HIGH COERCIVITY MULTIFILM HARD MAGNETIC LAYER FOR MAGNETICALLY STABILIZING A SPIN VALVE SENSOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a high coercivity multifilm hard magnetic layer for magnetically stabilizing a spin valve sensor and more particularly to a high coercivity multifilm hard magnetic layer at each side edge of a spin valve sensor wherein the sensor has a nickel oxide antiferromagnetic pinning layer for pinning a pinned layer of the sensor.

2. Description of the Related Art

A spin valve sensor is employed by a read head for sensing magnetic fields on a moving magnetic medium, such as a rotating magnetic disk. The sensor includes a nonmagnetic electrically conductive first spacer layer sandwiched between a ferromagnetic pinned layer and a ferromagnetic free layer. An antiferromagnetic pinning layer interfaces the pinned layer for pinning the magnetic moment of the pinned layer 90° to an air bearing surface (ABS) which is an exposed surface of the sensor that faces the magnetic medium. First and second leads are connected to the spin valve sensor for conducting a sense current therethrough. The magnetic moment of the free layer is free to rotate in positive and negative directions from a zero bias point position in response to positive and negative magnetic fields from a moving magnetic medium. The zero bias position is the position of the magnetic moment of the free layer when the sensor is in a quiescent state, namely when the sense current is conducted through the sensor without any magnetic field incursions from a rotating magnetic disk. The magnetic moment is preferably parallel to the ABS in the quiescent state of the sensor. If the magnetic moment of the free layer is not substantially parallel to the ABS in the quiescent state, there will be read signal asymmetry upon the occurrence of positive and negative magnetic field incursions from a rotating disk.

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The thickness of the spacer layer is chosen to be less than the mean free path of electrons conducted through the sensor. With this arrangement, a portion of the conduction electrons are scattered by the interfaces of the spacer layer with the pinned and free layers. When the magnetic moments of the pinned and free layers are parallel with respect to one another scattering is minimal and when their magnetic moments are antiparallel scattering is maximized. Changes in scattering changes the resistance of the spin valve sensor as a function of cos θ, where θ is the angle between the magnetic moments of the pinned and free layers. A spin valve sensor has a significantly higher magnetoresistive (MR) coefficient than an anisotropic magnetoresistive (AMR) sensor. For this reason it is sometimes referred to as a giant magnetoresistive (GMR) sensor.

The layers of the spin valve sensor form first and second side edges that are generally perpendicular to the ABS. First and second hard bias and lead layers are connected to the first and second side edges of the sensor. The first and second lead layers conduct the sense current through the sensor and the first and second hard bias layers stabilize the magnetic domains of various magnetic layers of the sensor. The magnetic domains have magnetic moments that are aligned along the direction of the magnetic spins therein. The magnetic domains interface each other along domain walls that are loosely positioned without stabilization. Upon the occurrence of a magnetic incursion the domain walls move and then upon removal of the magnetic incursion the domain walls may not return to their original positions or may subsequently move when the sensor is sensing magnetic incursions from the rotating disk. When the domain walls do not return to their same positions this can impose a different magnetic bias on the free layer causing read signal asymmetry. Further, when the domain walls move during a reading cycle this can impose noise in the signal. The first and second hard bias layers apply a magnetic field on the sensor that stabilizes the domain walls of the free layer of the sensor by preventing their movement.

A material typically employed for the first and second hard bias layers is cobalt platinum chromium (CoPtCr). This material is a hard magnetic material with a high coercivity. High coercivity is desirable for providing a field for stabilizing the sensor as well as for stabilizing the first and second hard bias layers. Should the first and second

hard bias layers be subjected to a field that exceeds their coercivity the atomic spins of the hard bias layers can switch their positions to the direction of the field. These fields can come from the write field of the write head or the rotating magnetic disk. It is the components of these fields that are perpendicular to the ABS that are especially troublesome. There is a need for high coercivity hard bias layers for emerging spin valve read heads.

SUMMARY OF THE INVENTION

I have discovered that the coercivity of cobalt platinum chromium (CoPtCr) is seriously degraded in a bottom spin valve read head. In a bottom spin valve read head a nickel oxide (NiO) layer is employed for the antiferromagnetic pinning layer. The nickel oxide (NiO) pinning layer has first and second portions that extend beyond the side edges of the spin valve sensor. The first and second cobalt platinum chromium (CoPtCr) hard bias layers are located on the first and second portions of the nickel oxide (NiO) pinning layer. Even when a chromium seedlayer is employed between the first and second portions of the nickel oxide (NiO) layers and the first and second cobalt platinum chromium (CoPtCr) hard bias layers the coercivity of the first and second cobalt platinum chromium (CoPtCr) hard bias layers is seriously degraded by the presence of the nickel oxide (NiO) pinning layer. I have found that for a 72 Å free layer and 135 Å first and second cobalt platinum chromium (CoPtCr) hard bias layers on 35 Å chromium (Cr) seedlayers the coercivity of the first and second cobalt platinum chromium (CoPtCr) hard bias layers is about 650 Oe. While this coercivity is acceptable it gets worse when the thicknesses of the free layer and the first and second cobalt platinum chromium (CoPtCr) hard bias layers are reduced for the purpose of increasing the linear track reading density of the spin valve read head. For instance, when the thickness of the free layer is reduced to 45 Å and the thickness of the first and second cobalt platinum chromium (CoPtCr) hard bias layers are reduced to 75 Å on first and second 35 Å chromium layers the coercivity is reduced to 550 Oe.

I have discovered that by employing a bilayer seedlayer of tantalum (Ta) and chromium (Cr) between the first and second cobalt platinum chromium (CoPtCr) hard bias layers and the first and second nickel oxide (NiO) layer portions that the coercivity of the first and second cobalt platinum chromium (CoPtCr) hard bias layers is significantly increased. For instance, for a 45 Å free layer, 35 Å tantalum (TA) first and second seedlayers on the first and second nickel (NiO) layer portions, 35 Å first and second chromium layers on the first and second tantalum (Ta) layers and 75 Å first and second cobalt platinum chromium (CoPtCr) hard bias layers on the first and second chromium (Cr) layers the coercivity of the first and second cobalt platinum chromium (CoPtCr) hard bias layers was increased to 900 Oe. Further, I have discovered that I can decrease the thicknesses of both seedlayers and still achieve substantially the same coercivity for 75 Å first and second cobalt platinum chromium (CoPtCr) hard bias layers.

I have found that when the thickness of each of the seedlayers is 20 Å that the coercivity of 75 Å first and second cobalt platinum chromium (CoPtCr) hard bias layers is still about 900 Oe. Since the first and second hard bias and lead layers is typically thicker than the spin valve sensor, this reduced thickness of the hard bias layers reduces the step between the sensor and the hard bias and lead layers. This reduced step ensures better coverage of the second gap layer for protecting the read head from shorts between the second shield layer and the lead layers. The invention is applicable to both simple bottom spin valves and antiparallel (AP) pinned bottom spin valves. The AP pinned layer has a ruthenium (Ru) film between first and second cobalt (Co) films as described in U.S. Patent 5,701,223 which is incorporated by reference herein.

An object of the present invention is to provide high coercivity hard bias layers on nickel oxide (NiO) pinning layer portions for stabilizing the magnetic domains of a bottom spin valve sensor.

Another object is to provide seedlayers that promote high coercivity of spin valve sensor stabilizing cobalt (Co) based hard magnetic bias layers that are located on nickel oxide (NiO) pinning layer portions of a bottom spin valve sensor.

A further object is to provide seedlayers with a total thickness of substantially 45 Å for promoting high coercivity of spin valve sensor stabilizing cobalt (Co) based hard magnetic bias layers that are located on nickel oxide (NiO) pinning layer extension portions of a bottom spin valve sensor.

Still another object is to provide minimal thickness high coercivity hard bias layers for stabilizing a bottom spin valve sensor.

Other objects and advantages of the invention will become apparent upon reading the following description taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a planar view of an exemplary magnetic disk drive;

Fig. 2 is an end view of a slider taken along plane 2-2 with a magnetic head shown in hidden lines;

Fig. 3 is an elevation view of the magnetic disk drive wherein multiple disks and magnetic heads are employed;

Fig. 4 is an isometric illustration of an exemplary suspension system for supporting the slider and magnetic head;

Fig 5 is an ABS illustration of the slider taken along plane 5-5 of Fig. 2;

Fig. 6 is a partial elevation view of the slider and magnetic head as seen in plane 6-6 of Fig. 2;

Fig. 7 is a partial ABS view of the slider taken along plane 7-7 of Fig. 6 to show the read and write elements of the magnetic head;

Fig. 8 is a view taken along plane 8-8 of Fig. 6 with all material above the coil layer removed;

Fig. 9 is a schematic isometric illustration of the present spin valve read head;

Fig. 10 is an ABS illustration of one embodiment of a bottom simple spin valve sensor with a 72 Å thick nickel iron (NiFe) free layer;

Fig. 11 is the same as Fig. 10 except a 35 Å thick nickel iron (NiFe) free layer is employed;

Fig. 12 is an ABS illustration of an antiparallel (AP) pinned bottom spin valve sensor with a 72 Å nickel iron (NiFe) free layer;

Fig. 13 is the same as Fig. 12 except a 45 Å thick nickel iron (NiFe) free layer is employed;

Fig. 14 is an ABS illustration of an anisotropic magnetoresistive (AMR) sensor with a hard bias film and a seedlayer on a first gap layer (G1);

Fig. 15 is an ABS illustration of a bottom spin valve sensor with a 72 Å thick nickel iron (NiFe) free layer and hard bias layers and seedlayers on pinning layer extensions of nickel oxide (NiO);

Fig. 16 is the same as Fig. 15 except a 45 Å free layer is employed and the hard bias layer has been reduced in thickness;

Fig. 17 is the same as Fig. 16 except dual seedlayers have been employed for the hard bias layers;

Fig. 18 is the same as Fig. 17 except the total thickness of the dual seedlayers has been significantly decreased without sacrificing coercivity of the hard bias layers; and

Figs. 18A-18E are elevation views of the formation of layers to construct a spin valve sensor with first and second hard bias layers and seedlayers connected thereto.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Magnetic Disk Drive

Referring now to the drawings wherein like reference numerals designate like or similar parts throughout the several views there is illustrated in Figs. 1-3 a magnetic disk drive 30. The drive 30 includes a spindle 32 that supports and rotates a magnetic disk 34. The spindle 32 is rotated by a motor 36 that is controlled by a motor controller 38. A combined read and write magnetic head 40 is mounted on a slider 42 that is supported by a suspension 44 and actuator arm 46. A plurality of disks, sliders and suspensions may be employed in a large capacity direct access storage device (DASD) as shown in Fig. 3. The suspension 44 and actuator arm 46 position the slider 42 so that the magnetic head 40 is in a transducing relationship with a surface of the magnetic disk 34. When the

disk 34 is rotated by the motor 36 the slider is supported on a thin (typically, .05 μm) cushion of air (air bearing) between the surface of the disk 34 and the air bearing surface (ABS) 48. The magnetic head 40 may then be employed for writing information to multiple circular tracks on the surface of the disk 34, as well as for reading information therefrom. Processing circuitry 50 exchanges signals, representing such information, with the head 40, provides motor drive signals for rotating the magnetic disk 34, and provides control signals for moving the slider to various tracks. In Fig. 4 the slider 42 is shown mounted to the suspension 44. The components described hereinabove may be mounted on a frame 54 of a housing 55, as shown in Fig. 3.

Fig. 5 is an ABS view of the slider 42 and the magnetic head 40. The slider has a center rail 56 that supports the magnetic head 40, and side rails 58 and 60. The rails 56, 58 and 60 extend from a cross rail 62. With respect to rotation of the magnetic disk 34, the cross rail 62 is at a leading edge 64 of the slider and the magnetic head 40 is at a trailing edge 66 of the slider.

Magnetic Head

Fig. 6 is a side cross-sectional elevation view of the magnetic head 40 which has a write head portion 70 and a read head portion 72, the read head portion employing a spin valve sensor 74 of the present invention. Fig. 7 is an ABS view of Fig. 6. The sensor 74 is located between first and second gap layers 76 and 78 and the gap layers are located between first and second shield layers 80 and 82. In response to external magnetic fields, the resistance of the sensor 74 changes. A sense current I_S (see Fig. 9) conducted through the sensor causes these resistance changes to be manifested as potential changes. These potential changes are then processed as readback signals by the processing circuitry 50 shown in Fig. 3.

The prior art write head portion of the magnetic head includes a coil layer 84 located between first and second insulation layers 86 and 88. A third insulation layer 90 may be employed for planarizing the head to eliminate ripples in the second insulation layer caused by the coil layer 84. The first, second and third insulation layers are

referred to in the art as an "insulation stack". The coil layer 84 and the first, second and third insulation layers 86, 88 and 90 are located between first and second pole piece layers 92 and 94. The first and second pole piece layers 92 and 94 are magnetically coupled at a back gap 96 and have first and second pole tips 98 and 100 which are separated by a write gap layer 102 at the ABS. As shown in Figs. 2 and 4, first and second solder connections 104 and 116 connect leads from the sensor 74 to leads 112 and 124 on the suspension 44. Third and fourth solder connections 118 and 106 connect leads 120 and 122 from the coil 84 (see Fig. 8) to leads 126 and 114 on the suspension. It should be noted that the magnetic head 40 employs a single layer 82/92 to serve a double function as a second shield layer for the read head and as a first pole piece for the write head. This type of magnetic head is referred to in the art as a "merged head". A piggyback head employs two separate layers for these functions.

Fig. 9 shows an isometric ABS illustration of a bottom spin valve read head 200 wherein the spin valve sensor 202 may be a bottom simple spin valve sensor or a bottom antiparallel (AP) pinned spin valve sensor which will be discussed in more detail hereinafter. In a bottom spin valve sensor the antiferromagnetic (AFM) pinning layer 204 interfaces a ferromagnetic pinned layer (described hereinafter) in the spin valve sensor 202 for pinning the magnetic moment of the pinned layer perpendicular to the ABS. In the invention nickel oxide (NiO) is employed for the pinning layer 204.

The spin valve sensor 202 including the pinning layer 204 are located between first and second nonmagnetic nonconductive gap layers 206 and 208 which may be aluminum oxide (Al_2O_3). The first and second gap layers 206 and 208 are located between first and second ferromagnetic shield layers 210 and 212 which may be nickel iron (NiFe) or Sendust. The distance between the first and second shield layers 210 and 212 determine the read gap of the read head 200. Efforts are ongoing to reduce the gap so that the read head has increased linear read bit density capability. This is accomplished by reducing the thicknesses of the layers between the first and second shield layers 210 and 212.

The spin valve sensor 202 has first and second side edges 214 and 216 which are perpendicular to the ABS. First and second hard bias and lead layers 218 and 220 have side edges which interfacially engage the first and second side edges 214 and 216 of the spin valve sensor 202 in what is called in the art as a contiguous junction, as described in U.S. Patent No. 5,018,037 which is incorporated by reference herein. The first hard bias and lead layers 218 has a first multifilm hard bias layer 222 and a multifilm first lead layer 224 and the second hard bias and lead layers 220 has a second multifilm hard bias lead layer 226 and a multifilm second lead layer 228. Each of the hard bias layers 224 and 226 include a high coercivity hard magnetic film which longitudinally biases the magnetic layers of the spin valve sensor 202 so as to stabilize the magnetic domains of these magnetic layers. The hard magnetic films orient and pin the magnetic spins of the domains in a common direction so that the domain walls at the interfaces of the domains do not shift around so as avoid changing the bias point of the free layer of the spin valve sensor or the introduction of noise into the read signal.

I have discovered that when the hard magnetic films of the hard bias layers 222 and 226 are located on the first and second portions of the pinning layer 204, which extend beyond the sensor, that the coercivity of the hard magnetic films are seriously degraded. This problem is aggravated when the thickness of the hard magnetic films of the hard bias layers 222 and 226 are reduced along with a corresponding reduction in the thickness of the free layer of the spin valve sensor 202 for the purpose of increasing the linear read density of the head. Further, there is a need to reduce the thicknesses of the films of the hard bias layers 222 and 226 as much as possible in order to provide a more efficient coupling between the hard bias layers and the free layer step between the first and second hard bias and lead layers 218 and 220 adjacent the first and second side edges 214 and 216 of the spin valve sensor. Steps at these locations pose a risk of inadequate coverage by the second gap layer 208 for preventing shorting between the first and second lead layers 224 and 228 and the second shield layer 212. I have discovered certain films with reduced thicknesses for the hard bias layers 222 and 226 that will stabilize the spin valve sensor without sacrificing coercivity.

Fig. 10 shows an ABS illustration of a first embodiment 300A of a bottom simple spin valve sensor on the first gap layer 206. The spin valve sensor 300A includes the pinning layer 204 which has first and second portions 302 and 304 which extend beyond the side edges 306 and 308 of the spin valve sensor. A nonmagnetic nonconductive spacer layer 310 is located between a ferromagnetic pinned layer 312 and a ferromagnetic free layer 314. A cap layer 316 may be located on the free layer 314. The pinning layer 204 may be 425 Å of nickel oxide (NiO), the pinned layer 312 may be 10 Å nickel iron (NiFe), a GMR enhancement layer 313 may be 15 Å of cobalt (Co), the spacer layer 310 may be 20 Å of copper (Cu), the free layer 314 may be 72 Å of nickel iron (NiFe) and the cap layer 316 may be 50 Å of tantalum (Ta).

Efforts are ongoing to reduce the thickness of the free layer 314 in Fig. 10 so as to increase the linear read density of the read head. Fig. 11 shows a bottom simple spin valve embodiment 300B which employs a ferromagnetic free layer that is 45 Å thick. A reduction of the thickness of the free layer from 72 Å in Fig. 10 to 45 Å in Fig. 11 poses a challenge for providing correspondingly thin hard bias layers which have sufficient coercivity to longitudinally bias the magnetic layers of the spin valve sensor without being switched by some magnetic field which has a strength that exceeds the coercivity of the hard bias layers. The present invention, described in detail hereinbelow, provides such hard bias layers.

Fig. 12 illustrates a bottom antiparallel (AP) pinned spin valve sensor 400A which is located on the first gap layer 206. The AP pinned spin valve sensor 400A includes a pinning layer 402 which is nickel oxide (NiO). The sensor further includes a nonmagnetic nonconductive spacer layer 404 which is located between an AP pinned layer 406 and the free layer 408. A cap layer 410 may be located on the free layer 408. The AP pinned layer 406 includes a spacer layer 412 which is located between first and second ferromagnetic pinned films 414 and 416. A ferromagnetic interface film 418 may be located between the first pinned film 414 and the pinning layer 402 for the purpose of enhancing exchange coupling and pinning the moment of the first pinned layer 414 in a direction perpendicular to the ABS. By exchange coupling between the second

pinned film 416 and the first pinned film 414, the second pinned film 416 is pinned antiparallel to the first pinned film 414. The pinning layer may be 425 Å of nickel oxide (NiO), the interface film 418 may be 10 Å of nickel iron (NiFe), the first pinned film 414 may be 20 Å of cobalt (Co), the spacer layer 412 may be 8 Å of ruthenium (Ru), the second pinned film 416 may be 20 Å of cobalt (Co), the spacer layer 404 may be 20 Å of copper (Cu), the free layer 408 may be 72 Å of nickel iron (NiFe) and the spacer layer 410 may be 50 Å of tantalum (Ta).

Efforts are ongoing to also reduce the thickness of the free layer 408 in Fig. 12. In Fig. 13 there is shown a bottom AP pinned spin valve sensor 400B which has a free layer 420 which has been reduced in thickness to 45 Å. Again, the challenge is to provide hard bias layers which will longitudinally bias the free layer of the spin valve sensor in Fig. 13 with sufficient coercivity so that extraneous magnetic fields will not switch the orientation of the magnetic spins of the hard bias layers.

Several investigations were conducted to determine the coercivities of various hard bias layers of cobalt platinum chromium (CoPtCr) with one or more seedlayers. Further investigation was conducted to determine minimal thicknesses of seedlayers for a cobalt platinum chromium (CoPtCr) hard bias layer wherein the free layer of a bottom spin valve sensor was reduced to 45 Å. These investigations are set forth in examples hereinbelow.

Example 1

The first investigation involves an anisotropic magnetoresistive (AMR) sensor 500 which differs from a spin valve sensor in that there is no pinned layer. In an AMR sensor a single nickel iron (NiFe) layer changes its resistance in response to flux incursions from a rotating magnetic disk. As shown in Fig. 14, the AMR sensor 500 is located on a first gap layer 502 of aluminum oxide (Al_2O_3). First and second hard magnetic layers 504 and 506 were separated from the first gap layer 502 by first and second seedlayers 508 and 510. Each of the hard magnetic layers 504 and 506 was 135 Å of cobalt platinum chromium (CoPtCr) and the seedlayers 508 and 510 were 35 Å of chromium (Cr). It can be seen that the first seedlayer 508 is located between the hard

magnetic layer 504 and a first edge 512 of the AMR sensor and that the second seedlayer 510 is located between the second hard magnetic layer 506 and a second side edge 514 of the AMR sensor. Accordingly, the hard magnetic layers 504 and 506 are magnetostatically coupled to the magnetic layers of the AMR sensor 500. It is this coupling that stabilizes the magnetic domains of the AMR sensor. In this example the coercivity of the first and second hard magnetic layers 504 and 506 were 1400 Oe. This is a desirable level for coercivity since it is above any expected strength of a magnetic field incursion applied to the hard magnetic layers 504 and 506. This example is presented to show that the coercivity of the hard magnetic layer 504/506 on a chromium (Cr) layer 508/510 which is, in turn, on an aluminum oxide (Al_2O_3) layer has a highly acceptable coercivity. Unfortunately this coercivity is significantly reduced when a nickel oxide (NiO) antiferromagnetic pinning layer is employed for pinning the pinned layer of the spin valve sensor which is demonstrated in the following examples.

Example 2

In this example the simple spin valve 300A in Fig. 10 and the AP pinned spin valve 400A in Fig. 12 were investigated wherein the free layer has a thickness of 72 Å, the spin valve sensor 300A and 400A being shown generically in Fig. 15. The pinning layer 204 or 402 was 425 Å of nickel oxide (NiO). The pinning layer has first and second portions which extend beyond the side edges 600 and 602 of the sensor 300A/400A. First and second hard magnetic layers 604 and 606 were 135 Å of cobalt platinum chromium (CoPtCr) and first and second seedlayers 608 and 610 between the hard magnetic layers 604 and 606 and the pinning layer extensions 204/402 were 35 Å of chromium (Cr). The coercivity of the first and second hard magnetic layers 604 and 606 was 650 Oe. It can be seen that the coercivity of the hard magnetic layers 604 and 606 dropped dramatically from 1400 Oe in Example 1 because of their location on the nickel oxide (NiO) pinning layer 204/402. While this level of coercivity may still be adequate to withstand flux incursions tending to rotate the coercivity of the hard

magnetic layers the problem occurs when the thickness of the free layer is reduced to below 72 Å, as shown in the following examples.

Example 3

In this example (Fig. 16) the spin valve sensors 300B and 400B of Figs. 11 and 13 were investigated which have a free layer with a thickness of 45 Å. The pinning layer 204/402 was 425 Å of nickel oxide (NiO). The first and second hard magnetic layers 700 and 702 were 75 Å of cobalt platinum chromium (CoPtCr) and the first and second seedlayers 704 and 706 were 35 Å of chromium (Cr). Unfortunately, the coercivity of the first and second hard magnetic layers 700 and 702 dropped from 650 Oe in Example 3 to 550 Oe in this example. This level of coercivity is considered to be too low to withstand magnetic incursions tending to switch the magnetic spins of the hard magnetic layers 700 and 702.

Example 4

In this example (Fig. 17) the spin valve sensors 300B and 400B were once again investigated with a free layer 45 Å in thickness. The spin valve sensor includes a pinning layer 204/402 which was 425 Å of nickel oxide (NiO). The first and second hard magnetic layers 800 and 802 were kept at 75 Å of cobalt platinum chromium (CoPtCr) and first and second seedlayers 804 and 806 were kept at 35 Å of chromium (Cr). I discovered that by adding first and second seedlayers 808 and 810 of 35 Å of tantalum (Ta) between the first and second chromium seedlayers 804 and 806 and the nickel oxide (NiO) pinning layer 204/402 that the coercivity of the hard magnetic layers 800 and 802 were significantly increased. The coercivity of the hard magnetic layers 800 and 802 was 900 Oe which is a significant increase from the 550 Oe in Example 3. However, the total thickness of 70 Å of the bilayer seedlayers can be reduced further to get the hard bias layers 800 and 802 closer to the free layer (F) for more efficient magnetostatic coupling therebetween.

Example 5

The spin valve sensors 300B/400B were still further investigated, as shown in Fig. 18, with a free layer that had a thickness of 45 Å. The sensor includes the pinning layer 204/402 which is 425 Å of nickel oxide (NiO). The first and second hard magnetic layers 900 and 902 were maintained at 75 Å of cobalt platinum chromium (CoPtCr), the first and second seedlayers 904 and 906 were 20 Å of chromium (Cr) and the third and fourth seedlayers 908 and 910 were 20 Å of tantalum (Ta). The total thickness of the chromium (Cr) and the tantalum (Ta) seedlayer was 40 Å. The coercivity of the first and second hard magnetic layers 900 and 902 was 900 Oe which is the same as the coercivity in Example 4. This is a highly acceptable coercivity for the hard magnetic layers and will efficiently stabilize the magnetic domains of the spin valve sensor, withstand magnetic incursions from extraneous fields.

Method of Making

Figs. 19A - 19D illustrate various steps of making a portion of the spin valve read head. In Fig. 19A a first gap layer 1000 is sputter deposited on a first shield layer (not shown). Next, a nickel oxide (NiO) layer 102 is sputter deposited on the first gap layer 1000. Next, multiple layers 1004 are sputter deposited on the pinning layer 1002 to form one of the spin valve sensors 300B or 400B in Figs. 11 or 13. In Fig. 19B a bilayer photoresist is formed on top of the spin valve sensor layers 1004 which has undercuts 1008 and 1010 so that unwanted layers can be lifted off in a subsequent step. In Fig. 19C ion milling is implemented to remove layers of the spin valve sensor except under the bilayer photoresist 1006. This will mill slightly into the pinning layer 1002 so as to ensure complete removal of the spin valve sensor layers 1004 beyond the sensor region. In Fig. 19D the various layers of the hard bias and lead layers are sputter deposited onto the substrate. In Fig. 19E the bilayer photoresist 106 is removed, thereby removing (lifting off) the unwanted layers leaving the completed hard bias and lead layers connected to side edges of the spin valve sensor. This process is described in U. S. Patent No. 5,018,037 which is incorporated by reference herein.

It should be understood that the hard magnetic materials may be a material other than cobalt platinum chromium (CoPtCr) and is intended to include all cobalt based hard magnetic materials such as cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

Clearly, other embodiments and modifications of this invention will occur readily to those of ordinary skill in the art in view of these teachings. Therefore, this invention is to be limited only by the following claims, which include all such embodiments and modifications when viewed in conjunction with the above specification and the accompanying drawings.



CLAIMS

1. A spin valve read head that has an air bearing surface (ABS) comprising:

a nonmagnetic nonconductive first gap layer;

an antiferromagnetic nickel oxide (NiO) pinning layer on the first gap layer;

a spin valve sensor including:

a ferromagnetic pinned layer exchange coupled to the pinning layer;

a nonmagnetic spacer layer and a ferromagnetic free layer;

the spacer layer being between the pinned layer and the free layer; and

first and second end edges that are formed by end edges of the pinning, spacer and free layers;

the pinning layer having first and second portions that extend beyond the first and second edges respectively of the spin valve sensor;

a first and second interfacially engaged hard bias and lead layers;

each of the first and second hard bias layers including:

a tantalum (Ta) film on and interfacially engaging a respective one of said first and second portions of the pinning layer and interfacially engaging a respective one of the first and second edges of the spin valve sensor;

a chromium (Cr) film on and interfacially engaging the tantalum (Ta) film; and

a cobalt (Co) based hard magnetic film on and interfacially engaging the chromium (Cr) film.

2. A read head as claimed in claim 1 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

3. A read head as claimed in claim 2 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

4. A read head as claimed in claim 3 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) film is substantially 20 Å.

5. A read head as claimed in claim 1 wherein the pinned layer is an antiparallel (AP) pinned layer that includes:

first and second ferromagnetic films;

a ruthenium (Ru) spacer film sandwiched between the first and second ferromagnetic films;

the first ferromagnetic film interfacing the pinning layer with its magnetic moment pinned by the pinning layer in a first direction; and

the second ferromagnetic film interfacing the spacer layer with its magnetic moment pinned by the first ferromagnetic film in a second direction that is antiparallel to said first direction.

6. A read head as claimed in claim 1 including:

a ferromagnetic first shield layer;

the first gap layer being on the first shield layer;

a nonmagnetic nonconductive second gap layer;

the second gap layer being on the spin valve sensor, the first and second hard bias and lead layers and the first gap layer; and

a ferromagnetic second shield layer on the second gap layer.

7. A read head as claimed in claim 6 wherein the pinned layer is an antiparallel (AP) pinned layer that includes:

first and second ferromagnetic films;

a ruthenium (Ru) spacer film sandwiched between the first and second ferromagnetic films;

the first ferromagnetic film interfacing the pinning layer with its magnetic moment pinned by the pinning layer in a first direction; and

the second ferromagnetic film interfacing the spacer layer with its magnetic moment pinned by the first ferromagnetic film in a second direction that is antiparallel to said first direction.

8. A read head as claimed in claim 7 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

9. A read head as claimed in claim 8 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

10. A read head as claimed in claim 9 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) film is substantially 20 Å and the thickness of the free layer is substantially 45 Å.

11. A magnetic head that has an air bearing surface (ABS) comprising:

a read head that includes:

a ferromagnetic first shield layer;

a nonmagnetic nonconductive first gap layer on the first shield layer;

an antiferromagnetic nickel oxide (NiO) pinning layer on the first gap layer;

a spin valve sensor including:

a ferromagnetic pinned layer exchange coupled to the pinning layer;

a nonmagnetic spacer layer and a ferromagnetic free layer;

the spacer layer being between the pinned layer and the free layer; and

first and second end edges that are formed by end edges of the pinning, spacer and free layers;

the pinning layer having first and second portions that extend beyond the first and second edges respectively of the spin valve sensor;

a first and second interfacially engaged hard bias and lead layers;

each of the first and second hard bias layers including:

a tantalum (Ta) film on and interfacially engaging a respective one of said first and second portions of the pinning layer and interfacially engaging a respective one of the first and second edges of the spin valve sensor;

a chromium (Cr) film on and interfacially engaging the tantalum (Ta) film; and

a cobalt (Co) based hard magnetic film on and interfacially engaging the chromium (Cr) film;

a nonmagnetic nonconductive second gap layer on the spin valve sensor, the first and second hard bias and lead layers and the first gap layer; and

a ferromagnetic second shield layer on the second gap layer;

a write head including:

first and second pole piece layers and a write gap layer;

the first and second pole piece layers being separated by the write gap layer at the ABS and connected at a back gap that is recessed rearwardly in the head from the ABS;

an insulation stack having at least first and second insulation layers;

at least one coil layer embedded in the insulation stack; and

the insulation stack and the at least one coil layer being located between the first and second pole piece layers.

12. A magnetic head as claimed in claim 11 wherein the pinned layer is an antiparallel (AP) pinned layer that includes:

first and second ferromagnetic films;

a ruthenium (Ru) spacer film sandwiched between the first and second ferromagnetic films;

the first ferromagnetic film interfacing the pinning layer with its magnetic moment pinned by the pinning layer in a first direction; and

the second ferromagnetic film interfacing the spacer layer with its magnetic moment pinned by the first ferromagnetic film in a second direction that is antiparallel to said first direction.

13. A magnetic head as claimed in claim 12 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

14. A magnetic head as claimed in claim 13 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

15. A magnetic head as claimed in claim 14 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) film is substantially 20 Å.

16. A magnetic disk drive that includes at least one magnetic head that has an air bearing surface (ABS), the disk drive comprising:

the magnetic head including a combined read head and write head;

a read head that includes:

a ferromagnetic first shield layer;

a nonmagnetic nonconductive first gap layer on the first shield layer;

an antiferromagnetic nickel oxide (NiO) pinning layer on the first gap layer;

a spin valve sensor including:

a ferromagnetic pinned layer exchange coupled to the pinning layer;

a nonmagnetic spacer layer and a ferromagnetic free layer;

the spacer layer being between the pinned layer and the free layer; and

first and second end edges that are formed by end edges of the pinning, spacer and free layers;

the pinning layer having first and second portions that extend beyond the first and second edges respectively of the spin valve sensor;

a first and second interfacially engaged hard bias and lead layers;

each of the first and second hard bias layers including:

a tantalum (Ta) film on and interfacially engaging a respective one of said first and second portions of the pinning layer and interfacially engaging a respective one of the first and second edges of the spin valve sensor;

a chromium (Cr) film on and interfacially engaging the tantalum (Ta) film; and

a cobalt (Co) based hard magnetic film on and interfacially engaging the chromium (Cr) film;

a nonmagnetic nonconductive second gap layer on the spin valve sensor, the first and second hard bias and lead layers and the first gap layer; and

a ferromagnetic second shield layer on the second gap layer;

the write head including:

first and second pole piece layers and a write gap layer;

the first and second pole piece layers being separated by the write gap layer at the ABS and connected at a back gap that is recessed rearwardly in the head from the ABS;

an insulation stack having at least first and second insulation layers;

at least one coil layer embedded in the insulation stack; and

the insulation stack and the at least one coil layer being located between the first and second pole piece layers;

the second shield layer and the first pole piece layer being a common layer;

a housing;

a magnetic disk rotatably supported in the housing;

a support mounted in the housing for supporting the magnetic head with its ABS facing the magnetic disk so that the magnetic head is in a transducing relationship with the magnetic disk;

means for rotating the magnetic disk;

positioning means connected to the support for moving the magnetic head to multiple positions with respect to said magnetic disk; and

processing means connected to the magnetic head, to the means for rotating the magnetic disk and to the positioning means for exchanging signals with the merged magnetic head, for controlling movement of the magnetic disk and for controlling the position of the magnetic head.

17. A disk drive as claimed in claim 16 wherein the pinned layer is an antiparallel (AP) pinned layer that includes:

first and second ferromagnetic films;

a ruthenium (Ru) spacer film sandwiched between the first and second ferromagnetic films;

the first ferromagnetic film interfacing the pinning layer with its magnetic moment pinned by the pinning layer in a first direction; and

the second ferromagnetic film interfacing the spacer layer with its magnetic moment pinned by the first ferromagnetic film in a second direction that is antiparallel to said first direction.

18. A disk drive as claimed in claim 17 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

19. A disk drive as claimed in claim 18 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

20. A disk drive as claimed in claim 19 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) is substantially 20 Å.

21. A method of making a magnetic head that has an air bearing surface (ABS) comprising:

forming a ferromagnetic first shield layer;

forming a nonmagnetic nonconductive first gap layer on the first shield layer;

forming an antiferromagnetic nickel oxide (NiO) pinning layer on the first gap layer;

forming a spin valve sensor including:

forming a ferromagnetic pinned layer exchange coupled to the pinning layer;

forming a nonmagnetic spacer layer and a ferromagnetic free layer with the spacer layer being between the pinned layer and the free layer; and

with the layer forming the spin valve sensor with first and second edges;

forming the pinning layer with first and second portions that extend beyond the first and second edges respectively of the spin valve sensor;

forming first and second interfacially engaged hard bias and lead layers;

forming each of the first and second hard bias layers including:

forming a tantalum (Ta) film on and interfacially engaging a respective one of said first and second portions of the pinning layer and interfacially engaging a respective one of the first and second edges of the spin valve sensor;

forming a chromium (Cr) film on and interfacially engaging the tantalum (Ta) film;

forming a cobalt (Co) based hard magnetic film on and interfacially engaging the chromium (Cr) film; and

forming a nonmagnetic nonconductive second gap layer on the spin valve sensor, the first and second hard bias and lead layers and the first gap layer;

forming a ferromagnetic second shield layer on the second gap layer; and

forming a write gap layer and an insulation stack with a coil layer embedded therein on the second shield layer so that the second shield layer also functions as a first pole piece for the write head; and

forming a second pole piece layer on the insulation stack and the write gap and connected at a back gap to the first pole piece.

22. A method as claimed in claim 21 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

23. A method as claimed in claim 22 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

24. A method as claimed in claim 23 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) is substantially 20 Å and the thickness of the free layer is substantially 45 Å.

25. A method as claimed in claim 21 wherein the pinned layer is an antiparallel (AP) pinned layer made by:

forming a first ferromagnetic film on the first shield layer;

forming a ruthenium (Ru) spacer film on the first ferromagnetic film; and

forming a second ferromagnetic film on the spacer film.

26. A method as claimed in claim 25 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

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27. A method as claimed in claim 26 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

28. A method as claimed in claim 27 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) is substantially 20 Å and the thickness of the free layer is substantially 45 Å.

29. A method of making a magnetic disk drive that includes at least one magnetic head that is a combined read and write head with an air bearing surface (ABS), the disk drive comprising:

forming a ferromagnetic first shield layer;

forming a nonmagnetic nonconductive first gap layer on the first shield layer;

forming an antiferromagnetic nickel oxide (NiO) pinning layer on the first gap layer;

forming a spin valve sensor including:

forming a ferromagnetic pinned layer exchange coupled to the pinning layer;

forming a nonmagnetic spacer layer and a ferromagnetic free layer with the spacer layer being between the pinned layer and the free layer; and

with the layer forming the spin valve sensor with first and second edges;

forming the pinning layer with first and second portions that extend beyond the first and second edges respectively of the spin valve sensor;

forming first and second interfacially engaged hard bias and lead layers;

forming each of the first and second hard bias layers including:

forming a tantalum (Ta) film on and interfacially engaging a respective one of said first and second portions of the pinning layer and interfacially engaging a respective one of the first and second edges of the spin valve sensor;

forming a chromium (Cr) film on and interfacially engaging the tantalum (Ta) film;

forming a cobalt (Co) based hard magnetic film on and interfacially engaging the chromium (Cr) film;

forming a nonmagnetic nonconductive second gap layer on the spin valve sensor, the first and second hard bias and lead layers and the first gap layer;

forming a ferromagnetic second shield layer on the second gap layer; and

forming a write gap layer and an insulation stack with a coil layer embedded therein on the second shield layer so that the second shield layer also functions as a first pole piece for the write head; and

forming a second pole piece layer on the insulation stack and the write gap and connected at a back gap to the first pole piece;

providing a housing;

rotatably supporting a magnetic disk in the housing;

providing a support in the housing for supporting the magnetic head with its ABS facing the magnetic disk so that the magnetic head is in a transducing relationship with the magnetic disk;

providing means for rotating the magnetic disk;

providing positioning means connected to the support for moving the magnetic head to multiple positions with respect to said magnetic disk; and

providing processing means connected to the magnetic head, to the means for rotating the magnetic disk and to the positioning means for exchanging signals with the merged magnetic head, for controlling movement of the magnetic disk and for controlling the position of the magnetic head.

30. A method as claimed in claim 29 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

31. A method as claimed in claim 30 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

32. A method as claimed in claim 31 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) is substantially 20 Å and the thickness of the free layer is substantially 45 Å.

33. A method as claimed in claim 29 wherein the pinned layer is an antiparallel (AP) pinned layer made by:

forming a first ferromagnetic film on the first shield layer;

forming a ruthenium (Ru) spacer film on the first ferromagnetic film; and

forming a second ferromagnetic film on the spacer film.

34. A method as claimed in claim 33 wherein the cobalt (Co) hard magnetic film is from the group comprising cobalt platinum chromium (CoPtCr), cobalt platinum (CoPt) and cobalt platinum chromium tantalum (CoPtCrTa).

35. A method as claimed in claim 34 wherein the cobalt (Co) based hard magnetic film is cobalt platinum chromium (CoPtCr).

36. A method as claimed in claim 35 wherein for each hard bias layer the thickness of each of the tantalum (Ta) film and the chromium (Cr) is substantially 20 Å and the thickness of the free layer is substantially 45 Å.