.

FIG. 3 shows the relationship between a coercivity H_c of the medium and an occurrence rate of recording instability when magnetic heads each including a main pole formed of different materials are used. The physical properties of the materials for the main poles are indicated by the product of the

magnetostriction constant λ [E-6] of the main pole and the stress S [MPa] acting on the main pole, i.e., the magnetostrictive energy.

The occurrence of recording instability is defined by occurrence of output degradation of read signals for recorded data under a situation that no current is supplied to the write head. Specifically, the occurrence of recording instability is determined when a degradation of 5% or more is observed with respect to the initial output of the read signals for recorded data.

The occurrence rate of recording instability refers to a rate at which the recording instability occurs for a great number of write heads that are fabricated using a material with the same magnetostrictive energy. Usually, the occurrence rate is calculated on the basis of experimental results relating to several hundred to several thousand write heads.

It is found from FIG. 3 that the occurrence rate of recording instability becomes higher as the coercivity H_c decreases. In addition, it is found that the coercivity H_c of the medium, with which the occurrence rate of recording instability becomes zero, varies depending on the product of λ and S .

FIG. 4 shows lower-limit conditions under which the occurrence rate of recording instability becomes

zero in the coordinate system of the coercivity H_c of the medium and the product of λ [E-6] $\times$ S [Mpa].

The curve in FIG. 4 is represented by the formula: $\lambda \times S = 30,000,000/H_c$. In a perpendicular magnetic disk apparatus that satisfies the condition
5 above the curve, data recorded on the medium is not erased by magnetization remaining on the main pole after recording operation.

In order to reduce the recording instability, it
10 is preferable that the value of magnetostrictive energy [$\lambda \times S$] be high. However, if the product of λ and S is excessively high, physical breakage of the main pole may occur. Thus, the product of λ and S is set within a range in which no physical breakage of
15 the main pole will occur.

While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel
20 methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions.
25 The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

WHAT IS CLAIMED IS:

1. A perpendicular magnetic disk apparatus
comprising:

5 a perpendicular recording medium including a soft
underlayer and a perpendicular recording layer; and

a write head including a main pole, a return yoke
and an exciting coil,

wherein a product of a magnetostriction constant
 λ [E-6] of the main pole and a stress S [MPa] acting
10 on the main pole, and a coercivity H_c [Oe] of the
medium meet the following formula:

$$\lambda \times S > 30,000,000/H_c.$$

2. The apparatus according to claim 1, wherein
the return yoke is disposed on a leading side of the
15 main pole.

3. The apparatus according to claim 1, wherein
the return yoke is disposed on a trailing side of the
main pole.