MAGNETIC HEAD SLIDER, METHOD OF MANUFACTURING THE SAME AND MAGNETIC DISK APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a magnetic head slider having at least either a magnetic head element for writing or a magnetic head element for reading, a method of manufacturing the magnetic head slider, and a magnetic disk apparatus.

2. Description of the Related Art

In recent years, in the field of a magnetic recording apparatus such as a magnetic disk apparatus, research and development for improving surface recording density has been actively carried out. As a recording/reproducing method of the magnetic disk apparatus, a method of CSS (Contact-Start-Stop) is in the mainstream at present. According to the method, a magnetic head slider (hereinafter, also simply described as "magnetic head" or "head") is in contact with a magnetic disk (hereinafter, also simply described as "disk") as a recording medium when the magnetic disk apparatus is not operative, and the head takes off from the surface of the disk and relatively moves above the disk to record and reproduce information when the magnetic disk apparatus is operative.

In order to improve the surface recording density of the magnetic

disk apparatus using the method, it is important to smooth the contact surfaces of the head and the disk and reduce a flying height of the head from the disk, that is, a gap between the flying head slider and the disk.

Fig. 10 shows a construction of a magnetic head slider as an example of a related art. The magnetic head slider comprises a magnetic head slider body 100 in which a head core part 102 having an inductive magnetic transducer for writing and a magnetoresistive element for reading is formed on a base body 101. On the whole surface (hereinafter, also described as ABS (Air Bearing Surface)) 100a to face a disk, of the magnetic head slider body 100, a protective film 110 made of diamond-like carbon (hereinafter, referred to as DLC) having the thickness of about 30 nm is formed. The protective film 110 has protruded parts 111. The protruded parts 111 are provided to prevent adsorption between the magnetic head slider and the disk each having a smooth facing surface.

The protective film 110 is also formed on a region in which the head core part 102 is formed on the air bearing surface 100a and plays a role of protecting the substrate 101 at the time of operation of the magnetic disk apparatus and also preventing, for example, a magnetoresistive film constructing the magnetoresistive element in the head core part 102 from being corroded or deteriorated by moisture or the like. Especially, since an Fe(iron)-Mn(manganese) alloy which is easily corroded is used as a material of the conventional magnetoresistive film, it is effective to form the protective film 110 on the whole air bearing surface.

In order to further improve the surface recording density of the

magnetic disk apparatus, it is necessary to make the distance between the head core part 102 and a disk shorter as compared with the case of the related art. When the protective film 110 is provided on the head core part forming region of the air bearing surface 100a, there is a problem such that the distance between the head core part 102 of the flying head slider and a disk is longer only by an amount corresponding to the thickness of the protective film 110.

SUMMARY OF THE INVENTION

The invention has been achieved in view of the problems and its object is to provide a magnetic head slider capable of attaining higher surface recording density by shortening the distance between a recording medium and a head core part, which face each other, at the time of operation, a method of manufacturing the magnetic head slider, and a magnetic disk apparatus using the magnetic head slider.

A magnetic head slider according to the invention comprises a magnetic head slider body in which a head core part including at least either a magnetic head element for writing or a magnetic head element for reading is formed, and a protective film selectively formed in a region, other than a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face a recording medium. In the case, "selectively" denotes the whole or a part of the region.

A method of manufacturing a magnetic head slider according to the invention comprises: a step of fabricating a magnetic head slider body by

forming a head core part including at least either a magnetic head element for writing or a magnetic head element for reading, on a substrate; a step of forming a mask at least in a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face a recording medium; a step of forming a protective film so as to cover the surface of the magnetic head slider body, the surface being to face the recording medium; and a step of removing the mask and the protective film on the mask.

According to the invention, there is provided a magnetic disk apparatus comprising a magnetic head slider and a recording medium which are disposed so as to face each other, wherein the magnetic head slider includes: a magnetic head slider body in which a head core part including at least either a magnetic head element for writing or a magnetic head element for reading is formed; and a protective film selectively formed in a region other than a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face the recording medium.

In each of the magnetic head slider, the method of manufacturing the magnetic head slider, and the magnetic disk apparatus of the invention, the protective film is selectively formed in the region except for the region where the head core part is formed on the surface (air bearing surface) to face a recording medium, of the magnetic head slider body. That is, the protective film is not formed on the head core part and its peripheral region. The protective film is formed by forming a mask at least in the region where

the head core part is formed on the air being surface, forming the protective film so as to cover the air bearing surface, and removing the mask and the protective film on the mask.

In each of the magnetic head slider, the method of manufacturing the magnetic head slider, and the magnetic disk apparatus of the invention, the protective film may be formed on the whole air bearing surface except for the region where the head core part is formed.

In each of the magnetic head slider, the method of manufacturing the magnetic head slider, and the magnetic disk apparatus, it is desirable that the protective film contains diamond-like carbon.

In each of the magnetic head slider, the method of manufacturing the magnetic head slider, and the magnetic disk apparatus, the magnetic head element for reading may be a magnetoresistive element. In this case, it is preferable that the magnetoresistive element has a magnetoresistive film containing at least nickel and manganese.

Further, in the method of manufacturing the magnetic head slider of the invention, it is preferable that the mask is made of organic material or metal material.

Other and further objects, features and advantages of the invention will appear more fully from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross section for explaining a process in a method of manufacturing a magnetic head slider according to an embodiment of the

invention.

Fig. 2 is a cross section for explaining a process following Fig. 1.

Fig. 3 is a cross section for explaining a process following Fig. 2.

Fig. 4 is a perspective view for explaining a process following Fig. 3.

Fig. 5 is a perspective view for explaining a process following Fig. 4.

Fig. 6 is a perspective view for explaining a process following Fig. 5.

Fig. 7 is a perspective view showing the outer construction of the magnetic head slider according to the embodiment of the invention.

Fig. 8 is a perspective view showing the construction of a magnetic disk apparatus using the magnetic head slider illustrated in Fig. 7.

Fig. 9A is a schematic diagram showing the positional relation between a head core part and a magnetic disk when the magnetic disk apparatus according to the embodiment of the invention shown in Fig. 8 is operative.

Fig. 9B is a schematic diagram showing the positional relation between a head core part and a magnetic disk when a magnetic disk apparatus of a related art is operative in a conventional magnetic disk apparatus.

Fig. 10 is a perspective view showing an outer construction of a magnetic head slider of a related art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the invention will be described below with reference to the drawings. As an example of a magnetic head slider according to the invention, a magnetic head slider comprising a composite thin film magnetic head in which a head core part has the structure such that a recording head having an inductive magnetic transducer for writing and a reproduction head including a magnetoresistive (hereinafter, also described as "MR") element for reading are stacked, and a method of manufacturing the magnetic head slider will be described.

A method of manufacturing a magnetic head slider 1 according to the embodiment of the invention will be described first with reference to Figs. 1 to 7. A magnetic head slider according to the embodiment will be embodied through a method of manufacturing the magnetic head slider according to the embodiment so that both will be described together in the followings. Figs. 1 to 3 are diagrams each showing a cross section perpendicular to the air bearing surface. Figs. 4 to 7 are perspective views seen above the air bearing surface side.

In the manufacturing method according to the embodiment, first, as shown in Fig. 1, an insulating layer 21 made of alumina (Al_2O_3) or the like is deposited on a substrate 11 made of AlTiC ($Al_2O_3 \cdot TiC$). On the insulating layer 21, a bottom shield layer 22 for the reproduction head is formed. On the bottom shield layer 22, a shield gap film 23 is formed through depositing alumina or the like to the thickness of about 100 to 200 nm (nanometer) through sputtering. On the shield gap film 23, an MR film

24 made of, for example, a Ni(nickel)-Mn(manganese) alloy for constructing the MR element for reproduction is formed in about few tens nanometers in thickness and patterned in a desired shape by high precision photolithography. A lead layer (not shown in figure) as a lead electrode layer which is electrically connected to the MR film 24 is formed on both sides of the MR film 24 and a shield gap film 25 is formed on the lead layer so that the MR film 24 is buried in the shield gap films 23 and 25. On the shield gap film 25, a top shield-cum-bottom pole (hereinafter, described as bottom pole) 26 made of magnetic material such as permalloy (NiFe) used for both the reproducing head and the recording head is formed. The MR element including the MR film 24 corresponds to an example of "magnetic head element for reading" in the invention.

As an MR element, besides an anisotropic magnetoresistive (hereinafter, described as AMR) element using the AMR effect as shown in the embodiment, a giant magnetoresistive (hereinafter, described as GMR) element having the GMR effect, or the like can be used.

As shown in Fig. 2, a recording gap layer 27 made of insulating material such as alumina is formed on the bottom pole 26. On the recording gap layer 27, a photoresist layer 28 is formed in a predetermined pattern by high precision photolithography. On the photoresist layer 28, a thin film coil 29 made of copper (Cu) or the like as a first layer of the thin film coils for the inductive recording head is formed by, for example, plating. Subsequently, a photoresist layer 30 is formed in a predetermined pattern through high precision photolithography so as to cover the photoresist layer

28 and the coil 29. In order to smooth the coil 29 and insulate turns of the coil 29 one another, heat treatment at the temperature of 250 degrees or the like is performed. On the photoresist layer 30, a thin film coil 31 made of copper or the like as a second layer of the thin film coils is formed through, for example, plating. On the photoresist layer 30 and the coil 31, a photoresist layer 32 is formed in a predetermined pattern through high precision photolithography and heat treatment at the temperature of 250 degrees or the like is performed to smooth the coil 31 and insulate turns of the coil 31 one another.

As shown in Fig. 3, in a position rearward of the coils 29 and 31 (right side in Fig. 3), an opening 27a is formed by partially etching the recording gap layer 27 to create a magnetic path. On the recording gap layer 27 and the photoresist layers 28, 30, and 32, a top yoke-cum-top pole (hereinafter, referred to as a top pole) 33 made of magnetic material for the recording head such as permalloy is selectively formed. The top pole 33 has a contact with the bottom pole 26 through the opening 27a to be magnetically coupled to each other. The recording gap layer 27 and the bottom pole 26 are etched to about 0.5 μm by ion milling using the top pole 33 as a mask. After that, an overcoat layer 34 made of alumina or the like is formed on the top pole 33 and thus the head core part 20 is completed. The part including the bottom pole 26, the recording gap layer 27, coils 29 and 31, and the top pole 33 corresponds to an example of the "magnetic head element for writing" in the invention.

A wafer on which the head core part is thus formed is divided into

elements by dicing or the like, thereby forming the magnetic head slider body 10 as shown in Fig. 4. For example, the magnetic head slider body 10 is subjected to polishing process to form an air bearing surface 10a including one end face of the substrate 11 and one end face of the head core part 20. The air bearing surface 10a is lapped so as to be smooth.

The air bearing surface 10a is selectively etched so as to have a U shape including a region in which the head core part 20 is formed and to create a negative-pressure-generating groove 10b for making the magnetic head taking off from a recording medium. The negative-pressure-generating groove 10b is formed to generate airflow between the magnetic head slider and a disk when the recording medium is rotated. At that occasion, the pressure inside the negative-pressure-generating groove is lower than the outside pressure.

As illustrated in Fig. 5, a mask 41 made of organic material is formed on the region in which the head core part 20 is formed on the air bearing surface 10a and on a bottom region, which is close to the above-mentioned region, of the negative-pressure-generating groove 10b. Specifically, photoresist as organic material is applied by spin coating and subjected to a photolithographic process. In another alternative, a mask-shaped resist film may be adhered. Although the mask 41 can be made of metal material, the resist is more preferable. This is because the mask 41 can be formed more easily using the resist. The mask forming process corresponds to an example of the step of forming a mask "only in the region where the head core part is formed" in the invention.

As illustrated in Fig. 6, a protective film 42 made of DLC having the thickness of about 5 to 10 nm, preferably, 6 to 8 nm is deposited through CVD (Chemical Vapor Deposition) or the like so as to cover the exposed air bearing surface 10a of the magnetic head slider body 10. After that, protruded parts 42a made of DLC having the height of about 5 to 15 nm, preferably, 8 to 12 nm, and more preferably 10 nm are formed through, for example, photolithography and CVD. DLC is a kind of a synthetic diamond thin film.

As illustrated in Fig. 7, the mask 41 is dissolved and removed by using a mixture for peeling the resist, which is made of organic solvent such as acetone, thereby peeling off the protective film 42 on the mask 41. The magnetic head slider 1 of the embodiment is thus completed.

The magnetic head slider 1 manufactured in such a manner can be applied to a magnetic disk apparatus of a ramp load type (or load-unload type) as shown in Fig. 8.

As shown in Fig. 8, the magnetic disk apparatus has the magnetic head slider 1 according to the embodiment. The head slider 1 is placed so as to face the surface of a magnetic disk 50 as a recording medium. The magnetic disk apparatus usually has a plurality of magnetic disks and a magnetic head slider is provided for each of the surfaces of each magnetic disk. In Fig. 8, only one magnetic head slider and one magnetic disk are shown and the rest is omitted. The magnetic disk 50 is rotated by a spindle motor 51. The magnetic head slider is held by an end portion 62q of a suspension 62 whose other end portion 62p is attached to a drive arm 61.

The magnetic disk apparatus also has a carriage unit 70 for positioning the magnetic head slider 1 onto the track in the magnetic disk 50, at the side of the axis of the drive arm 61. The carriage unit 70 comprises a shaft 71, a carriage 72 which swings about the shaft 71, and an actuator 73 such as a voice coil motor. The actuator 73 drives the carriage 72 to allow it to swing about the shaft 71, so that the magnetic head 100 can travel in the radial direction of the magnetic disk 50 (direction shown by the arrow A in Fig. 8). Further, the magnetic disk apparatus is provided with a suspension holder 80 for holding the suspension 62 outside of the magnetic disk 50 when the magnetic disk apparatus is not operative.

In the magnetic disk apparatus having such a construction, generally, information is recorded and reproduced in the following manner. When the magnetic disk apparatus is not operative, the suspension 62 is held by the suspension holder 80 and the magnetic head slider 1 is positioned in the region outside the magnetic disk 50. When the magnetic disk apparatus is operative, the disk 50 is rotated and the actuator 73 drives to move the magnetic head slider 1 above the disk 50. Such a driving method is called a ramp load method. Between the magnetic head slider 1 and the disk 50, airflow generates from the end face side opposite to the other end face side where the head core part 20 is formed toward the outer end face side where the head core part 20 is formed so that a lift is created. As a result, the magnetic head slider 1 travels relatively to the disk 50 while holding a very small space by balancing the lift with the pressing force by the suspension 62. In such a state, by feeding electric

current to the coils 29 and 31 of the head core part 20, a magnetic flux for writing is generated and information is recorded on the magnetic disk 50. A sense current is fed to the MR film 24 and the magnetic flux from the magnetic disk 50 is detected, thereby reading the information recorded on the magnetic disk 50.

Fig. 9A schematically shows the relation between the head core part 20 and the disk 50 when the magnetic disk apparatus including the magnetic head slider 1 is operative. Fig. 9B schematically shows the relation between the head core part 102 (refer to Fig. 10) and the disk 50 when the magnetic disk apparatus including the magnetic head slider of the related art is operative. As shown in Figs. 9A and 9B, in the case of the magnetic head slider 1 of the embodiment, a distance L_1 between the head core part 20 and the disk 50 is shorter than that in the case of the magnetic head slider of the related art by the thickness L_2 of the protective film. This is because the protective film 42 is not formed in the region where the head core part 20 is formed on the air bearing surface 10a. Accordingly, the width of the magnetic flux which is generated from the head core part 20 and reaches the surface of the disk 50 is narrowed, and the density of the magnetic flux reaching the surface of the disk 50 becomes higher. As a result, information can be recorded on the disk 50 at higher density. The width of the magnetic flux which is generated from the disk surface and reaches the head core part 20 is narrower, and the intensity of the magnetic field near the head core part 20 is higher. A reproduction output is therefore larger and subtle signals magnetically recorded on the disk can be

read.

According to the embodiment as described above, the protective film 41 is formed by using the mask 41 only on the region except for the region where the head core part 20 is formed, of the air bearing surface 10a. The distance L_1 between the head core part 20 and the disk 50 can be consequently made shorter than that of the magnetic head slider in which the protective film is formed on the whole air bearing surface including the region where the head core part 20 is formed. In the magnetic disk apparatus having the magnetic head slider 1 of the embodiment, therefore, the head core part 20 can be brought close to the magnetic disk 50, so that magnetic information can be recorded onto the magnetic disk 50 with a subtle magnetic flux and a subtle magnetic signal recorded on the disk 50 can be reproduced. That is, the surface recording density of the magnetic disk apparatus is improved.

Since the MR film 24 is made of Ni-Mn alloy having excellent corrosion resistance, even though the protective film 42 is not formed in the head core part forming region of the air bearing surface 10a, there is very little fear that the MR film 24 corrodes.

Although the invention has been described above through the foregoing embodiment, the invention is not limited to the embodiment but can be variously modified. For example, although the protective film 42 is formed in the region except for the head core part forming region and its neighborhood to protect about 90 percent of the air bearing surface 10a in the foregoing embodiment, it is sufficient to prevent the head core part

forming region of the air bearing surface 10a from being covered with the protective film 42. For example, the protective film may cover only the region from the end on the side opposite to the side where the head core part 20 is formed in the air bearing surface 10a to the center of the air bearing surface 10a.

Further, although the protective film 42 has the protruded parts 42a in the embodiment, the protruded parts may not be provided for the protective film 42 for the following reason. In the ramp load type magnetic disk apparatus, the magnetic head slider 1 is not in contact with the disk 50 when the apparatus is not operative. Therefore, it is unnecessary to prevent adsorption between the magnetic head slider 1 and the disk 50 by the protruded parts 42a.

In the embodiment, although the magnetic head slider 1 is used for the magnetic disk apparatus employing the ramp load method, the magnetic head slider 1 can be also used for one employing the CSS method.

Although the head core part 20 is formed on one of the ends of the U-shaped air bearing surface 10a, the head core part 20 may be formed on both ends. Further, it is also possible to selectively provide a pad having the height which is about the depth of the groove in the center region of the negative-pressure-generating groove 10b and to form the head core part 20 on the pad.

Although the magnetic head slider 1 has the composite thin film magnetic head in the above embodiment, the invention can be also applied to a magnetic head slider having an inductive magnetic transducer

dedicated for writing or an inductive magnetic transducer for both recording and reproduction. Further, the invention can be applied to a magnetic head slider having the structure in which the stacking order of the element for writing and the element for reading in the case of Fig. 3 is reversed.

According to the magnetic head slider, the method of manufacturing the magnetic head slider, or the magnetic disk apparatus, the protective film is selectively formed in a region, other than the region where the head core part is formed, on the surface of the magnetic head slider body, the surface being to face a recording medium. Consequently, the distance between the head core part and the recording medium is shorter than that in the magnetic head slider of the related art in which the protective film is formed on the whole surface of the magnetic head slider body, the surface being to face the recording medium. Thus, the surface recording density in the magnetic recording and reproduction can be improved.

According to the magnetic head slider or the magnetic disk apparatus, the magnetoresistive element has a magnetoresistive film containing at least nickel and manganese. Consequently, even if the protective film is not formed in the region where the head core part is formed on the surface of the magnetic head slider body, the surface being to face a recording medium, there is very little fear that the magnetoresistive film corrodes.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to

be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:



1. A magnetic head slider comprising:

a magnetic head slider body in which a head core part including at least either a magnetic head element for writing or a magnetic head element for reading is formed; and

a protective film selectively formed in a region, other than a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face a recording medium.

2. A magnetic head slider according to claim 1, wherein the protective film is formed on the whole surface except for the region where the head core part is formed.

3. A magnetic head slider according to claim 2, wherein the protective film contains diamond-like carbon.

4. A magnetic head slider according to claim 3, wherein the magnetic head element for reading is a magnetoresistive element.

5. A magnetic head slider according to claim 4, wherein the magnetoresistive element has a magnetoresistive film containing at least nickel and manganese.

6. A method of manufacturing a magnetic head slider, comprising:

a step of fabricating a magnetic head slider body by forming a head core part including at least either a magnetic head element for writing or a magnetic head element for reading, on a substrate;

a step of forming a mask at least in a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face a recording medium;

a step of forming a protective film so as to cover the surface of the magnetic head slider body, the surface being to face the recording medium; and

a step of removing the mask and the protective film on the mask.

7. A method of manufacturing a magnetic head slider according to claim 6, wherein the mask is formed only in the region where the head core part is formed, on the surface being to face the recording medium.

8. A method of manufacturing a magnetic head slider according to claim 7, wherein the protective film contains diamond-like carbon.

9. A method of manufacturing a magnetic head slider according to claim 8, wherein the magnetic head element for reading is a magnetoresistive element.



10. A method of manufacturing a magnetic head slider according to

claim 9, wherein the magnetoresistive element has a magnetoresistive film containing at least nickel and manganese .

11. A method of manufacturing a magnetic head slider according to claim 7, wherein the mask is made of organic material.

12. A method of manufacturing a magnetic head slider according to claim 7, wherein the mask is made of metal material.

13. A magnetic disk apparatus comprising a magnetic head slider and a recording medium which are disposed so as to face each other,

wherein the magnetic head slider includes:

a magnetic head slider body in which a head core part including at least either a magnetic head element for writing or a magnetic head element for reading is formed; and

a protective film selectively formed in a region, other than a region where the head core part is formed, on a surface of the magnetic head slider body, the surface being to face the recording medium.

14. A magnetic disk apparatus according to claim 13, wherein the protective film is formed on the whole surface other than the region where the head core part is formed.



15. A magnetic disk apparatus according to claim 14, wherein the

protective film contains diamond-like carbon.

16. A magnetic disk apparatus according to claim 14, wherein the magnetic head element for reading is a magnetoresistive element.

17. A magnetic disk apparatus according to claim 16, wherein the magnetoresistive element has a magnetoresistive film containing at least nickel and manganese.

