Description

The present invention relates to a process for making a shielded magnetoresistive sensor.

Known magnetoresistive (MR) sensors or heads are capable of reading data from a magnetic record surface at great linear densities. An MR sensor 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 MR element.

The drive towards increased recording density has led to the requirement for narrower recording tracks and increased linear recording density along the tracks. In order for an MR read head to be capable of reading data from a magnetic medium at these high recording densities, the MR element must be incorporated in the gap between two magnetic shields. For example, U. S. -A- 4,639,806, which is reflected in the preamble of claim 1, discloses a shielded MR element, and discloses that the shields may be made of high permeability magnetic material such as Ni-Zn ferrite, Mn-Zn ferrite, sendust and permalloy.

When using an MR read transducer with a rigid magnetic disk storage system, certain design conditions are imposed since materials exposed at the air bearing surface (ABS) of the flying slider, which supports the transducer, are susceptible to damage when the sliders are hit by the asperities or contaminants which may exist on the magnetic recording disks. Among the different conductive materials exposed at the MR head ABS, the leading magnetic shield presents the most serious problem since the shield provides a large volume of material which can be easily scratched or smeared to form a short circuit conducting path between the leading shield and the MR sensor layers, thereby resulting in sensor shorting. This represents an unacceptable MR sensor failure, so the structure of the MR sensor must be designed to avoid such sensor shorting.

One way to avoid sensor shorting would be to use a nonconducting material, such as a ferrite material for the shields. However, this solution introduces other design problems which make this solution less attractive.

This invention seeks to provide an improved shielded magnetoresistive (MR) read transducer suitable for use in a rigid magnetic disk storage system and in which the shields are formed of conductive materials.

The invention provides a process for making a shielded magnetoresistive sensor comprising the steps of: (a) depositing a layer of a magnetic material to form a first shield member; (b) depositing a first layer of a suitable electrically insulating material over the first shield member; (c) depositing, in the presence of a magnetic field, a thin film of a magnetoresistive material, the magnetic field being operable to orient the layer of magnetoresistive material in a preferred direction; (d) depositing a second layer of a suitable electrically insulating material over the layer of magnetoresistive material; and (e) depositing a layer of a magnetic material over the second layer of electrically insulating material to form a second shield member; the method being characterised by the combination of: using a magnetic alloy as the magnetic material deposited in step (a), the magnetic alloy comprising 3 to 6% aluminium, 6 to 12% silicon, the balance being iron; heat treating the layer of the magnetic alloy, prior to deposition step (b), at a temperature greater than 400°C for a predetermined time to enhance the magnetic properties of the first shield member; and using a soft magnetic material as the magnetic material deposited in step (e).

How the invention can be carried out will now be described by way of example, with reference to the accompanying drawing which is a view of the air bearing surface of a magnetoresistive read transducer suitable for use with a rigid magnetic disk storage system.

Referring to the accompanying drawing, an MR read head assembly 10 comprises a first shield member 12 which is separated from a substrate 14 by a nonconductive layer 16 of alumina, for example. A first nonmagnetic gap layer 18 serves as a base for an MR sensor element 20. Although the MR sensor element 20 is shown as having a single layer, it will be apparent to those skilled in the art that additional layers for properly biasing the sensor, for example, may also be included. The MR sensor element 20 is contacted by electrically conductive leads 22 and 24, which are isolated from the second shield member 28 by a second nonmagnetic gap layer 26. A protective layer 30 is deposited to a desired thickness at the trailing end of the assembly.

In operation, the flying direction of the slider, which supports the MR read transducer, is as shown by arrow 34, so, should any sensor shorting occur, this would be evidenced by a bridging of conductive material between the leading shield member 12 (i.e., the first shield that would be subjected to contact with any asperities on the disk) and the MR sensor element 20 or between the first shield member 12 and conductive lead structure 22 or 24.

From the standpoint of its magnetic characteristics and its compatibility with other materials and processes being used, the NiFe alloy known as permalloy is the preferred material to be used for both first shield member 12 and second shield member 28. However, this cannot be done due to the ductile nature of permalloy, which may lead to sensor shorting.

By application of the present invention, the first shield member 12 and the second shield member 28 are formed from such materials that MR sensor shorts are eliminated while at the same time the

shield members 12 and 28 have magnetic characteristics equivalent to those of permalloy.

Our preferred material for the first shield member 12 is the FeSiAl alloy known as sendust and the material for the second shield member 28 is a soft magnetic material such as permalloy. It is not obvious that such a combination of materials can be produced since sendust in its as-deposited state has magnetic characteristics that are vastly inferior to the magnetic characteristics of permalloy. However, the magnetic characteristics of sendust can be enhanced by annealing. To obtain magnetic characteristics equivalent to permalloy, the annealing temperature must be at least 400°C. This presents a problem since, at this temperature, the MR sensor element would be destroyed. However, this problem has been overcome by means of the process to be described.

The preferred process for making an MR read transducer comprises the steps of depositing a layer of FeSiAl alloy near the composition known as Sendust (5.4 wt % Al, 9.6 wt % Si, 85 wt % Fe). Alloys having between 6 and 12% Si and 3 to 6% Al and the balance Fe are suitable. The alloy known as Super Sendust is also suitable and this alloy includes 3 wt % Ni, 4 wt % Al, 6 wt % Si and 87 wt % Fe. The sendust alloy layer is preferably sputter deposited in a vacuum to a thickness of greater than 1 micron, preferably at least 1.6 micron. Preferably the sendust alloy layer should be deposited in such a way as to produce magnetic anistropy in the as-deposited film. The deposited sendust film has a very low permeability which can be enhanced by annealing.

The sendust shield layer is heat treated at a temperature greater than 400°C for a suitable time preferably in an oriented magnetic field. The preferred treatment is at a temperature of 450-500°C, either in a vacuum or a nitrogen atmosphere, for a time of two hours, for example. A higher temperature can be used in which case the treatment time can be reduced. This heat treatment step must be done prior to deposition of the MR sensor element 20.

The first insulating gap layer 18 is then deposited to serve as a base for the deposition, in the presence of a magnetic field, of the MR sensor element 20. MR sensor element 20 may be NiFe, for example, and the magnetic field during deposition causes the orientation of the NiFe material of the MR sensor element 20 in a chosen direction.

The second nonmagnetic gap layer 26 is then deposited, followed by deposition of the second shield member 28. Note that Sendust cannot be used for the second shield member since it would be necessary to anneal the sendust film, after deposition, at a temperature of at least 400°C. This temperature would be above the curie temperature of the NiFe and therefore would destroy the orientation of the NiFe layer. For this reason permalloy is used for the second shield member 28. This material is used due to its magnetic characteristics, its compatibility with other materials and processes used in the MR read transducer, and the fact that no heat treatment is required to achieve the desired magnetic characteristics.

Claims

1. A method for making a shielded magnetoresistive sensor comprising the steps of:
   (a) depositing a layer (12) of a magnetic material to form a first shield member;
   (b) depositing a first layer (18) of a suitable electrically insulating material over the first shield member;
   (c) depositing, in the presence of a magnetic field, a thin film (20) of a magnetoresistive material, the magnetic field being operable to orient the layer of magnetoresistive material in a preferred direction;
   (d) depositing a second layer (26) of a suitable electrically insulating material over the layer of magnetoresistive material; and
   (e) depositing a layer (28) of a magnetic material over the second layer of electrically insulating material to form a second shield member;
   the method being characterised by the combination of:
   using a magnetic alloy as the magnetic material deposited in step (a), the magnetic alloy comprising 3 to 6% aluminium, 6 to 12% silicon, the balance being iron;
   heat treating the layer of the magnetic alloy, prior to deposition step (b), at a temperature greater than 400°C for a predetermined time to enhance the magnetic properties of the first shield member; and
   using another magnetic material as the magnetic material deposited in step (e).

2. A method as claimed in claim 1, wherein the magnetic alloy is that known as sendust.

3. A method as claimed in Claim 1, wherein the magnetic alloy also includes 3% nickel.

4. A method as claimed in claim 3, wherein the magnetic alloy is that known as super sendust.

5. A method as claimed in any preceding claim, wherein the heat treatment is carried out at a temperature of 450-500°C for a time of about two hours.

6. A method as claimed in any preceding claim, wherein the soft magnetic material is NiFe.

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shield members 12 and 28 have magnetic characteristics equivalent to those of permalloy.

Our preferred material for the first shield member 12 is the FeSiAl alloy known as sendust and the material for the second shield member 28 is a soft magnetic material such as permalloy. It is not obvious that such a combination of materials can be produced since sendust in its as-deposited state has magnetic characteristics that are vastly inferior to the magnetic characteristics of permalloy. However, the magnetic characteristics of sendust can be enhanced by annealing. To obtain magnetic characteristics equivalent to permalloy, the annealing temperature must be at least 400°C. This presents a problem since, at this temperature, the MR sensor element would be destroyed. However, this problem has been overcome by means of the process to be described.

The preferred process for making an MR read transducer comprises the steps of depositing a layer of FeSiAl alloy near the composition known as Sendust (5.4 wt % Al, 9.6 wt % Si, 85 wt % Fe). Alloys having between 6 and 12% Si and 3 to 6% Al and the balance Fe are suitable. The alloy known as Super Sendust is also suitable and this alloy includes 3 wt % Ni, 4 wt % Al, 6 wt % Si and 87 wt % Fe. The sendust alloy layer is preferably sputter deposited in a vacuum to a thickness of greater than 1 micron, preferably at least 1.6 micron. Preferably the sendust alloy layer should be deposited in such a way as to produce magnetic anistropy in the as-deposited film. The deposited sendust film has a very low permeability which can be enhanced by annealing.

The sendust shield layer is heat treated at a temperature greater than 400°C for a suitable time preferably in an oriented magnetic field. The preferred treatment is at a temperature of 450-500°C, either in a vacuum or a nitrogen atmosphere, for a time of two hours, for example. A higher temperature can be used in which case the treatment time can be reduced. This heat treatment step must be done prior to deposition of the MR sensor element 20.

The first insulating gap layer 18 is then deposited to serve as a base for the deposition, in the presence of a magnetic field, of the MR sensor element 20. MR sensor element 20 may be NiFe, for example, and the magnetic field during deposition causes the orientation of the NiFe material of the MR sensor element 20 in a chosen direction.

The second nonmagnetic gap layer 26 is then deposited, followed by deposition of the second shield member 28. Note that Sendust cannot be used for the second shield member since it would be necessary to anneal the sendust film, after deposition, at a temperature of at least 400°C. This temperature would be above the curie temperature of the NiFe and therefore would destroy the orientation of the NiFe layer. For this reason permalloy is used for the second shield member 28. This material is used due to its magnetic characteristics, its compatibility with other materials and processes used in the MR read transducer, and the fact that no heat treatment is required to achieve the desired magnetic characteristics.

Claims

1. A method for making a shielded magnetoresistive sensor comprising the steps of:
   (a) depositing a layer (12) of a magnetic material to form a first shield member;
   (b) depositing a first layer (18) of a suitable electrically insulating material over the first shield member;
   (c) depositing, in the presence of a magnetic field, a thin film (20) of a magnetoresistive material, the magnetic field being operable to orient the layer of magnetoresistive material in a preferred direction;
   (d) depositing a second layer (26) of a suitable electrically insulating material over the layer of magnetoresistive material; and
   (e) depositing a layer (28) of a magnetic material over the second layer of electrically insulating material to form a second shield member;
   the method being characterised by the combination of:
   using a magnetic alloy as the magnetic material deposited in step (a), the magnetic alloy comprising 3 to 6% aluminium, 6 to 12% silicon, the balance being iron;
   heat treating the layer of the magnetic alloy, prior to deposition step (b), at a temperature greater than 400°C for a predetermined time to enhance the magnetic properties of the first shield member; and
   using another magnetic material as the magnetic material deposited in step (e).

2. A method as claimed in claim 1, wherein the magnetic alloy is that known as sendust.

3. A method as claimed in Claim 1, wherein the magnetic alloy also includes 3% nickel.

4. A method as claimed in claim 3, wherein the magnetic alloy is that known as super sendust.

5. A method as claimed in any preceding claim, wherein the heat treatment is carried out at a temperature of 450-500°C for a time of about two hours.

6. A method as claimed in any preceding claim, wherein the soft magnetic material is NiFe.

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7. A shielded magnetoresistive sensor comprising:
   (a) a first shield member formed by a layer (12) of a magnetic material ,
   (b) a first layer (18) of a suitable electrically insulating material deposited over the first shield member (12)
   (c) a thin film (20) of a magnetoresistive material deposited in the presence of a magnetic field and thus being oriented in a preferred direction,
   (d) a second layer (26) of a suitable electrically insulating material deposited over the layer of magnetoresistive material, and
   (e) a second shield member formed by a layer (28) of magnetic material deposited over the second layer (26) of electrically insulting material,
   characterized in that
   the material for the layer (12) forming the first shield member comprises 3 to 6% aluminium, 6 to 12% silicon, the balance being iron, and has been heat treated prior to the deposition of the subsequent layers at a temperature greater than 400°C for a predetermined time so that the magnetic properties of it are enhanced, and in that the second shield member is formed of another material.

Patentansprüche

1. Verfahren zur Herstellung eines abgeschirmten magnetoresistiven Sensors mit folgenden Schritten:
   (a) Aufbringen einer Schicht (12) aus einem magnetischen Material, um ein erstes Abschirmelement zu bilden;
   (b) Aufbringen einer ersten Schicht (18) aus einem geeigneten, elektrisch isolierenden Material über dem ersten Abschirmelement;
   (c) Aufbringen eines dünnen Films (20) aus einem magnetoresistiven Material in Anwesenheit eines magnetischen Feldes, wobei das magnetische Feld zum Ausrichten der Schicht aus magnetoresistivem Material in einer Vorzugsrichtung einstellbar ist;
   (d) Aufbringen einer zweiten Schicht (26) aus einem geeigneten, elektrisch isolierenden Material über der Schicht aus magnetoresistiven Material; und
   (e) Aufbringen einer Schicht (28) aus magnetischem Material über der zweiten Schicht aus elektrisch isolierendem Material, um ein zweites Abschirmelement zu bilden;
   wobei das Verfahren gekennzeichnet ist durch die Kombination von:
   Verwenden einer magnetischen Legierung als dem in Schritt (a) aufgebrachten magnetischen Material, wobei die magnetische Legierung 3 % bis 6 % Aluminium und 6 % bis 12 % Silizium beinhaltet und der Rest aus Eisen besteht;
   Wärmebehandeln der Schicht aus der magnetischen Legierung vor dem Depositionsschritt (b) bei einer Temperatur höher als 400 °C für eine vorgegebene Zeitdauer, um die magnetischen Eigenschaften des ersten Abschirmelementes zu verbessern; und
   Verwenden eines weiteren weichmagnetischen Materials als dem in Schritt (e) aufgebrachten magnetischen Material.

2. Verfahren nach Anspruch 1, wobei die magnetische Legierung diejenige ist, die als Sendust bekannt ist.

3. Verfahren nach Anspruch 1, wobei die magnetische Legierung außerdem 3 % Nickel beinhaltet.

4. Verfahren nach Anspruch 3, wobei die magnetische Legierung diejenige ist, die als Super-Sendust bekannt ist.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Wärmebehandlung bei einer Temperatur von 450 °C bis 500 °C während einer Zeitdauer von etwa zwei Stunden durchgeführt wird.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei das weichmagnetische Material NiFe ist.

7. Abgeschirmter magnetoresistiver Sensor mit:
   (a) einem ersten, durch eine Schicht (12) aus einem magnetischen Material gebildeten Abschirmelement,
   (b) einer ersten, über dem ersten Abschirmelement (12) aufgebrachten Schicht (18) aus einem geeigneten, elektrisch isolierenden Material,
   (c) einem dünnen Film (20) aus einem magnetoresistiven Material, der in Anwesenheit eines magnetischen Feldes aufgebracht und dadurch in einer Vorzugsrichtung orientiert ist,
   (d) einer zweiten, über der Schicht aus magnetoresistivem Material aufgebrachten Schicht (26) aus einem geeigneten, elektrisch isolierenden Material und
   (e) einem zweiten Abschirmelement, das durch eine Schicht (28) aus magnetischem Material gebildet ist, die über der zweiten Schicht (26) aus elektrisch isolierendem Material aufgebracht ist,
   dadurch gekennzeichnet, daß
   das Material für die Schicht (12), die das erste Abschirmelement bildet, 3 % bis 6 % Aluminium und

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6 % bis 12 % Silizium enthält, wobei der Rest Eisen ist, und vor der Deposition der nachfolgenden Schichten bei einer Temperatur höher als 400 °C für eine vorgegebene Zeitdauer wärmebehandelt wurde, so daß dessen magnetische Eigenschaften verbessert werden, und dadurch, daß das zweite Abschirmelement aus einem anderen Material gebildet ist.

Revendications

1. Procédé pour fabriquer un capteur magnéto-résistif blindé comprenant les étapes consistant à :
   (a) déposer une couche (12) d'un matériau magnétique pour former un premier élément de blindage,
   (b) déposer une première couche (18) d'un matériau électriquement isolant approprié sur le premier élément de blindage,
   (c) déposer, en la présence d'un champ magnétique, un film mince (20) d'un matériau magnéto-résistif, le champ magnétique étant mis en oeuvre pour orienter la couche de matériau magnéto-résistif dans une direction préférée,
   (d) déposer une seconde couche (26) d'un matériau électriquement isolant approprié sur la couche de matériau magnéto-résistif, et
   (e) déposer une couche (28) d'un matériau magnétique sur la seconde couche du matériau électriquement isolant afin de former un second élément de blindage, le procédé étant caractérisé par la combinaison consistant à :
   utiliser un alliage magnétique en tant que matériau magnétique déposé à l'étape (a), l'alliage magnétique comprenant 3 à 6 % en poids d'aluminium, 6 à 12 % en poids de silicium, le reste étant du fer,
   traiter à chaud la couche de l'alliage magnétique avant l'étape de dépôt (b), à une température supérieure à 400°C pendant une durée prédéterminée pour augmenter les propriétés magnétiques du premier élément de blindage, et
   utiliser un autre matériau magnétique doux en tant que matériau magnétique déposé à l'étape (e).

2. Procédé selon la revendication 1, dans lequel l'alliage magnétique est celui connu comme sendust.

3. Procédé selon la revendication 1, dans lequel l'alliage magnétique comporte également 3 % en poids de nickel.

4. Procédé selon la revendication 3, dans lequel l'alliage magnétique est celui connu comme super sendust.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel le traitement thermique est effectué à une température située entre 450 et 500°C pendant une durée d'environ deux heures.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel le matériau magnétique doux est NiFe.

7. Capteur magnéto-résistif blindé comprenant :
   (a) un premier élément de blindage formé par une couche (12) d'un matériau magnétique,
   (b) une première couche (18) d'un matériau électriquement isolant approprié déposée sur le premier élément de blindage (12),
   (c) un film mince (20) d'un matériau magnéto-résistif déposé en la présence d'un champ magnétique qui est de ce fait orienté dans une direction préférée,
   (d) une seconde couche (26) d'un matériau électriquement isolant approprié déposée sur la couche du matériau magnéto-résistif, et
   (e) un second de blindage formé par une couche (28) du matériau magnétique déposée sur la seconde couche (26) du matériau électriquement isolant,
   caractérisé en ce que
   le matériau pour la couche (12) formant le premier élément de blindage comprend 3 à 6 % en poids d'aluminium, 6 à 12 % en poids de silicium, le reste étant du fer et a été traité à chaud avant le dépôt des couches suivantes à une température supérieure à 400°C pendant une durée prédéterminée, de sorte que ses propriétés magnétiques soient augmentées et en ce que le second élément de blindage est formé d'un autre matériau.