

LOW-INDUCTANCE THIN-FILM HEAD

TECHNICAL FIELD

5 The present invention relates to magnetic recording systems, and more particularly to a low-inductance thin-film magnetic recording head.

BACKGROUND OF THE INVENTION

10 The use of thin-film heads for magnetic recording is well known. The heads are used in computer disk drives to provide high-density recording of digital data.

A conventional thin-film head includes an upstream pole and a downstream pole, both formed from a ferromagnetic flux-conductive material, such as nickel iron cobalt (NiFeCo) alloy and thin film conductors arranged to induce the requisite flux between the poles, and to sense changes in the flux.
15 The poles are magnetically isolated at a narrow tip region of the head, such as by mechanically spacing them apart. In addition, the poles are magnetically coupled at the opposite wide end, commonly referred to as a yoke, by mechanically joining them.

20 A problem with known thin-film heads is that if the stray flux becomes too great, the inductance of the head becomes too large and limits the frequency at which the head can operate. That is, the rate at which the head can either read data from, or write data to the disk is limited by the head inductance.

25 An example of the problems caused by high head inductance is that during a read operation, a resonance may occur between the inductance of the head and the input capacitance of a preamplifier circuit in the sensing circuitry. This resonance may be within the frequency band of the signals retrieved from the disks, and therefore interfere with the integrity of the retrieved data.

30 This problem is especially troublesome when the density of the recorded data on the disk is increased. Additional windings might be added to the head in an effort to detect weaker signals associated with high density recording. However, this would increase the inductance of the head to an unacceptable level, particularly in view of the high data rates associated with
35 high density recording.

Increased head inductance also creates problems during the write cycle. The larger the inductance of the head, the more time it takes for current

to build up through the winding before sufficient flux is available at the tip region to write to the disk. Hence, a designer has to select a write speed sufficiently slow to ensure that the disk operates within acceptable criteria, or the designer has to provide a larger drive circuit to drive the head hard
5 enough (i.e., increase the applied voltage) to overcome the high inductance.

Therefore, to operate a thin-film head at high data rates, it is highly desirable to reduce the inductance of the head.

SUMMARY OF THE INVENTION

A principal object of the present invention is to reduce the inductance of a thin-film magnetic head.

Another object is to provide an easily manufacturable thin-film
5 magnetic head with low-inductance.

Briefly, a thin-film magnetic head embodying the invention includes a flux barrier layer of electrically conductive, non-magnetic material positioned over (i.e., downstream of) the downstream pole to reduce leakage or stray flux, which contributes to the head inductance, but does not contribute to the
10 transfer of energy between the winding of the head and the disk. Stray flux that enters the barrier layer creates an eddy current in the layer. The flux developed by this current opposes and thereby tends to cancel the stray flux, thus reducing the inductance of the head and improving its read performance.

According to another aspect of the invention, a similar flux barrier can
15 also be placed below (i.e., upstream of) the upstream pole to reduce head inductance and improve the write performance of the head.

According to yet another aspect of the invention, a flux barrier of electrically conductive, non-magnetic material may be disposed between the poles. Stray flux between the yokes members (i.e., the poles) is thus reduced,
20 again reducing the head inductance.

Gold is a preferred material for the flux barrier layers since it involves fewer deposition steps because of its compatibility with the other films which form the various layers of the head. Alternative materials for these layers include copper, aluminum, or any other highly conductive material which is
25 compatible with the other materials of a thin-film magnetic head and is easily deposited to form the flux barriers of the present invention.

The present invention may also be used in a system which comprises a magneto-resistive (MR) read head and an inductive thin-film write head.

The term "conductive layer" and "flux barrier" are synonymous as
30 used herein, and, as such, the terms may be used interchangeably herein.

An advantage of the invention is that more turns can be added to the head to improve the read signal strength without unduly increasing the head inductance.

Another advantage of the present invention is that a low-inductance
35 head of the present invention may be less susceptible to cross talk through glass disks.

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed

description of preferred embodiments thereof, as illustrated in the accompanying drawings.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a schematic side view of a low-inductance thin-film read/write head in operational position above a rotating magnetic disk;

Fig. 1B is a schematic frontal view of the head illustrated in Fig. 1A;

Fig. 2 is a schematic side view of an alternative of the head with a flux
10 barrier layer positioned between the poles;

Fig. 3 is a schematic side view of yet another alternative embodiment of the head with a first flux barrier placed above the head and a second flux barrier layer positioned between the poles; and

Fig. 4 is a schematic side view of still another embodiment of the head
15 having a flux barrier layer upstream of the upstream pole.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1A shows an electromagnetic head 10 in operational position over a rotating magnetic disk 12. The head 10 includes an upstream pole 14 and a downstream pole 16. The poles 14,16 are formed from a ferromagnetic flux-conductive material, such as nickel iron cobalt (NiFeCo) alloy. Other suitable pole materials include cobalt zirconium CoZr, cobalt zirconium neodymium CoZrNd, iron nitride (FeN) or iron silicia and the like. The poles are narrowly spaced apart by a gap 22 in a tip region 18. In addition, they are magnetically coupled at the upper end (yoke) 20, by mechanically joining them to provide an overall horseshoe configuration to the head, as known to those skilled in the art.

The space between the poles is occupied by a layer 21 extending from the tip region 18 to the yoke 20. The layer 21 is formed from a material which is both non-magnetic and electrically insulating, such as Al_2O_3 or SiO_2 .

A ridge/bump 24 of baked photoresist or ceramic is formed on the downstream pole 16, to allow the layer 21 to accommodate a plurality of conductors 26a positioned in the space between the poles 14,16 and interconnected (not shown) to conductors 26b above the downstream pole 16 to form a coil 26. Further conductors (not shown) conduct electric current between the coil 26 and read/write circuitry (not shown). The head 10 also includes a protective ceramic outer layer 34 that cooperates with a substrate 32 to encapsulate the head 10.

The magnetic disk 12 is perpendicular to and opposite the poles 14,16 at the tip region 18 and stores the recorded information in a well known manner. Specifically, the tip region 18 is positioned in close proximity (e.g., about 0.05 to 0.1 microns) above the disk 12 to sense flux from the disk during the read cycle, and to alter the polarization in successive bit locations during a write cycle.

During read operations, as various sections of the disk 12 having different recorded polarizations pass under the tip region 18, magnetic flux travels through the poles 14,16. The changing flux in turn induces an electric potential in the coil 26 which provides an electrical indication of the sensed magnetic field.

During write operations, the process is reversed, with a current of either polarity being applied through the coil in a well known manner. This creates a magnetic field in one direction or the other depending upon the polarity of the current, with sufficient strength to set the magnetization of a small portion of the disk 12 adjacent the tip 18 in order to write a bit of information to the disk.

In order to facilitate magnetic flux conduction in the poles, the yoke 20 is often made as wide as possible (perpendicular to the plane of the drawing) and the magnetic path length is made as short as possible, to reduce the yoke reluctance and thus increase the amplitude of the signal from the head during a read operation. However, this also increases the leakage inductance by increasing the lengths of the conductors 26b.

According to the present invention, the head 10 includes a flux barrier layer to cut-off stray flux paths, and thus reduce the inductance of the head 10. Specifically, a flux barrier 42 in Fig. 1A, in the form of an electrically conductive, non-magnetic layer is disposed adjacent to the protective ceramic layer 34 and thus closely spaced from the downstream pole 16.

The invention is premised on the fact that if a layer of electrically conductive, non-magnetic material is placed over a conductor, the current in the conductor will induce a negative image of itself in the layer of conductive material that will cancel the stray magnetic fields that would otherwise enter the space occupied by the barrier layer. Ordinarily, the thickness of the conducting sheet will exceed the skin depth. As known, skin depth is a measure of the depth of penetration by electrical current into a metallic conductor.

Placing the flux barrier layer 42 over the head suppresses stray flux from the conductors 26b and those portions of the conductors 26a that are external to the yoke 20. This reduces the inductance of the coil 26 and it allows additional coil turns to be added to the head, which facilitates detecting weaker fluxes associated with denser disks.

The flux barrier layer 42 may be formed from gold, copper, aluminum or similar materials, but gold is preferred because of its compatibility with the other materials in the head. However, if a lower-cost material is required, then copper, aluminum, or a similar material may be used if the proper compatibility layers are provided to ensure material compatibility between the respective layers. If gold, which has a skin depth of 17 microns at 20 MHz is used, that layer may be about 10 to 50 microns thick, preferably 17 to 30 microns thick. Thicker shields will maintain performance to lower frequencies. However, the negative effects of high inductance occur at high frequencies, and therefore the thickness can be reduced for manufacturability without degrading the high frequency inductance by much.

The flux barrier layer 42 may be deposited on the ceramic layer 34 using any of a number of known techniques including electroplating, vacuum

evaporation, ionic sputtering, and vacuum deposition. A preferred technique for depositing the flux barrier layer 42 is electroplating.

Fig. 1B illustrates a schematic frontal view of the head wherein the flux barrier layer 42 is positioned over the coil 26 and yoke 20 regions of the head (note, for ease of illustration and clarity the head has been shown in phantom without the encapsulation layers 32, 34).

Fig. 2 illustrates another low-inductance thin-film head 50 having a flux barrier layer 52 positioned between the poles 14,16. This embodiment is similar to the embodiment in Fig. 1A, with the exception that the barrier layer 52 is positioned to reduce the stray flux through the space between the poles 14, 16. As shown in Fig. 2, the flux barrier layer 52 extends under the conductors 26a and the upstream pole 14. The flux barrier layer may be approximately five (5) microns.

Fig. 3 illustrates yet another low-inductance thin-film head embodiment 60 which is substantially similar to the embodiments in Figs. 1A and 2, with the exception that first and second flux barrier layers 42,52 are placed, respectively i) downstream of the ceramic layer 34 and ii) between the poles 14,16. The first flux barrier layer 42 is primarily responsible for cutting off flux paths from the yoke similar to the embodiment in Fig. 1A, while the second flux barrier layer 52 is positioned between the poles 14,16 to cut-off the flux paths inside of the yoke region similar to the embodiment in Fig. 2.

Fig. 4 illustrates still another embodiment 70 of the present invention in which a flux barrier layer 72 is positioned upstream of the upstream pole 14 to cut-off stray flux paths and improve the read and write performance of the head.

Tests of the present invention indicate a substantial reduction in head inductance. In one such test, an embodiment similar to Fig. 1A having a ceramic layer thickness of 35 microns and forty-two coil turns was tested with and without the flux barrier layer 42. The test indicated coil inductance may be reduced by more than 20% at frequencies above 30 MHz.

Although the present invention has been discussed in the context of an inductive read/write head, it is contemplated that the present invention may also be used in a system which comprises a magneto-resistive (MR) read head and an inductive thin-film write head.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, it should be understood by those skilled in the art that various other changes, omissions and additions to

the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

CLAIMS

- 1 1. A magnetic recording device, comprising:
 - 2 A. a data storage disk;
 - 3 B. a thin-film head positioned over said data storage disk to write
4 data to said data storage disk, wherein said data is carried to said head
5 via an electrically conductive coil, and said head includes a first
6 electrically conductive flux barrier layer positioned to reduce the stray
7 flux generated by current in said coil, thereby reducing the inductance
8 of said head.
- 1 2. The magnetic recording device of claim 1 wherein
 - 2 B1. said head comprises a downstream pole and an upstream pole,
3 attached at a yoke end of said head and separated at a tip end of said
4 head by an electrically insulating non-magnetic gap layer having a
5 plurality of electrical conductors running therein, and having an
6 encapsulation layer which is disposed over said downstream pole; and
7 B2. said first flux barrier layer is positioned adjacent to said
8 encapsulation layer.
- 1 3. The magnetic recording device of claim 2, further comprising:
 - 2 C. a second electrically conductive flux barrier layer disposed
3 between said downstream pole and said upstream pole, wherein stray
4 flux between said first and second poles is reduced by said second flux
5 barrier layer.
- 1 4. The magnetic recording device of claims 3, further comprising:
 - 2 D. a layer of electrically insulating, non-magnetic material disposed
3 between said second electrically conductive flux barrier layer and said
4 upstream pole.
- 1 5. The magnetic recording device of claim 4, wherein said first and second
2 electrically conductive flux barriers are selected from a group
3 comprising copper, gold and aluminum.
- 1 6. The magnetic recording device of claim 5, wherein said electrically
2 insulating non-magnetic gap layer and said layer of electrically



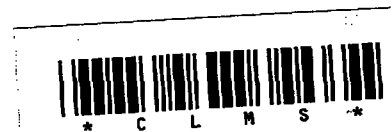
- 3 insulating non-magnetic material are selected from a group comprising
4 Al_2O_3 and SiO_2 .
- 1 7. The magnetic recording device of claim 6, wherein said first electrically
2 conductive flux barrier layer is about 20 microns thick.
- 1 8. The magnetic recording device of claim 1 wherein
2 B3. said thin-film head comprises a downstream pole and an
3 upstream pole, separated at a tip end of said head by an electrically
4 insulating non-magnetic layer and attached at a yoke end of said head,
5 and
6 B4. said first flux barrier layer is positioned downstream of said
7 downstream pole.
- 1 9. The magnetic recording device of claim 8, further comprising:
2 F. a second electrically conductive flux barrier layer disposed
3 between said downstream pole and said upstream pole.
- 1 10. A low-inductance thin-film head, comprising:
2 A. a thin-film head including first and second magnetically
3 conductive poles connected at a yoke region within said head and
4 spaced apart at a tip end of said head, with an electrically insulating
5 non-magnetic gap layer placed between said poles and a plurality of
6 electrical conductors disposed therein and wrapped around said
7 upstream and downstream at said yoke region to create a data carrying
8 electrical coil; and
9 B. a first flux barrier layer of electrically conductive non-magnetic
10 material disposed adjacent to said thin-film head, wherein stray flux
11 emanating from said head is cut-off by said first flux barrier layer which
12 reduces the inductance of said head.
- 1 11. The low-inductance thin-film head of claim 10, wherein said first flux
2 barrier layer is selected from the group of conductive materials
3 comprising copper, gold and aluminum.
- 1 12. The low-inductance thin-film head of claim 11, wherein said first flux
2 barrier layer has a thickness of about 20 microns.



- 1 13. The low-inductance thin-film head of claim of 10, wherein said first pole
2 is positioned upstream of said second pole, and said low-inductance
3 thin-film head further comprises:
4 C. a second flux barrier layer disposed between said gap layer and
5 said first pole, wherein stray flux between said conductors and first
6 pole is cut-off by said second flux barrier layer to reduce the
7 inductance of said head.
- 1 14. The low-inductance thin-film head of claim 13, wherein said first flux
2 barrier layer is positioned adjacent to said second pole.
- 1 15. The low-inductance thin-film head of claim 10, further comprising a
2 substrate layer onto which a second insulating layer is deposited,
3 wherein said first flux barrier layer is positioned between said first pole
4 and said second insulating layer.
- 1 16. A method of forming a stray flux barrier on a thin-film head, comprising
2 the step of:
3 A. depositing a first flux barrier layer of electrically conductive
4 non-magnetic material over the thin-film head to reduce the inductance
5 of the head by intercepting stray flux.
- 1 17. The method of claim 16 further comprising the steps of first forming the
2 thin-film film head:
3 B. providing a substrate material;
4 C. depositing a first layer of ferromagnetic material over said
5 substrate material to form a first pole;
6 D. depositing a layer of electrically insulating non-magnetic
7 material over said first layer of ferromagnetic material, wherein said
8 layer of electrically insulating non-magnetic material includes a plurality
9 of planar electrical conductors running therein;
10 E. depositing a second layer of ferromagnetic material over said
11 layer of electrically insulating non-magnetic material to form a second
12 pole; and
13 F. depositing an encapsulation layer.
- 1 18. The method of claim 16 wherein said step A of depositing said first flux
2 barrier layer comprises the step of:



- 3 A1. depositing said first flux barrier layer to a thickness of about 20
4 microns.
- 1 19. The method of claim 18 wherein prior to performing step A, the method
2 comprises the step of:
3 A2. selecting a conductive material for said first flux barrier layer
4 from the group of materials comprising copper, gold and aluminum.
- 1 20. The method of claim 18 wherein said step A further comprises the step
2 of:
3 A3. depositing said first flux barrier layer by vapor deposition.
- 1 21. The method of claim 19 wherein said step A further comprises the step
2 of:
3 A4. depositing said first flux barrier layer by electroplating.
- 1 22. The method of claim 17 further comprising the steps of:
2 G. after depositing said first layer of ferromagnetic material to form
3 said first pole, depositing a second insulating layer; and
4 H. depositing a second flux barrier layer of electrically conductive
5 material over said second insulating layer.
- 1 23. The method of claim 17 further comprises the step of
2 I. forming a flux barrier layer between said first and second pole.
- 1 24. A method of forming a stray flux barrier on a thin-film head comprising
2 a substrate layer onto which a first insulating layer is deposited, said
3 method comprising the steps of:
4 A. depositing a flux barrier layer of electrically conductive non-
5 magnetic material on the first insulating layer; and
6 B. depositing successive thin-film layers to form the thin-film head,
7 wherein said flux barrier layer intercepts stray flux, thereby reducing
8 the inductance of the head.
- 1 25. The method of claim 24 wherein said step A of depositing comprises
2 the step of:



- 3 A1. selecting a material for said first flux barrier layer from a group
4 of electrically conductive materials comprising copper, gold and
5 aluminum.
- 1 26. The method of claim 25 wherein said step A of depositing comprises
2 the step of
3 A2. depositing said first flux barrier layer by vapor deposition.
- 1 27. The method of claim 25 wherein said step A of depositing comprises
2 the step of
3 A3. depositing said first flux barrier layer by electroplating through a
4 mask.
- 1 28. The method of claim 25 further comprising the step of:
2 C. depositing a second flux barrier layer over said thin film head.
- 1 29. The magnetic recording device of claim 1 wherein
2 B1. said head comprises a downstream pole and an upstream pole,
3 attached at a yoke end of said head and separated at a tip end of said
4 head by an electrically insulating non-magnetic gap layer having a
5 plurality of electrical conductors running therein, and having an
6 encapsulation layer which is disposed over said downstream pole; and
7 B2. said first electrically conductive flux barrier layer is disposed
8 between said downstream pole and said upstream pole to reduce stray
9 flux between said poles.
- 1 30. The magnetic recording device of claims 3, further comprising:
2 C. a layer of electrically insulating, non-magnetic material disposed
3 between said first electrically conductive flux barrier layer and said
4 upstream pole.

