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MAGNETIC RECORDING MEDIUM

This invention relates to a magnetic recording medium comprising a substrate with a magnetic layer formed thereon, for use in a magnetic recording tape, disk, or the like.

Metal film media called continuous media that use a ferromagnetic material such as a Co-based magnetic alloy have recently been used as magnetic recording media. However, such magnetic materials as are currently used, if formed into a thin film, do not inherently possess strong in-plane magnetic anisotropy suitable for longitudinal recording. Therefore, a non-magnetic underlayer is provided on a non-magnetic substrate, and a magnetic layer is provided on the underlayer, so as to obtain in-plane magnetic anisotropy. In these magnetic media, however, the characteristics of the magnetic layer vary with the film configuration and the status of non-magnetic underlayer. Therefore, the magnetic layer must be fabricated as carefully as the underlayer, which complicates the control of the process for fabricating the underlayer film.

On the other hand, it is known that exchange coupling between magnetized fine grains increases the magnetization transitional width and causes medium noise. In order to increase the recording density, it is important to suppress medium noise. JA PUPA 1-232516 and JA PUPA 1-23517 disclose techniques for reducing medium noise wherein a new alloy of quaternary or higher degree is prepared by adding an element or elements (C, P, Bi, and so forth) to a Co-based magnetic ternary alloy, and a film of the obtained alloy is fabricated on a substrate. However, because coupling between magnetic alloy grains remains in the magnetic layer, medium noise is not suppressed sufficiently. Further, the coercivity obtained may be less than 1000 (Oe). In addition, a Cr underlayer is still required.

Accordingly, the invention provides a magnetic recording medium comprising a substrate and a magnetic layer formed thereupon, said

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magnetic layer comprising a mixture of a magnetic material and a non-magnetic compound, said magnetic material being Co-based, Fe-based, or FeCo-based and said non-magnetic compound being an oxide or a nitride.

Such a magnetic recording medium is suitable for longitudinal recording, with low medium noise and high coercivity, for example in magnetic disks for computer disk drives, or in magnetic tapes. The magnetic recording medium using a Co-based, Fe-based, or FeCo-based magnetic alloy for its magnetic layer together with a non-magnetic compound selected from a group consisting of oxides and nitrides has magnetic characteristics suitable for longitudinal magnetic recording, without using an underlayer. This medium has a simple structure because an underlayer is not necessary and the manufacturing process is consequently simplified.

In the prior art the magnetic anisotropy of a single film composed of magnetic alloys does not preferentially grow in the in-plane direction. Therefore, a non-magnetic underlayer has hitherto been provided in order to obtain in-plane anisotropy of the magnetic layer. However, in a mixture of a non-magnetic compound film and a magnetic material film, the non-magnetic compound, which is not fused into the magnetic material, can exist in the magnetic layer, and thereby incline the magnetic anisotropy direction of the magnetic layer in a direction parallel to the medium surface without an underlayer. This inclination is assumed to be caused by a non-magnetic compound changing the crystal growth orientation of the magnetic alloy and inducing an anisotropy suitable for in-plane magnetic recording. It is also noted that a non-magnetic compound causes high coercivity and reduces medium noise because it isolates and makes magnetic alloy grains finer.

In a preferred embodiment, the magnetic layer is formed directly on the substrate (ie without an underlayer), although an underlayer may be desired to adjust the magnetic characteristics of the magnetic layer. In general, a protective layer will be formed on the magnetic layer.

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Examples of suitable Co-based magnetic materials for the magnetic layer are ternary alloys such as CoNiCr, CoNiPt, CoCrPt, and CoCrTa. Examples of suitable non-magnetic compounds for the magnetic layer are silicon oxide, zirconium oxide, tantalum oxide, silicon nitride, boron nitride, titanium nitride, and aluminum nitride.

Overall estimation of the magnetic characteristics, read/write characteristics, and reliability indicates that preferred compositions for Co-based magnetic alloys can be expressed by the following general formulas:

$$Co_{(1-x-y)}Ni_{(x)}Cr_{(y)}$$

where x = 0.2 to 0.4 and y = 0.05 to 0.1;

$$Co_{(1-x-y)}Ni_{(x)}Pt_{(y)}$$

where x = 0.2 to 0.4 and y = 0.01 to 0.2;

$$Co_{(1-x-y)}Cr_{(x)}Pt_{(y)}$$

where x = 0.1 to 0.3 and y = 0.01 to 0.2, and

$$Co_{(1-x-y)}Cr_{(x)}Ta_{(y)}$$

where x = 0.1 to 0.3 and y =0.01 to 0.05, (see A. Terada: Journal of the Magnetics Society of Japan Vol. 13, No. 3, 493(1989))

The volume percentage of non-magnetic compound in the entire volume of mixed magnetic alloy and non-magnetic compound (hereafter called the mixed volume percentage) is preferably not less than about 2% and not more than about 30%. The maximum effect is obtained at about 5%.

Even if the Co-based alloy is binary (for example, CoNi, CoPd, CoCr, and CoPt), quaternary (for example, CoNiCrV and CoNiCrCu), or of

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higher degree, the coupling status among grains in the Co-based alloy film is substantially the same as in the ternary alloy. Therefore, the same effects are expected to be caused by mixing a non-magnetic compound with these alloys. For the same reason, substantially the same effects are expected even when the magnetic material to be mixed with the non-magnetic compound is replaced by an Fe-based alloy (for example, -Fe_2O_3 or FeNi), or an FeCo-based alloy (for example, FeCoCr).

Preferably the magnetic layer is formed by depositing a magnetic material film and a non-magnetic compound film simultaneously, both films being deposited by evaporation and/or sputtering. The important factor in whatever technique is used is the need to obtain the mixture of a magnetic alloy and a non-magnetic compound in a magnetic film.

Thus the invention also provides a method for producing a magnetic recording medium comprising the steps of:

providing a substrate; and

forming a magnetic layer consisting of a mixture of a magnetic material and a non-magnetic compound by depositing both simultaneously onto said substrate, the deposition process being performed by evaporation and/or sputtering.

An embodiment of the invention will now be described by way of example with reference to the following drawings:

Fig. 1 is a cross-sectional view of a magnetic recording medium according to the invention.

Fig. 2 is a cross-sectional view of a conventional magnetic recording medium without a non-magnetic underlayer, which was prepared for the purpose of comparison.

Fig. 3 is a graph showing the relations between the thickness and coercivity of a magnetic recording medium as shown in Figure 1 and of a conventional magnetic recording medium.

Fig. 4 is a graph showing the relations between the mixed volume percentage of the non-magnetic compound and the coercivity of the magnetic recording medium.

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Fig. 5 is a graph showing the recording characteristics (signal-to-noise ratios) of a magnetic recording medium as shown in Figure 1 and of a conventional magnetic recording medium.

Fig. 1 shows the structure of a magnetic recording medium with a magnetic layer 2 formed on a non-magnetic glass substrate 1. By using DC magnetron sputtering for $Co_{75.5}Cr_{12.5}Pt_{11.5}$ (argon back pressure: 5 mTorr) and RF magnetron sputtering for compound SiO_2, a magnetic alloy film and a non-magnetic film are fabricated at the same time. The mixed volume percentage of SiO_2 is set at 5%. On the magnetic layer 2 a ZrO_2 film (30 nm thick) was formed as a non-magnetic protective layer 3 by RF sputtering. Further, a medium using SiN instead of SiO_2 and a medium using ZrO_2 were prepared in the same conditions (composition of magnetic alloy, mixed-volume percentage, and so on) as for SiO_2. In addition, for comparison purposes, a medium having a Co-based magnetic alloy layer 4 was prepared by forming a film consisting of $Co_{70}Cr_{14}Pt_{16}$ on a non-magnetic glass substrate 1, the other conditions being identical with those in the foregoing cases (Fig. 2).

Fig. 3 shows the results obtained when the coercivity was measured by varying the thickness of the magnetic layer 2 or 4. It can be understood from the figure that the magnetic characteristics are significantly improved throughout the entire thickness range by admixture of a non-magnetic compound. In particular, the improvement is remarkable in the thinner range. In Fig. 3, the values of coercivity measured for a medium using BN (instead of) SiO_2, a medium using TaO_2, a medium using TiN, and a medium using AlN are also shown, although with only one point for each medium. The conditions for preparing these media (composition of magnetic alloy, mixed volume percentage, and so on) were the same as for the medium using SiO_2. In addition, a medium was prepared by using the binary alloy $Co_{80}Ni_{20}$ as a magnetic alloy and SiO_2 as a non-magnetic compound. DC magnetron sputtering was performed for a film of the former and RF sputtering for the latter. The other conditions (mixed volume percentage, etc.) were the same as for SiO_2.

Fig. 3 also shows the result of measuring the coercivity for this medium, although with only one point.

Next, the magnitudes of the torque in the in-plane direction were measured for the sample whose magnetic layer is a mixed film of $Co_{75.5}Cr_{12.9}Pt_{11.6}$ and SiO_2 (mixed volume percentage: 5 vol%) and the sample whose magnetic layer consists of $Co_{75.5}Cr_{12.9}Pt_{11.6}$ alone. The thickness of the magnetic layer was 85 nm for both samples. The results of the measurement are shown in Table 1. It can be understood from the table that admixture of SiO_2 gives a greater in-plane anisotropy.

TABLE 1

Sample	Torque(x 10^5 dyne-cm)
$Co_{75.5}Cr_{12.9}Pt_{11.6}$ + SiO2	9.75
$Co_{75.5}Cr_{12.9}Pt_{11.6}$	4.52

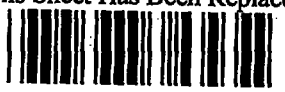
Next, in order to find the relation between the mixed volume percentage of the non-magnetic compound and the coercivity of the medium, an experiment was performed on media having the structure shown in Fig. 1, with the substrate 1 being a glass substrate, the magnetic layer 2 being 43 nm thick, and the protective layer 3 being a 30-nm-thick ZrO_2 film. The result is shown in Fig. 4. In the figure, black circles indicate data obtained from a medium in which the non-magnetic compound in the magnetic layer 2 is SiO_2, while black diamond shapes indicate data obtained from a medium whose non-magnetic compound is SiN. It can be understood from the figure that excellent characteristics are obtained when the mixed volume percentage of the non-magnetic compound is not less than about 2% and not more than about 30%. In particular, when the mixed volume percentage is about 5 vol%, a coercivity of as much as about 2000 (Oe) is obtained.

Finally, an experiment was performed on each sample (disk) shown in Table 1 to find the relation between write density and medium noise. The rotational speed of the disk was 3600 rpm, the recording current was 100 mAp-p, and a thin film head was used as a recording head. The recording characteristic (signal-to-noise ratio) was measured by varying the number of flux changes per millimeter. It can be understood from the figure that the sample including a non-magnetic compound shows an excellent S/N characteristic.

As explained above, disk with appropriate mixtures of magnetic and non-magnetic compunds have excellent magnetic characteristics suitable for longitudinal recording without an underlayer. However, such an underlayer may be interposed between a substrate and a magnetic layer for the purpose of adjusting the magnetic characteristic obtained by mixing a magnetic alloy and a non-magnetic compound in the magnetic layer, and the scope of the invention extends to such media.

Note that the protective layer is not limited to the ZrO_2 film described above, but may be a film of any single material such as amorphous carbon or SiO_2 that is known to be suitable for protection of a magnetic film.

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CLAIMS

1. A magnetic recording medium comprising a substrate (1) and a magnetic layer (2) formed thereupon, said magnetic layer comprising a mixture of a magnetic material and a non-magnetic compound, said magnetic material being Co-based, Fe-based, or FeCo-based and said non-magnetic compound being an oxide or a nitride.

2. The magnetic recording medium of claim 1 wherein the volume percentage of said non-magnetic compound in said mixture is between 2% and 30%.

3. The magnetic recording medium of any preceding claim, wherein said magnetic layer is formed directly on said substrate.

4. The magnetic recording medium of any preceding claim, further comprising a protective layer (3) formed on said magnetic layer.

5. The magnetic recording medium of any preceding claim, wherein said non-magnetic compound contains at least one of silicon oxide, zirconium oxide, tantalum oxide, silicon nitride, boron nitride, titanium nitride, and aluminum nitride.

6. The magnetic recording medium of any preceding claim, wherein said magnetic material is a ternary alloy selected from a group consisting of CoNiCr, CoNiPt, CoPtCr, and CoCrTa.

7. The magnetic recording medium of claim 6, wherein the composition of said Co-based ternary magnetic alloy is expressed by $Co_{(1-x-y)}Ni_{(x)}Cr_{(y)}$, where $0.2<=x<=0.4$ and $0.05<=y<=0.1$.

8. The magnetic recording medium of claim 6, wherein the composition of said Co based ternary magnetic alloy is expressed by $Co_{(1-x-y)}Ni_{(x)}Pt_{(y)}$, where $0.2<=x<=0.4$ and $0.01<=y<=0.2$.



9. The magnetic recording medium of claim 6, wherein the composition of said Co-based ternary magnetic alloy is expressed by $Co_{(1-x-y)}Cr_{(x)}Pt_{(y)}$, where $0.1<=x<=0.3$ and $0.01<=y<=0.2$.

10. The magnetic recording medium of claim 6, wherein the composition of said Co-based ternary magnetic alloy is expressed by $Co_{(1-x-y)}Cr_{(x)}Ta_{(y)}$, where $0.1<=x<=0.3$ and $0.01<=y<=0.05$.

11. The magnetic recording medium of any preceding claim, wherein said magnetic layer is formed by depositing a magnetic material film and a non-magnetic compound film simultaneously, both films being deposited by evaporation and/or sputtering.

12. A magnetic recording disk including the magnetic recording medium of any preceding claim.

13. A method for producing a magnetic recording medium comprising the steps of:

providing a substrate (1); and

forming a magnetic layer (2) consisting of a mixture of a magnetic material and a non-magnetic compound by depositing both simultaneously onto said substrate, the deposition process being performed by evaporation and/or sputtering.

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