Description

BACKGROUND OF THE INVENTION

This invention relates to a structure for use in magnetic induction recording comprising a substrate, a film of recording media formed on said substrate and a protective layer formed above said film. The invention especially relates to thin film magnetic recording media and more specifically to magnetic media covered with material which prevents corrosion, improves wear resistance, and reduces the head to media dynamic and static friction coefficients. The invention also relates to a method for manufacturing a magnetic data storage device for use in magnetic induction recording comprising the steps of forming a film of magnetic recording media on a substrate and vacuum depositing a protective layer over said magnetic recording media.

Metallic magnetic thin film disks used in memory applications typically comprise a substrate material which is coated with a magnetic alloy film which serves as the recording medium. Typically, the recording medium used in such disks is a cobalt-based alloy such as Co-Ni, Co-Cr, Co-Ni-Cr, Co-Pt or Co-Ni-Pt which is deposited by vacuum sputtering as discussed by J. K. Howard in "Thin Films For Magnetic Recording Technology: A Review", published in Journal of Vacuum Science & Technology, in January, 1986, incorporated herein by reference. Other prior art recording media comprises a Co-P or Co-Ni-P film deposited by chemical plating as discussed by Tu Chen et al. in "Microstructure and Magnetic Properties of Electroless Co-P Thin Films Grown on an Aluminum Base Disk Substrate", published in the Journal of Applied Physics in March, 1978, and Y. Suganuma et al. in "Production Process and High Density Recording Characteristics of Plated Disks", published in IEEE Transactions on Magnetics in November, 1982, also incorporated herein by reference. Several problems are encountered in using unprotected metallic thin film recording media. For example, unprotected metallic thin films tend to corrode, particularly under high humidity conditions. Further, such films have very little resistance to wear caused by frequent contact with the recording head.

To prevent these problems, it is known in the art of recording technology that overcoating thin film magnetic recording media with a hard protective layer such as a carbon or SiO_2 layer improves the wear resistance of the recording media and also provides some corrosion protection to the magnetic film in a low humidity and low temperature environment. Carbon overcoatings for magnetic disks are described by F. K. King in "Datapoint Thin Film Media", published in IEEE Transactions on Magnetics in July, 1981, and Japanese Patent Application 58140/77 filed May 18, 1977 by Hinata et al., incorporated herein by reference. It is possible, in principle, to increase the corrosion protection by increasing the thickness of the carbon or SiO_2 overcoat. However, the maximum thickness of the overcoat that is tolerable for high performance disk media is about 50 nm to permit the read-write head to fly close to the media. Of importance, the electrical performance of the disk is improved as the overcoat is made even thinner. The decrease in overcoat thickness decreases the "effective flying height" of the head on the media (i.e. the gap between the surface of the head and the magnetic layer), thereby improving the signal to noise ratio (S/N), resolution, and overwrite characteristics of the recording media. Unfortunately, if the carbon or SiO_2 overcoat thickness is less than 50 nm, the overcoat does not provide sufficient corrosion protection for the magnetic media.

JP-A-60-258727 discloses a structure comprising a substrate, a magnetic recording medium, a protective layer and a solid vacuum-deposited lubricating layer. The lubricating layer is formed by hydrocarbon plasma polymerization. JP-A-60-258727 suggests that the protective layer can be at least one of the following: a non-magnetic metal such as Rh, Cr or Ni-P, an oxide such as SiO_2, Al_2O_3, TiO_2 and ZrO_2, a carbon such as graphite or diamond, a carbide such as SiC, WC, TiC, NbC and B_4C, or a nitride such as CrN, TiN, NbN and ZrN. JP-A-60-258727 emphasizes the necessity of covering the protective layer with a vacuum-deposited solid lubricant. Further, we have found that at least some of the oxides such as Al_2O_3 and SiO_2 without the vacuum-deposited solid lubricant gave bad results.

JP-A-58-019739 is similar to JP-A-60-258727 except that JP-A-58-019739 recommends using molybdenum disulfide and tungsten disulfide as the solid lubricant and pertains to a magnetic tape. It is reported that without such a solid lubricant, poor results are achieved (see the table in JP-A-58-019739). In stark contrast to the teachings of JP-A-58-019739 and JP-A-60-258727, it is unnecessary to apply the solid lubricating films required by JP-A-58-019739 and JP-A-60-258727 on a thin film oxide constructed in accordance with the present invention to achieve excellent results and surprisingly low friction.

To improve the corrosion protection of the magnetic media provided by carbon, it is known in the art to deposit a thin chromium layer between the magnetic thin film media and the overcoat layer. In this multilayer overcoat structure, the chromium layer provides enhanced corrosion resistance while the carbon overcoat provides good wear resistance. However, in order to have effective corrosion resistance as well as

good wear resistance provided by the carbon-chromium multilayer structure, the total overcoat thickness must be greater than 50 nm, which is not desirable for a high performance disk.

As mentioned earlier, the overcoat must not only protect the magnetic film from corrosion, but it must also protect the magnetic film from wear. A further requirement is that the static and dynamic friction coefficients between the read-write head and the overcoat must remain low over a large number of start/stop cycles. (The static friction coefficient is the ratio of lateral force to the normal loading force on the head as the disk starts to rotate. The dynamic friction coefficient is the ratio of the lateral force to the normal loading force after the disk has started to rotate.) If the static friction coefficient between the head and the overcoat material are too high (greater than 1.0), a small motor used in the drive will have difficulty starting rotation of the disk from a stationary position, and if a large motor drives the disk, the motor may cause the head to break off from the head suspension. In addition, if the static and dynamic friction coefficients are too high, mechanical contact between the read-write head and the disk will cause excessive wear in the overcoat and eventually a head crash.

When the disk is rotating in the drive, the head "flies" at a typical distance of about 125 nm to 375 nm above the disk. When the drive is turned off, the head comes into physical contact with the disk. Since the drive is likely to be repeatedly turned on and off during its lifetime, the overcoat must protect the magnetic film from wear, and at the same time, the static and dynamic friction coefficients between the head and the overcoat must remain low after repeated start/stop cycles. It has been demonstrated that even though hard carbon and SiO_2 overcoats resist wear well, their static and dynamic friction coefficients increase dramatically after repeated start/stop cycles.

Because of the above-described mechanical and corrosion problems, it would be desirable to coat a magnetic disk with an overcoat material which would improve corrosion protection of the magnetic film without being excessively thick and at the same time exhibit good wear resistance and consistently low static and dynamic friction coefficients.

SUMMARY

The structure according to our invention is characterized in that said protective layer comprises vacuum deposited ZrO_2 and a stabilizer wherein said protective layer is the uppermost vacuum deposited layer on said structure and is free of other vacuum deposited solid lubricants. The magnetic recording media can be any suitable media, such as a Co-Pt, Co-Ni-Cr, Co-Ni-Pt, Co-Cr, Co-Ni, Co-Cr-Pt, or other cobalt-based alloy deposited by sputtering or plating, or Co-P or Co-Ni-P deposited by a chemical plating process. In addition, the magnetic recording media can also be an iron-based alloy. We have found that a thin layer of the zirconium oxide greatly inhibits corrosion in such films and provides good wear resistance and a low static friction coefficient even after repeated start/stop cycles.

Preferably, the layer of zirconium oxide, is formed by sputtering. In one embodiment, the sputtering target used to provide the ZrO_2 layer comprises a solid solution including ZrO_2 and a stabilizer such as Y_2O_3, CaO, MgO or any of a number of other stabilizers.

In one embodiment, an intermediate layer of material is provided between the ZrO_2 layer and the magnetic media. Of importance, the intermediate layer adheres strongly to both the ZrO_2 layer and the media. We have discovered that by providing the intermediate layer, the disk wear resistance is enhanced. In addition, the tendency of the static and dynamic friction coefficients to increase after repeated start/stop cycles is reduced by the presence of the intermediate layer. The reason for this is that without the intermediate layer, the stress applied to the bond between the ZrO_2 and media by the friction force of the read-write head against the disk may cause the ZrO_2 layer to peel and blister after prolonged repeated start/stop cycles if the bonding between the ZrO_2 and magnetic media is not sufficiently strong. The peeling can cause asperities on the media surface which further increase static and dynamic friction between the head and disk, and therefore increase wear. The peeling also causes entrapment of debris (comprised mainly of the overcoat material) between the head and media surface, which further increases static and dynamic friction. This can eventually cause a head crash or a catastrophic failure. By providing the intermediate layer, which exhibits strong adhesion to both the ZrO_2 layer and the media, peeling and blistering can be substantially avoided, and the tendency of the static and dynamic friction coefficients to increase as a function of the number of start/stop cycles can be reduced. In an embodiment including a ZrO_2 overcoat, the intermediate layer typically comprises chromium, zirconium, hafnium, titanium, tantalum, tungsten or an alloy thereof.

It is noted that an intermediate layer as described above can also be used in conjunction with overcoats other than only ZrO_2. For example, in one embodiment, an intermediate layer as described above is provided between the disk media and a hard protective layer also comprising the boride, nitride, or carbide

of hafnium, zirconium, tantalum or titanium. In another embodiment, the hard protective layer comprises the oxide of tantalum, titanium, or hafnium. As described below, the identity of the intermediate layer depends in part on the identity of the material selected for the protective overcoat.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the results of a static and dynamic friction test performed on a disk coated with ZrO_2 in which the disk was repeatedly rotationally displaced to a maximum rotation of 300 rev/min from a stationary position (i.e. a start/stop cycle test);

Figures 2a and 2b illustrate the results of a static and dynamic friction test performed on a pair of conventional carbon coated disks in which the disks were repeatedly rotationally displaced from a stationary position:

Figure 3 illustrates the variation in the static friction coefficient as function of the number of start/stop cycles for a number of disks having various overcoats;

Figure 4 illustrates the increase, as a result of repeated start/stop cycles, in dynamic and static friction coefficients between a read-write head and a disk in which ZrO_2 is formed directly on the media; and

Figure 5 illustrates the increase in dynamic and static friction coefficients between a read-write head and a disk coated with a chromium layer which in turn is coated with ZrO_2.

DETAILED DESCRIPTION

A hard disk constructed in accordance with one embodiment of our invention is fabricated by plating an NiP layer onto an aluminum substrate. A film of magnetic recording media is then formed on the NiP layer. The film can be Co-Ni-Pt, Co-Ni, Co-Pt, Co-Ni-Cr, Co-Cr, Co-Cr-Pt, or any other appropriate cobalt-based alloy deposited by any appropriate process such as vacuum evaporation, sputtering, electroplating, or electroless plating. In addition, Co-P, Co-Ni-P, iron-based or other alloys can also be used. The recording media is typically about 70 nm thick or less.

A ZrO_2 layer is then sputtered onto the recording media, typically to a thickness between 10 and 60 nm. The ZrO_2 is typically formed by RF diode or RF magnetron sputtering. During RF sputtering, the gas pressure in the sputtering apparatus is typically 0.4 to 4 Pa of argon. The ZrO_2 film can also be formed by electron beam evaporation, chemical vapor deposition, or plasma assisted chemical vapor deposition Advantageously, the ZrO_2 layer inhibits corrosion in the magnetic recording media. This is illustrated in Table 1 below which compares corrosion in ZrO_2 coated films with corrosion in films coated with carbon instead of ZrO_2. The data of Table 1 was taken by placing four disks in an environment of 90 to 95% relative humidity and 80 °C for seven days. The first disk in Table I included a Co-Ni-Pt media covered with 25 nm thick carbon, the second disk included a chromium layer covered with Co-Ni media covered with 25 nm thick carbon, the third disk included Co-Ni-Pt media covered with 20 nm thick ZrO_2, and the fourth disk included Co-Ni-Pt covered with 20 nm thick chromium covered with 20 nm thick ZrO_2. Corrosion was evaluated by visual tests, magnetic tests and glide height tests.

Corrosion on disks can be visibly detected since Co-based films corrode to form cobalt oxide or cobalt hydroxide, and thus appear blue compared to the original gold or brown color.

The magnetic test includes testing for an increase in the number of defect sites on the surface of the disk after exposure to the above-described environment. An increase in the number of defect sites occurs because the magnetic media corrodes and becomes nonmagnetic, hence the recording head is not able to record data at the site of corrosion. A typical uncorroded disk contains less than 10 defects per surface. If the defect count in one of the disks of Table 1 increased by 20 defects from an initial defect count, it was considered to have failed.

A film failed the glide height test if a read-write head suspended 125 nm above the disk surface struck a mound of residual material from corrosion while the disk rotated. As can be seen, the films covered with ZrO_2 showed no sign of corrosion after five days in the above-described environment, while the films which were not covered by ZrO_2 became unusable due to corrosion. After seven days, both the ZrO_2 covered films passed the visual, magnetic and glide height tests although one of the films exhibited a slight increase in the number of defect sites on the seventh day (possibly due to some corrosion on areas without the ZrO_2overcoat e.g., because of dust particles resting on the media surfase prior to ZrO_2 deposition).

As shown in Table 1, ZrO_2 and ZrO_2-chromium overcoated disks show extremely high corrosion resistance even though the thickness of the ZrO_2 overcoat is less than 25 nm and the thickness of the ZrO_2-chromium overcoat is less than 50 nm. These results show that the ZrO_2 overcoat alone or ZrO_2-chromium overcoat is a superior corrosion barrier for high performance disks compared to a carbon

overcoat. (As described in greater detail below, the chromium layer also causes the ZrO_2 layer to adhere more strongly to the underlying media and enhances disk reliability.)

TABLE 1

DAY: TEST		70 nm Thick Co-Ni-Pt Alloy Covered With 25 nm Thick Carbon	100 nm Thick Cr Covered with 70 nm Thick Co-Ni Covered with 25 nm Thick Carbon	70 nm Thick Co-Ni-Pt Covered with 20 nm Thick ZrO_2	70 nm Thick Co-Ni-Pt Covered with 20 nm Thick Cr Covered With 20 nm Thick ZrO_2
1	Visual Magnetic Glide Height	Clear No change Passed	Tiny spot No change Passed	Clear No change Passed	Clear No change Passed
2	Visual Magnetic Glide height	Blue spots Increased/reject Failed	Blue spots Increased Failed	Clear No change Passed	Clear No change Passed
3	Visual Magnetic Glide height	Blue spots Rejected Failed	Blue spots Rejected Failed	Clear No change Passed	Clear No change Passed
5	Visual Magnetic Glide height	All blue Rejected Failed		Clear No change Passed	Clear No change Passed
7	Visual Magnetic Glide height	All blue Rejected Failed		Clear Slight increase Passed	Clear No change Passed

When the ZrO_2 is sputtered onto the magnetic recording media, in one embodiment, the sputtering target includes a stabilizer such as Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2, Sc_2O_3, or other rare earth oxide. In addition, a number of other stabilizers are also appropriate. (The stablizer prevents phase transformation of the ZrO_2 to the monoclinic phase, thus making the ZrO_2 sputtering target and the resulting film less brittle.) A typical sputtering target used in accordance with our invention is 1 to 20% stabilizer by weight (preferably 4 to 15%) and the remainder ZrO_2. (If the stablizer concentration in the film is too high, its strength is degraded. The film composition depends on the sputtering target composition.) In another embodiment of our invention, the ZrO_2 sputtering target contains a film including more than 20% stabilizer.

In yet other embodiments of our invention, the sputtering target includes Al_2O_3 as well as a stablizer to further enhance the hardness of the sputtered protective overcoat. Of importance, both Al_2O_3 and the stablizer prevent the sputtering target from fracturing. In one embodiment, the target includes about 12% Y_2O_3, 5 to 20% Al_2O_3, and the remainder ZrO_2. Films having this composition are particularly suitable for disks used with thin film read-write heads made of titanium carbide. In addition, other strength enhancing oxides such as CeO_2 or TiO_2 can also be included in the sputtering target and hence protective overcoat.

We have discovered that aside from being corrosion resistant, the ZrO_2 layer also exhibits superior mechanical qualities. Figure 1 illustrates the results of a static friction test for a magnetic disk including an overcoat of 88% ZrO_2 and 12% Y_2O_3 stabilizer formed directly on Co-Ni-Pt magnetic media by RF sputtering while Figures 2a and 2b illustrate corresponding results for two magnetic disks coated with diamond-like carbon instead of the ZrO_2 and the stablizer. The disks of Figures 2a and 2b have slightly different surface textures on the microscopic level. The data in these figures was taken by repetitively starting to rotate the disks from a stationary position to a maximum rotational velocity of 300 rev/min then stopping the disks and measuring the lateral force exerted on the read-write head caused by static friction between the read-write head and the carbon coated and ZrO_2 coated disks. During these tests, each read-write head was pushed against the corresponding disk with a force of 15 grams applied in a direction perpendicular to the disk surface. The read-write head was positioned at an approximately fixed distance from the center of the disk before the disk started to rotate. As the disk started to rotate, the lateral force exerted on the head by the static friction force was measured by a transducer attached to the suspension of the head. A signal from the transducer was then recorded on the strip chart shown in Figures 1, 2a, and 2b. The static friction coefficient is approximately proportional to the distance from the center of the waveforms of Figures 1, 2a, and 2b to the envelope 8 surrounding the waveforms. In the strip charts of Figures 1, 2a,

and 2b, each start/stop cycle caused one upwardly extending spike such as spike 10 and two downwardly extending spikes such as spikes 12. The static friction coefficient μs equals the static friction force exerted on the read-write head and dividing it by the normal head loading force, which in this case is 15 grams. As can be seen, the static friction force exerted on the read-write head by the carbon coated film increased over time much more rapidly than the static friction force exerted on the read-write head by the ZrO_2 coated film.

Referring to Figure 1, a static friction coefficient of less than 0.3 was consistently measured when performing about 45 start/stop cycle tests on the ZrO_2 coated disk In contrast, in Figure 2a, an initial static friction coefficient of about 0.4 was measured during the first pass of the static friction test on the carbon-coated disk, which then rapidly increased to about 0.8 by the eighth pass. In Figure 2b, an initial static friction coefficient of 0.2 was measured, increasing to about 0.8 by the eleventh pass. (The read-write head in Figures 1, 2a and 2b was displaced in both positive and negative directions. This is because of oscillatory motion of the read-write head during the start/stop tests.)

Figure 3 illustrates the change in static friction coefficient versus the number of start/stop cycles for four disks including a conventional diamond-like carbon coating formed directly on a Co-Ni-Pt film (curves 1 to 4), and for two disks each with a coating including 88% ZrO_2 and 12% Y_2O_3 formed directly on a Co-Ni-Pt film (curves 5 and 6). (The data illustrated in Figures 3 to 5 was taken by performing start/stop tests in the same manner as to the tests described above in relation to Figures 1, 2a and 2b.) The surface roughness textures of the disks of curves 1 to 4 were different, thus causing the static friction characteristics of these disks to differ. Specifically, the surface of the NiP layer on the aluminum substrate of the disk of curve 1 (and therefore the surface of the carbon coating of the disk of curve 1) was smoother than the surfaces of the disks of curves 2 to 4 and, therefore, the disk of curve 1 exhibited greater static friction than the disks of curves 2 to 4. In addition, the surface roughness texture of the disks of curves 5 and 6, although differing slightly, had a roughness texture similar to the surface roughness textures of the disks of curves 2 to 4.

As can be seen, the static friction coefficient for a first disk coated with ZrO_2 started at 0.32 and increased to 0.39 after 100 cycles (curve 5). A second disk coated with ZrO_2 initially exhibited a static friction coefficient of 0.39 which increased to 0.40 after 20 cycles (curve 6). In contrast, the carbon-coated disk corresponding to curve 1 initially exhibited a static friction coefficient of about 0.49 which increased to a value greater than 1.4 after only 5 starts. The other films coated with carbon initially exhibited static friction coefficients of 0.30, 0.35, and 0.40, respectively, which increased to 0.90, 0.60 and 0.80, after 45, 10, and 20 cycles, respectively (curves 2, 3, and 4). Accordingly, it is seen that films coated with ZrO_2 exhibited static friction coefficients which remained at lower values over time than carbon-coated Co-Ni-Pt films.

The wear resistance of ZrO_2 overcoated disks is superior to carbon overcoated disks. We have discovered that a ZrO_2 overcoated disk without additional lubrication can last more than 10,000 fast start/stop cycles while a diamond like carbon overcoated disk without additional lubrication tends to wear out in less than 5,000 fast start/stop cycles. (In a fast start/stop cycle test, the disk is repeatedly rotated from a stationary position to a rotational velocity of about 3600 rev/min so that the disk head flies above the media surface. This is in contrast to the start/stop cycles discussed in relation to Figures 1, 2a and 2b, in which the disk is rotated to a maximum velocity of 300 rev/min and the read-write head never flies. A fast start/stop cycle test, which closely simulates actual use, causes less wear than a 300 rev/min start/stop cycle test.) Application of lubrication increases the wear resistance of both ZrO_2 and carbon coated disks such that they continue to function properly after more than 50,000 fast start/stop cycles. (Typical lubricants used to enhance the wear resistance of magnetic disks are discussed in the above-incorporated Suganuma paper.) However, after a large number of start/stop cycles (e.g. more than 10,000 fast cycles), the static friction coefficient of a disk coated with ZrO_2 and a lubricant generally remains lower than the static friction coefficient of a disk coated with carbon and a lubricant.

As mentioned above, although a disk including magnetic media covered with ZrO_2 exhibits superior mechanical qualities, the control of reliability of such a disk can be enhanced by sputtering an intermediate layer of material onto the recording media prior to forming the ZrO_2 layer. The intermediate layer typically comprises chromium, zirconium, hafnium, titanium, tantalum, tungsten, or any alloy thereof. Advantageously, these materials alloy easily with magnetic recording media such as Co-Ni-Pt and therefore strongly adhere to the media. In addition, each of these materials forms a strong bond to ZrO_2. In one embodiment, the intermediate layer is between 1 and 10 nm, and preferably between 3 and 4 nm. The intermediate material is thin to minimize the total thickness of the layers above the magnetic media, but thick enough to adequately cover the media.

When the intermediate layer comprises chromium, it is typically desirable to use a high voltage biased sputtering target. This ensures that the sputtered chromium particles have a high velocity when they strike the recording media, and thus the resulting chromium layer adheres strongly to the underlying media.

As mentioned above, the intermediate layer enhances control of the reliability of the magnetic disk. Even though a ZrO_2 protective film formed directly on magnetic media provides excellent protection against wear, we have discovered that after repeated start/stop cycles (e.g. greater than 100 cycles in a 300 rev/min start/stop cycle test), the ZrO_2 film formed directly on magnetic media may blister and peel because of stress introduced at the bond between the ZrO_2 and the media by the friction force exerted by the read-write head on the ZrO_2. This results in entrapment of debris (comprised mainly of the overcoat material) between the head and media surface. This further increases the static and dynamic friction coefficients and the rate of wear finally causes a head crash or a catastrophic failure in the media. By providing the intermediate layer, the peeling and blistering problems are avoided, the abovementioned increase in static and dynamic friction is reduced, and catastrophic media failure or a head crash is prevented.

Figure 4 illustrates the gradual increase in static and dynamic friction as a result of repeated 300 rev/min start/stop cycles between a read-write head and an 88% ZrO_2 12% Y_2O_3 layer formed by RF magnetron sputtering directly on Co-Ni-Pt recording media. As was the case in Figures 1, 2a, and 2b, the distance from the center of the waveform in Figure 4 to the waveform envelope is proportional to the static friction coefficient. The distance from the waveform center to the lower envelope of dark region 14 of the waveform is proportional to the dynamic friction coefficient. (Dark region 14 represents read/write head displacement caused by dynamic friction.) As can be seen, the static and dynamic friction coefficients are initially 0.2 and 0.12, respectively, but increase to 0.6 and 0.4, respectively, after about 231 start/stop cycles.

Figure 5 illustrates the static and dynamic friction coefficients as a result of repeated 300 rev/min start/stop cycles between a read-write head and an 88% ZrO_2 12% Y_2O_3 layer formed under the same sputtering conditions as the ZrO_2/Y_2O_3 film of Figure 4 but with the addition of a chromium layer formed between the ZrO_2 and the Co-Ni-Pt recording media. As can be seen, the static and dynamic friction coefficients are initially 0.22 and 0.21, respectively, but increase to only 0.4 and 0.3, respectively, after 1008 start/stop cycles. Thus, it is seen that the intermediate layer further enhances the superior qualities of a ZrO_2 protective overcoat on a magnetic disk.

It is noted that the intermediate layer can be used to enhance protective overcoats other than ZrO_2 overcoats. For example, when the oxide of hafnium, tantalum, or titanium is used as a hard protective overcoat on a magnetic disk, chromium, zirconium, hafnium, tantalum, titanium, tungsten, or an alloy thereof can be used as the intermediate layer. In such an embodiment, the hard protective layer is about 20 nm thick and the intermediate layer is about 1 to 10 nm thick.

In yet another embodiment of the invention, if a plurality of layers are formed on magnetic recording media, an intermediate layer is formed between the media and the bottom layer of the plurality of layers to enhance adhesion between the plurality of layers and the media.

For example, an intermediate layer in accordance with our invention can be formed in a magnetic disk using other multilayer structures.

In addition, instead of using an NiP plated aluminum substrate, other substrates can be used, e.g. glass or ceramic substrates. Also, in some embodiments of our invention, a ZrO_2 layer is applied to a floppy disk. A ZrO_2 layer in accordance with our invention can also be formed on magnetic tape or a recording drum as well. Accordingly, all such changes come within the invention.

Claims

1. Structure for use in magnetic induction recording comprising a substrate, a film of recording media formed on said substrate, and a protective layer formed above said film: said structure characterized in that said protective layer comprises vacuum deposited ZrO_2 and a stabilizer, wherein said protective layer is the uppermost vacuum deposited layer on said structure and is free of other vacuum deposited solid lubricants.

2. Structure of claim 1, further characterized in that said protective layer also comprises one or more materials selected from the group consisting of CeO_2, Al_2O_3 and as the stabilizer Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 and/or Sc_2O_3.

3. Structure of claim 1 further characterized in that said protective layer has a thickness greater than or equal to 5 nm.

4. Structure of claim 1 further characterized in that said protective layer has a thickness between 10 and 60 nm.

As mentioned above, the intermediate layer enhances control of the reliability of the magnetic disk. Even though a ZrO_2 protective film formed directly on magnetic media provides excellent protection against wear, we have discovered that after repeated start/stop cycles (e.g. greater than 100 cycles in a 300 rev/min start/stop cycle test), the ZrO_2 film formed directly on magnetic media may blister and peel because of stress introduced at the bond between the ZrO_2 and the media by the friction force exerted by the read-write head on the ZrO_2. This results in entrapment of debris (comprised mainly of the overcoat material) between the head and media surface. This further increases the static and dynamic friction coefficients and the rate of wear finally causes a head crash or a catastrophic failure in the media. By providing the intermediate layer, the peeling and blistering problems are avoided, the abovementioned increase in static and dynamic friction is reduced, and catastrophic media failure or a head crash is prevented.

Figure 4 illustrates the gradual increase in static and dynamic friction as a result of repeated 300 rev/min start/stop cycles between a read-write head and an 88% ZrO_2 12% Y_2O_3 layer formed by RF magnetron sputtering directly on Co-Ni-Pt recording media. As was the case in Figures 1, 2a, and 2b, the distance from the center of the waveform in Figure 4 to the waveform envelope is proportional to the static friction coefficient. The distance from the waveform center to the lower envelope of dark region 14 of the waveform is proportional to the dynamic friction coefficient. (Dark region 14 represents read/write head displacement caused by dynamic friction.) As can be seen, the static and dynamic friction coefficients are initially 0.2 and 0.12, respectively, but increase to 0.6 and 0.4, respectively, after about 231 start/stop cycles.

Figure 5 illustrates the static and dynamic friction coefficients as a result of repeated 300 rev/min start/stop cycles between a read-write head and an 88% ZrO_2 12% Y_2O_3 layer formed under the same sputtering conditions as the ZrO_2/Y_2O_3 film of Figure 4 but with the addition of a chromium layer formed between the ZrO_2 and the Co-Ni-Pt recording media. As can be seen, the static and dynamic friction coefficients are initially 0.22 and 0.21, respectively, but increase to only 0.4 and 0.3, respectively, after 1008 start/stop cycles. Thus, it is seen that the intermediate layer further enhances the superior qualities of a ZrO_2 protective overcoat on a magnetic disk.

It is noted that the intermediate layer can be used to enhance protective overcoats other than ZrO_2 overcoats. For example, when the oxide of hafnium, tantalum, or titanium is used as a hard protective overcoat on a magnetic disk, chromium, zirconium, hafnium, tantalum, titanium, tungsten, or an alloy thereof can be used as the intermediate layer. In such an embodiment, the hard protective layer is about 20 nm thick and the intermediate layer is about 1 to 10 nm thick.

In yet another embodiment of the invention, if a plurality of layers are formed on magnetic recording media, an intermediate layer is formed between the media and the bottom layer of the plurality of layers to enhance adhesion between the plurality of layers and the media.

For example, an intermediate layer in accordance with our invention can be formed in a magnetic disk using other multilayer structures.

In addition, instead of using an NiP plated aluminum substrate, other substrates can be used, e.g. glass or ceramic substrates. Also, in some embodiments of our invention, a ZrO_2 layer is applied to a floppy disk. A ZrO_2 layer in accordance with our invention can also be formed on magnetic tape or a recording drum as well. Accordingly, all such changes come within the invention.

Claims

1. Structure for use in magnetic induction recording comprising a substrate, a film of recording media formed on said substrate, and a protective layer formed above said film: said structure characterized in that said protective layer comprises vacuum deposited ZrO_2 and a stabilizer, wherein said protective layer is the uppermost vacuum deposited layer on said structure and is free of other vacuum deposited solid lubricants.

2. Structure of claim 1, further characterized in that said protective layer also comprises one or more materials selected from the group consisting of CeO_2, Al_2O_3 and as the stabilizer Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 and/or Sc_2O_3.

3. Structure of claim 1 further characterized in that said protective layer has a thickness greater than or equal to 5 nm.

4. Structure of claim 1 further characterized in that said protective layer has a thickness between 10 and 60 nm.

5. Structure of claim 1, characterized in that said protective layer also comprises a strength enhancing oxide.

6. Structure of claim 1 further characterized by including a lubricant applied to said protective layer.

7. Structure of claim 1, characterized by further comprising an intermediate layer formed between said film of recording media and said protective layer, said intermediate layer adhering strongly to said media and said protective layer.

8. Structure of claim 7, characterized in that said intermediate layer comprises a material selected from the group consisting of chromium, titanium, tantalum, zirconium, tungsten and hafnium.

9. Structure of any of the preceding claims, characterized in that said protective layer is formed by sputtering.

10. Structure of claim 1 characterized in that said protective layer comprises Al_2O_3, the concentration of said Al_2O_3 in said protective layer being between 5 and 20%.

11. Method for manufacturing a magnetic data storage device for use in magnetic induction recording comprising the steps of forming a film of magnetic recording media on a substrate and vacuum depositing a protective layer over said magnetic recording media, said method characterized in that said protective layer comprises ZrO_2 and a stabilizer and is free of other vacuum deposited solid lubricants, said protective layer being the uppermost vacuum deposited layer on said device.

12. Method of claim 11 further characterized in that said film comprises one or more materials from the group consisting of Al_2O_3, CeO_2 and as the stabilizer Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 and/or Sc_2O_3.

13. Method of claim 11 further characterized by comprising the step of forming an intermediate layer between said media and said protective layer, said intermediate layer enhancing adhesion between said protective layer and the rest of said magnetic data storage device.

14. Method of claim 13 characterized in that said intermediate layer comprises a material selected from the group consisting of chromium, titanium, tantalum, zirconium and tungsten.

15. Method of claims 11 to 14 characterized in that said protective layer is formed by sputtering.

16. Method of claim 11 characterized in that said protective layer comprises Al_2O_3, the concentration of said Al_2O_3 being between 5 and 20%.

17. Method of claim 11 characterized in that said protective layer also comprises a strength enhancing oxide.

Patentansprüche

1. Aufbau zur Anwendung in einem magnetischen Induktionsaufzeichnungsträger, bestehend aus einem Substrat, einem Film eines Aufzeichnungsmediums, welcher auf dem Substrat gebildet ist, und einer Schutzschicht, die auf dem Film gebildet ist, dadurch gekennzeichnet, daß die Schutzschicht vakuumbeschichtetes ZrO_2 und einen Stabilisator aufweist, wobei diese Schutzschicht die oberste vakuumbeschichtete Lage auf der Struktur darstellt, welche frei von anderen vakuumbeschichteten festen Gleitmitteln ist.

2. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß die Schutzschicht ferner einen oder mehrere Stoffe aufweist, die aus der Gruppe ausgewählt sind, welche aus CeO_2, Al_2O_3 und als Stabilisator Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 und/oder Sc_2O_3 bestehen.

3. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß die Schutzschicht eine Dicke aufweist, welche gleich oder größer als 5 nm ist.

4. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß die Schutzschicht eine Dicke zwischen 10 und 60 nm aufweist.

5. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß die Schutzschicht ein die Stärke erhöhendes Oxid aufweist.

6. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß dieser ein Gleitmittel umfaßt, welches auf der Schutzschicht aufgetragen ist.

7. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß dieser ferner eine Zwischenschicht aufweist, welche zwischen dem Film des Aufzeichnngsmediums und der Schutzschicht gebildet ist, wobei diese Zwischenschicht stark an das Aufzeichnungsmedium und der Schutzschicht haftet.

8. Aufbau nach Anspruch 7, dadurch gekennzeichnet, daß die Zwischenschicht ein Material aufweist, welches aus der Gruppe ausgewählt ist, die aus Chrom, Titan, Tantal, Zirkon, Wolfram und Hafnium besteht.

9. Aufbau nach einem der voranstehenden Ansprüche, dadurch gekennzeichnet, daß die Schutzschicht durch Zerstäubung gebildet ist.

10. Aufbau nach Anspruch 1, dadurch gekennzeichnet, daß die Schutzschicht Al_2O_3 aufweist, wobei die Konzentration des Al_2O_3 in der Schutzschicht zwischen 5 und 20% beträgt.

11. Verfahren zur Herstellung eines magnetischen Datenspeichers zur Verwendung für die magnetische Induktionsaufzeichnung mit Verfahrensschritten zur Bildung eines Films aus einem magnetischen Aufzeichnungsmedium auf einem Substrat und einer Vakuumablagerung einer Schutzschicht über das magnetische Aufzeichnungsmedium, dadurch gekennzeichnet, daß die Schutzschicht ZrO_2 und einen Stabilisator aufweist und frei von anderen vakuumbeschichteten festen Gleitmitteln ist, wobei diese Schutzschicht die oberste vakuumbeschichtete Lage auf dem Aufbau darstellt.

12. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß der Film einen oder mehrere Stoffe aufweist, die aus der Gruppe ausgewählt sind, welche aus Al_2O_3, CeO_2 und als Stabilisator Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 und/oder Sc_2O_3 besteht.

13. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß eine Zwischenschicht zwischen dem Medium und der Schutzschicht gebildet wird, wobei diese Zwischenschicht die Haftung zwischen der Schutzschicht und dem Rest des magnetischen Datenspeichers verstärkt.

14. Verfahren nach Anspruch 13, dadurch gekennzeichnet, daß die Zwischenschicht ein Material aufweist, welches aus der Gruppe ausgewählt ist, die aus Chrom, Titan, Tantal, Zirkon und Wolfram besteht.

15. Verfahren nach den Ansprüchen 11 bis 14, dadurch gekennzeichnet, daß die Schutzschicht durch Aufstäuben gebildet wird.

16. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß die Schutzschicht Al_2O_3 aufweist, wobei die Konzentration des Al_2O_3 zwischen 5 und 20% liegt.

17. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß die Schutzschicht ein die Stärke erhöhendes Oxid aufweist.

Revendications

1. Structure pour utilisation dans un enregistrement par induction magnétique comprenant un substrat, un film de support d'enregistrement formé sur ledit substrat et une couche protectrice formée au-dessus dudit film, ladite structure étant caractérisée en ce que ladite couche protectrice comprend du ZrO_2 déposé sous vide et un stabilisateur, dans laquelle la couche protectrice est la couche déposée sous vide la plus extérieure de ladite structure et est libre d'autres lubrifiants solides déposés sous vide.

* C L M S *

2. Structure selon la revendication 1, caractérisée, de plus, en ce que ladite couche protectrice comprend aussi un ou plusieurs des matériaux sélectionnés parmi le groupe constitué de CeO_2, Al_2O_3, et comme stabilisateur Y_2O_3, LaO, CaO, ThO_2, CeO_3, MgO, HfO_2 et/ou Sc_2O_3.

3. Structure selon la revendication 1, caractérisée, de plus, en ce que ladite couche protectrice a une épaisseur supérieure ou égale à 5 nm.

4. Structure selon la revendication 1, caractérisée, de plus, en ce que ladite couche protectrice a une épaisseur comprise entre 10 et 60 nm.

5. Structure selon la revendication 1, caractérisée, de plus, en ce que ladite couche protectrice comprend aussi un oxyde améliorant la résistance.

6. Structure selon la revendication 1, caractérisée, de plus, par l'inclusion d'un lubrifiant appliqué à ladite couche protectrice.

7. Structure selon la revendication 1, caractérisée en comprenant, de plus, une couche intermédiaire formée entre ledit film de support d'enregistrement et ladite couche protectrice, ladite couche intermédiaire adhérant très fortement audit support et à ladite couche protectrice.

8. Structure selon la revendication 7, caractérisée en ce que ladite couche intermédiaire comprend un matériau sélectionné parmi le groupe constitué de chrome, de titane, de tantale, de zirconium, de tungstène et d'hafnium.

9. Structure selon l'une quelconque des revendications précédentes, caractérisée en ce que ladite couche protectrice est formée par pulvérisation cathodique.

10. Structure selon la revendication 1, caractérisée en ce que ladite couche protectrice comprend du Al_2O_3, la concentration dudit Al_2O_3 dans ladite couche protectrice étant comprise entre 5 et 20 %.

11. Procédé de fabrication d'un dispositif magnétique de stockage de données pour utilisation dans un enregistrement par induction magnétique, comprenant les étapes de formation d'un film de support d'enregistrement magnétique sur un substrat et de dépôt sous vide d'une couche protectrice sur ledit support d'enregistrement magnétique, ledit procédé étant caractérisé en ce que ladite couche protectrice comprend du ZrO_2 et un stabilisateur, et est libre d'autres lubrifiants solides déposés sous vide, ladite couche protectrice étant la couche déposée sous vide la plus extérieure dudit dispositif.

12. Procédé selon la revendication 11, caractérisé, de plus, en ce que ledit film comprend un ou plusieurs des matériaux parmi le groupe constitué de Al_2O_3, CeO_2, et comme stabilisateur Y_2O_3, LaO, CaO, ThO_2, CeO_2, MgO, HfO_2 et/ou Sc_2O_3.

13. Procédé selon la revendication 11, caractérisé, de plus, en ce qu'il comprend l'étape de formation d'une couche intermédiaire entre ledit support et ladite couche protectrice, ladite couche intermédiaire améliorant l'adhérence entre ladite couche protectrice et le reste dudit dispositif magnétique de stockage de données.

14. Procédé selon la revendication 13, caractérisé en ce que ladite couche intermédiaire comprend un matériau sélectionné parmi le groupe constitué de chrome, de titane, de tantale, de zirconium et de tungstène.

15. Procédé selon les revendications 11 à 14, caractérisé en ce que ladite couche protectrice est formée par pulvérisation cathodique.

16. Procédé selon la revendication 11, caractérisé en ce que ladite couche protectrice comprend du Al_2O_3, la concentration dudit Al_2O_3 étant comprise entre 5 et 20 %.

17. Procédé selon la revendication 11, caractérisé en ce que ladite couche protectrice comprend aussi un oxyde améliorant la résistance.