Description

This invention relates to a magnetoresistive read transducer for reading information signals from a magnetic record medium.

A magnetoresistive (MR) transducer detects magnetic field signals through the resistance changes of a read element made from a magnetoresistive material as a function of the amount and direction of magnetic flux being sensed by the element.

In the past, problems with unstable operating characteristics and Barkhausen noise have limited the use of MR sensors. These problems arise because there generally exists more than one stable state for the magnetization, a degeneracy which typically produces various multi-domain configurations. Random changes in this configuration are the cause of the above-mentioned unstable operating characteristics and Barkhausen noise.

U.S.-A-4,103,315 discloses the use of antiferromagnetic-ferromagnetic exchange coupling to produce a uniform longitudinal bias along the entire MR sensor for domain suppression. However, this structure provides response characteristics that are less sensitive than those required for some applications.

The conceptual solution to these prior art problems was attained only recently through the implementation of patterned longitudinal bias. This solution is described in EP-A-216062 and briefly involves the creation of appropriate single domain states directly in only the passive end regions of the MR layer. This can be achieved by producing a longitudinal bias in the end regions only of the MR layer to maintain the end regions in a single domain state and these single domain states induce a single domain state in the central active region of the MR layer. EP-A-265798 (state of the art according to Art. 54 (3)) discloses an MR sensor in which a longitudinal bias is produced in only the passive end regions in a single domain state, and a thin film of soft magnetic material is produced parallel to, but spaced from the MR sensor in the central active region only, to produce a transverse bias in the central region, where the output is sensed, and maintain the MR sensor in a linear response mode.

The invention seeks to provide an MR sensor in which the bias directions in different regions of the bias film are defined to produce an optimum device performance.

The invention provides a magnetoresistive read transducer comprising a decoupling layer covering an active central region of a magnetoresistive conductive layer; a soft magnetic material film extending over the magnetoresistive conductive layer and the decoupling layer, the soft magnetic material film being in contact with the decoupling layer and separated from the active central region of the magnetoresistive layer by the decoupling layer and the soft magnetic material film being in contact with the passive end regions of the magnetoresistive layer; the transducer being characterised by further comprising an antiferromagnetic material film in direct contact with the soft magnetic material film, the magnetisation of the antiferromagnetic material film being so set as to produce an exchange bias field which is oriented substantially longitudinally within the passive end regions of the magnetoresistive layer and the end regions of the soft magnetic material film and which is oriented transversely in the central active region of the magnetoresistive layer.

How the invention can be carried out will now be described by way of example, with reference to the accompanying drawings, in which :

Fig. 1 is a view looking at the sensing edge of magnetoresistive read transducer assembly as disclosed in EP-A-265798

Fig. 2 is a view looking at the sensing edge of a magnetoresistive read transducer assembly embodying the invention ;

Fig. 3 is a top view with some parts cut away which shows the desired exchange bias configuration for the magnetic read transducer assembly of Fig. 2 ;

Fig. 4 is a view looking at the sensing edge of another magnetoresistive read transducer assembly embodying the invention ;

Fig. 5 is a top view with some parts cut away which shows the desired exchange bias configuration for the magnetic read transducer assembly of Fig. 4 ;

Fig. 6 is an exploded view which shows the magnetization configuration of the thin film of soft magnetic material and the MR layer of the magnetic read transducer assembly of Fig. 2 when the temperature is greater than the Neel temperature of the means for producing an exchange bias ;

Fig. 7 is an exploded view which shows the magnetization configuration of the thin film of soft magnetic material, the MR layer and the means for producing an exchange bias of the magnetic read transducer assembly of Fig. 2 when the temperature is less than the Neel temperature of the means for producing an exchange bias ;

Fig. 8 is a sketch showing the thermal setting procedure for the means for producing an exchange bias for the magnetic read transducer assembly of Fig. 2 ; and

Fig. 9 is a sketch showing the thermal setting procedure for the means for producing an exchange bias for the magnetic read transducer assembly of Fig. 4.

Prior to describing embodiments of the present invention, a known magnetoresistive read transducer will be described briefly in conjunction with Fig. 1. A magnetic read head 11 utilizes a magnetoresistive (MR) sensor 10, and the MR sensor can be divided into two regions, the central active region 14, where

actual sensing of data is accomplished, and passive end regions 12. The regions are biased in different manners with longitudinal bias only in the end regions 12 and transverse bias in the active region 14. The transverse bias is produced by soft magnetic film layer 16 which is separated from the MR layer 10 in the central region 14 by a thin nonmagnetic spacer layer 17 so that a transverse bias can be produced only in the central region 14 of the MR sensor 10 to produce a linear response mode in MR sensor 10. The longitudinal bias is produced by an antiferromagnetic exchange bias layer 15 which is deposited to be in direct physical contact with the soft magnetic film layer 16 only in the end regions 12. Antiferromagnetic layer 15 creates an interfacial exchange interaction with the soft magnetic film layer 16 which results in an effective bias field experienced by the soft magnetic film layer 16 and also by the MR sensor 10 which is in contact with the soft magnetic film layer 16. The resulting bias field is oriented longitudinally to retain the end regions uniformly magnetized in a longitudinal direction. Conductor leads 18 and 19, over which the output signal is sensed, are deposited only in the end regions 12 over the antiferromagnetic layer 15.

A bias current source 13 is connected between conductor leads 18 and 19 to produce a bias current in the central region 14 of the MR sensor 10 to magnetically bias the MR sensor with transverse bias. The transverse bias is produced in that part of the central active region 14 of the MR sensor 10 in which the bias current and the thin spacer layer 17 are both present. The transverse bias produces magnetization at a chosen angle in the central region 14 of the MR sensor 10, so that the MR sensor 10 is maintained in a high sensitivity condition. In the embodiment shown in Fig. 1, the transverse bias is provided in a central active region Ra.

With reference to Fig. 2, a magnetic read head assembly 20, embodying the invention, comprises a magnetoresistive (MR) sensor 22, spacer layer 28, a soft magnetic layer 30 and an antiferromagnetic layer 32 which is initialized such as to provide a substantially longitudinal bias over the passive regions 24 and a substantially transverse bias over the active region 26 of the soft magnetic film layer 30. As used in this description, the active region 26 is defined as the region which produces an MR output signal in response to magnetic excitation, and this region has both a bias/sense current and a spacer layer 28. The passive regions 24, produce no output in response to magnetic excitation, and these regions do not have both a bias/sense current and a spacer layer 28.

The MR sensor 22 is first deposited over both passive end regions 24 and central active region 26. Thin nonmagnetic spacer layer 28 is deposited to cover at least the active region 26 and soft magnetic film layer 30 is deposited over both the passive regions 24 and the active region 26. The soft magnetic film layer 30 is separated from MR sensor 22 in the active region 26 by thin spacer layer 28 so that a transverse bias can be produced only in the central region 26 of the MR sensor 22 to produce a linear response mode in MR sensor 22. The preferred material for the MR sensor 22 is NiFe, and the preferred material for the soft magnetic film layer 30 is NiFeRh. An antiferromagnetic layer 32 is deposited over the soft magnetic film layer 30 in both the central region 26 and the end regions 24. The preferred material for the antiferromagnetic layer 32 is MnFe. Antiferromagnetic layer 32 creates an interfacial exchange interaction with the soft magnetic film layer 30 that results in an effective bias field experienced by soft magnetic film layer 30 and also by the MR sensor 22 where it is in contact with the soft magnetic film layer 30. The resulting bias field is oriented longitudinally within the passive end regions 24 to retain them uniformly magnetized in a longitudinal direction as is shown in Fig. 3. Conductor leads 34 and 36, over which the output signal is sensed, are deposited only in the passive regions 24 over the antiferro-magnetic layer 32, and their edge defines the active/passive region boundary.

Improved MR sensor performance is achieved by having exchange bias cover not only the passive regions of the MR sensor and the soft magnetic film layer but also the active region of the soft magnetic film layer. The different regions are biased along different directions, as shown in Fig. 3, as required for optimal device performance.

The exchange bias field in the passive regions 24 of antiferromagnetic layer 32 is substantially parallel to the sensing edge 38 of the magnetic head read assembly 39, and the exchange bias field in the active region 26 of antiferromagnetic layer 32 is at a selected angle to the sensing edge 38. These bias directions are defined after device fabrication, as will be described in greater detail below, by means of a thermal setting procedure which employs a suitable combination of bias current and applied magnetic field while the sensor is cooling through the Neel temperature. The use of this approach also improves exchange bias consistency due to in-situ deposition of the exchange bias interface comprising the biasing and biased films.

Another MR read transducer assembly, embodying the invention, is shown in Fig. 4. In this embodiment, the MR sensor 42 is deposited over both the passive regions 40 and the active region 41, but, in this embodiment, the extent of the thin nonmagnetic spacer layer 44 is less than the extent of the conductor leads 50 and 52. The soft magnetic film layer 48 and antiferromagnetic layer 46 are deposited over both the passive regions 40 and the active region 41. The active region Ra is again defined by the extent of the MR sensor 42 within the active region 41 in which a bias current and thin spacer layer 44 are present. In

this embodiment, the MR read transducer assembly 39 has a sensing edge 54 which is closely spaced from the magnetic medium during normal operation.

The MR sensor 42, the soft magnetic film layer 48 and the antiferromagnetic layer 46 are shaped as shown in Fig. 5 in which only the active region of the sensor extends to the sensing edge 54. The passive regions 40 of these components of the head are recessed from the sensing edge 54, and conductor leads 50 and 52 are in contact with the passive regions 40 away from the sensing edge 54. As shown in Fig. 5, the exchange bias field in the passive regions 40 of antiferromagnetic layer 46 is substantially parallel to the sensing edge 54 of the MR sensor, and the exchange bias field in the active region 41 of antiferromagnetic layer 46 is at a selected angle to the sensing edge 54. The preferred angle is in the range of about 60 degrees to about 85 degrees with respect to the sensing edge 54.

The embodiment of the invention shown in Fig. 4 has the advantage of less sensitivity to its operating environment since only the active region of the MR sensor 42 extends to the sensing edge 54. The fact that the conductor leads 50 and 52 do not extend to the sensing edge 54 eases mechanical problems, and the recessing of the MR sensor 42 in the passive regions 40 leads to reduced side reading.

The present invention has the principal advantage that it makes possible the in-situ deposition of the soft magnetic layer and the layer of antiferromagnetic material since these layers define the critical exchange bias interface. Since no fabrication steps are needed between the deposition of the soft magnetic layer and the deposition of the layer of antiferromagnetic material, it is much easier to maintain an uncontaminated exchange bias interface.

The present invention has the additional advantage that the regions of exchange bias need not be patterned physically, for example, by means of a photolithographic process, but can instead be patterned to a desired orientation during a thermal setting procedure. The thermal setting procedure comprises the steps of raising the temperature of the magnetic read head assembly above the Neel temperature of the antiferromagnetic layer where this layer becomes nonmagnetic, and applying suitable values of initiallization magnetic field and bias current. As the device cools to below the Neel temperature, the magnetization configuration of the soft magnetic film layer is copied into the antiferromagnetic layer. Now the biasing film, the antiferromagnetic layer, produces a pattern of exchange bias on active regions of the soft magnetic film layer and on the passive regions of both the soft magnetic film layer and the MR layer.

The thermal setting procedure is shown for the Fig. 2 embodiment in Fig. 8. The procedure uses an externally applied longitudinal magnetic initialization field, Hi, and an initialization current Ii, supplied by current source 56 as shown in Fig. 8. The cross sections include the current flow pattern schematically through the conductor leads and the layers of metallurgy. In this embodiment the width of the active region is defined by the current flow pattern.

The magnetization configuration is shown for temperatures above the Neel temperature in Fig. 6 in which a longitudinal bias is produced in the passive regions due to the applied magnetic field. A transverse bias is also generated in the active region. In most cases the current Ii is chosen so that the soft magnetic film layer is saturated, and in this case the magnetization would be at ninety degrees to the sensing edge. However, the applied magnetic field adds sufficient field so that the magnetization in the central region is at a selected angle. The angle can be chosen by an appropriate choice of the applied magnetic field Hi and the field generated by the current Ii.

As the device cools to below the Neel temperature, as shown in Fig. 7, the magnetization configuration in the soft magnetic film layer is copied into the antiferromagnetic layer. This configuration of magnetization then remains after the applied magnetic field Hi and the current Ii are removed. This completes the thermal setting of a patterned exchange bias orientation within the continuous antiferromagnetic layer.

The thermal setting procedure is carried out in the same way for the embodiment of the invention shown in Fig. 4. The procedure is illustrated in Fig. 9. In this case the width of the active region is determined by the width of the nonmagnetic spacer rather than the current flow path.

Claims

1. A magnetoresistive read transducer comprising : a decoupling layer (28) covering an active central region of a magnetoresistive conductive layer (22) ; a soft magnetic material film (30) extending over the magnetoresistive conductive layer (22) and the decoupling layer (28), the soft magnetic material film being in contact with the decoupling layer and separated from the active central region of the magnetoresistive layer by the decoupling layer and the soft magnetic material film being in contact with the passive end regions of the magnetoresistive layer ; and an antiferromagnetic material film (32) in direct contact with the soft magnetic material film, the magnetisation of the antiferromagnetic material film being so set as to produce an exchange bias field which is oriented substantially longitudinally within the passive end regions of the magnetoresistive layer and the end regions of the soft magnetic material film and which is oriented transversely in the central active region of the said magnetoresistive layer.

2. A magnetoresistive read transducer as claimed

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this embodiment, the MR read transducer assembly 39 has a sensing edge 54 which is closely spaced from the magnetic medium during normal operation.

The MR sensor 42, the soft magnetic film layer 48 and the antiferromagnetic layer 46 are shaped as shown in Fig. 5 in which only the active region of the sensor extends to the sensing edge 54. The passive regions 40 of these components of the head are recessed from the sensing edge 54, and conductor leads 50 and 52 are in contact with the passive regions 40 away from the sensing edge 54. As shown in Fig. 5, the exchange bias field in the passive regions 40 of antiferromagnetic layer 46 is substantially parallel to the sensing edge 54 of the MR sensor, and the exchange bias field in the active region 41 of antiferromagnetic layer 46 is at a selected angle to the sensing edge 54. The preferred angle is in the range of about 60 degrees to about 85 degrees with respect to the sensing edge 54.

The embodiment of the invention shown in Fig. 4 has the advantage of less sensitivity to its operating environment since only the active region of the MR sensor 42 extends to the sensing edge 54. The fact that the conductor leads 50 and 52 do not extend to the sensing edge 54 eases mechanical problems, and the recessing of the MR sensor 42 in the passive regions 40 leads to reduced side reading.

The present invention has the principal advantage that it makes possible the in-situ deposition of the soft magnetic layer and the layer of antiferromagnetic material since these layers define the critical exchange bias interface. Since no fabrication steps are needed between the deposition of the soft magnetic layer and the deposition of the layer of antiferromagnetic material, it is much easier to maintain an uncontaminated exchange bias interface.

The present invention has the additional advantage that the regions of exchange bias need not be patterned physically, for example, by means of a photolithographic process, but can instead be patterned to a desired orientation during a thermal setting procedure. The thermal setting procedure comprises the steps of raising the temperature of the magnetic read head assembly above the Neel temperature of the antiferromagnetic layer where this layer becomes nonmagnetic, and applying suitable values of initialization magnetic field and bias current. As the device cools to below the Neel temperature, the magnetization configuration of the soft magnetic film layer is copied into the antiferromagnetic layer. Now the biasing film, the antiferromagnetic layer, produces a pattern of exchange bias on active regions of the soft magnetic film layer and on the passive regions of both the soft magnetic film layer and the MR layer.

The thermal setting procedure is shown for the Fig. 2 embodiment in Fig. 8. The procedure uses an externally applied longitudinal magnetic initialization field, Hi, and an initialization current Ii, supplied by current source 56 as shown in Fig. 8. The cross sections include the current flow pattern schematically through the conductor leads and the layers of metallurgy. In this embodiment the width of the active region is defined by the current flow pattern.

The magnetization configuration is shown for temperatures above the Neel temperature in Fig. 6 in which a longitudinal bias is produced in the passive regions due to the applied magnetic field. A transverse bias is also generated in the active region. In most cases the current Ii is chosen so that the soft magnetic film layer is saturated, and in this case the magnetization would be at ninety degrees to the sensing edge. However, the applied magnetic field adds sufficient field so that the magnetization in the central region is at a selected angle. The angle can be chosen by an appropriate choice of the applied magnetic field Hi and the field generated by the current Ii.

As the device cools to below the Neel temperature, as shown in Fig. 7, the magnetization configuration in the soft magnetic film layer is copied into the antiferromagnetic layer. This configuration of magnetization then remains after the applied magnetic field Hi and the current Ii are removed. This completes the thermal setting of a patterned exchange bias orientation within the continuous antiferromagnetic layer.

The thermal setting procedure is carried out in the same way for the embodiment of the invention shown in Fig. 4. The procedure is illustrated in Fig. 9. In this case the width of the active region is determined by the width of the nonmagnetic spacer rather than the current flow path.

Claims

1. A magnetoresistive read transducer comprising : a decoupling layer (28) covering an active central region of a magnetoresistive conductive layer (22) ; a soft magnetic material film (30) extending over the magnetoresistive conductive layer (22) and the decoupling layer (28), the soft magnetic material film being in contact with the decoupling layer and separated from the active central region of the magnetoresistive layer by the decoupling layer and the soft magnetic material film being in contact with the passive end regions of the magnetoresistive layer ; and an antiferromagnetic material film (32) in direct contact with the soft magnetic material film, the magnetisation of the antiferromagnetic material film being so set as to produce an exchange bias field which is oriented substantially longitudinally within the passive end regions of the magnetoresistive layer and the end regions of the soft magnetic material film and which is oriented transversely in the central active region of the said magnetoresistive layer.

2. A magnetoresistive read transducer as claimed

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in claim 1, in which the magnetoresistive conductive layer consists of NiFe.

3. A magnetoresistive read transducer as claimed in claim 1 or claim 2, in which the soft magnetic material film consists of NiFeRh.

4. A magnetoresistive read transducer as claimed in any preceding claim, in which the antiferromagnetic material film consists of MnFe.

5. A magnetoresistive read transducer as claimed in any preceding claim, in which the decoupling layer covers substantially only the central active region of the magnetoresistive layer.

6. A magnetoresistive read transducer as claimed in any of claims 1 to 4, in which the decoupling layer covers a further portion of the magnetoresistive layer on either side of the active central region thereof.

7. A magnetoresistive read transducer as claimed in claim 6, further comprising spaced conductor means electrically connected to the magnetoresistive layer, the gap between the spaced conductor means defining the active central region of the magnetoresistive layer.

8. A magnetoresistive read transducer as claimed in claim 7, in which the magnetoresistive layer is so shaped that only its active central region extends to the sensing edge of the transducer.

9. A magnetoresistive read transducer as claimed in claim 8, in which the exchange bias field is oriented at an angle from about 60 to about 85 degrees to the sensing edge of the transducer.

Patentansprüche

1. Magnetoresistiver Lesewandler, der aufweist: eine Entkopplungsschicht (28), die einen aktiven zentralen Bereich einer magnetoresistiven, leitenden Schicht (22) überdeckt, eine Schicht (30) aus weichmagnetischem Material, die sich über die magnetoresistive, leitende Schicht (22) und die Entkopplungsschicht (28) erstreckt, wobei sich die Schicht aus weichmagnetischem Material in Kontakt mit der Entkopplungsschicht befindet und von dem aktiven zentralen Bereich der magnetoresistiven Schicht durch die Entkopplungsschicht getrennt ist und wobei sich die Schicht aus weichmagnetischem Material in Kontakt mit den passiven Endbereichen der magnetoresistiven Schicht befindet und sich eine Schicht (32) aus antiferromagnetischem Material in unmittelbarem Kontakt mit der Schicht aus weichmagnetischem Material befindet und die Magnetisierung der Schicht aus antiferromagnetischem Material so eingestellt ist, daß ein Austauschvormagnetisierungsfeld erzeugt wird, das im wesentlichen longitudinal innerhalb der passiven Endbereiche der magnetoresistiven Schicht und der Endbereiche der Schicht aus weichmagnetischem Material ausgerichtet ist und das quer in dem zentralen aktiven Bereich der magnetoresistiven Schicht ausgerichtet ist.

2. Magnetoresistiver Lesewandler nach Anspruch 1, bei welchem die magnetoresistive leitende Schicht aus NiFe besteht.

3. Magnetoresistiver Lesewandler nach Anspruch 1 oder Anspruch 2, bei welchem die Schicht aus weichmagnetischem Material aus NiFeRh besteht.

4. Magnetoresistiver Lesewandler nach irgend einem vorgehenden Anspruch, bei welchem die Schicht aus antiferromagnetischem Material aus MnFe besteht.

5. Magnetoresistiver Lesewandler nach irgend einem vorgehenden Anspruch, bei welchem die Entkopplungsschicht im wesentlichen nur den zentralen aktiven Bereich der magnetoresistiven Schicht überdeckt.

6. Magnetoresistiver Lesewandler nach irgend einen der Ansprüche 1 bis 4, bei welchem die Entkopplungsschicht einen weiteren Teil der magnetoresistiven Schicht auf beiden Seiten ihres aktiven zentralen Bereich überdeckt.

7. Magnetoresistiver Lesewandler nach Anspruch 6, der ferner beabstandete Leitermittel aufweist, die mit der magnetoresistiven Schicht elektrisch verbunden sind, wobei der Zwischenraum zwischen den beabstandeten Leitermitteln den aktiven zentralen Bereich der magnetoresistiven Schicht definiert.

8. Magnetoresistiver Lesewandler nach Anspruch 7, bei welchem die magnetoresistive Schicht so ausgebildet ist, daß sich nur ihr aktiver zentraler Bereich zu dem Abtastrand des Wandlers erstreckt.

9. Magnetoresistiver Lesewandler nach Anspruch 8, bei welchem das Austauschvormagnetisierungsfeld unter einem Winkel von ungefähr 60 bis ungefähr 85 Grad zu dem Abtastrand des Wandlers ausgerichtet ist.

Revendications

1. Transducteur de lecture magnétorésistant comprenant : une couche de découplage (28) couvrant une région centrale active d'une couche conductrice magnétorésistante (22) ; un film de matière faiblement magnétique (30) qui s'étend sur la couche conductrice magnétorésistante (22) et la couche de découplage (28), le film de matière faiblement magnétique étant en contact avec la couche de découplage et séparé de la région centrale active de la couche magnétorésistante par la couche de découplage, et le film de matière faiblement magnétique étant en contact avec les régions d'extrémité passives de la couche magnétorésistante ; et un film de matière antiferromagnétique (32) en contact direct avec le film de matière faiblement magnétique,

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l'aimantation du film de matière antiferromagnétique étant établie de manière à produire un champ de polarisation d'échange qui est orienté sensiblement longitudinalement dans les régions d' extrémité passives de la couche magnétorésistante et les régions d'extrémité du film de matière faiblement magnétique et qui est orienté transversalement dans la région centrale active de ladite couche magnétorésistante.

2. Transducteur de lecture magnétorésistant suivant la revendication 1, dans lequel la couche conductrice magnétorésistante est en NiFe.

3. Transducteur de lecture magnétorésistant suivant la revendication 1 ou la revendication 2, dans lequel le film de matière faiblement magnétique est en NiFeRh.

4. Transducteur de lecture magnétorésistant suivant l'une quelconque des revendications précédentes, dans lequel le film de matière antiferromagnétique est en MnFe.

5. Transducteur de lecture magnétorésistant suivant l'une quelconque des revendications précédentes, dans lequel la couche de découplage couvre sensiblement seulement la région centrale active de la couche magnétorésistante.

6. Transducteur de lecture magnétorésistant suivant l'une quelconque des revendications 1 à 4, dans lequel la couche de découplage couvre une partie supplémentaire de la couche magnétorésistante, de chaque côté de sa région centrale active.

7. Transducteur de lecture magnétorésistant suivant la revendication 6, comprenant en outre des conducteurs espacés électriquement connectés à la couche magnétorésistante, l'intervalle entre les conducteurs espacés définissant la région centrale active de la couche magnétorésistante.

8. Transducteur de lecture magnétorésistant suivant la revendication 7, dans lequel la couche magnétorésistante a une configuration telle que seule sa région centrale active s'étend jusqu'au bord de détection du transducteur.

9. Transducteur de lecture magnétorésistant suivant la revendication 8, dans lequel le champ de polarisation d'échange est orienté suivant un angle de 60° environ à 85° environ par rapport au bord de détection du transducteur.