

Title of the Invention

Magnetic Recording Medium and Manufacturing Process thereof

5 Field of the Invention

This invention relates to a magnetic recording medium for use in the memory of an information-related instrument and manufacturing process thereof.

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Prior Art

With the emergence of a highly information-oriented society, a greater demand has risen recently for the memory of an information-related
15 instrument, including computers, to attain a higher recording density. There has been an improvement in the performance of a recording head to read in and out a magnetic recording medium, and the recording density of a medium in a magnetic recording device.

20 Dense recording in the medium assumes an increase in a ratio of reproduction signals to medium noises when recorded signals are reproduced.

In general, a magnetic recording medium comprises a non-magnetic
25 substrate, a non-magnetic ground layer, a magnetic recording layer, and a protecting layer. Magnetic recording layer records information. Protecting layer protects the magnetic recording layer from the abrasion caused by slide with a magnetic head. A non-magnetic ground layer, a magnetic recording layer, and a protecting layer are formed consecutively
30 on the non-magnetic substrate, including aluminum alloy and glass, one on top of another. Non-magnetic ground layer controls the crystal orientations of the magnetic recording layer that is deposited thereon. Figure 1 is a typical chart showing layer constitution of a conventional magnetic recording medium. Ground layer 2 is usually formed on a
35 non-magnetic substrate 1 such as glass and aluminum alloy plated with Ni-P. Material used for the ground layer 2 includes a chromium and a chromium

alloy thin film. Further, magnetic recording layer 3 formed on the ground layer 2 employs a magnetic thin film composed of a cobalt and chromium alloy doped with several kinds of elements. And, a thin film mainly composed of carbon is used for the uppermost protecting layer 4.

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Layered structure of the medium is usually formed with a sputtering technique. Because sputtering technique facilitates the control of layer characteristics and enables the manufacture of a high-quality thin film.

10 Magnetic recording layer 3 formed with the sputtering technique on the ground layer 2 is a polycrystal consisting of minute grains of cobalt alloy. In the same way as the magnetic recording layer 3, the ground layer 2 is a polycrystal consisting of minute grains of chromium metal or chromium alloy. Magnetic recording layer 3 grows epitaxially on the ground layer
15 2 with crystallographic orientation of magnetic recording layer 3 coordinated with that of ground layer 2. Magnetic recording layer, on the one hand, is usually made of a cobalt and chromium alloy doped with element such as platinum and tantalum that has larger metal bond radius than cobalt. Hence, it is usual that the cobalt alloy has higher lattice constant than
20 pure cobalt metal. On the other hand, the ground layer was once made of pure chromium metal for its excellent crystallinity and low cost. However, pure chromium metal has smaller lattice constant than cobalt alloy used in a magnetic recording layer, affecting the epitaxial growth thereof adversely. Then, it is a common practice of late to use chromium alloy doped
25 with element, including molybdenum, tungsten, vanadium, and titanium, that have larger metal bond radius than chromium to give a ground layer. This enlarges the lattice constant of the ground layer crystal and facilitates the epitaxial growth of a magnetic recording layer on a ground layer. Further, Japanese Laid-Open Patent Publication No. 7-21543 and so
30 forth discloses a magnetic recording medium. Ground layer thereof has a layered structure of a chromium metal and a binary chromium alloy layer, enabling the potentiality for epitaxial growth to consist with required grain growth.

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Object of the Invention

At present, with the development of a magnetic recording medium with higher recording density, there has been a growing demand for increased SNR.

Magnetic recording layer is made of a polycrystal consisting of minute crystal grains of a cobalt alloy as mentioned earlier. In order to form a minute recording bit in the magnetic recording layer, it is desired that the crystal grain dimensions of the cobalt alloy in the magnetic recording layer be more minute and uniform. Achieving this requires control of the thin ground layer located under the magnetic recording layer in terms of a crystallographic property.

Pure chromium ground layer in a magnetic recording medium facilitates the formation of minute crystal grains in the magnetic recording layer. However, difference in the lattice spacing of pure chromium and cobalt alloy crystal set forth earlier provides no increased SNR. Magnetic recording medium with a chromium alloy ground layer, and magnetic recording medium with the layered ground layer consisting of a chromium metal and binary chromium alloy layers disclosed in Japanese Laid-Open Patent Publication No.7-21543 has the following problems. That is, a conventional magnetic recording medium has been successful in reducing the crystal grain dimensions of a magnetic recording layer to some extent. However, it has found difficulty sizing the crystal grains in a sufficiently uniform manner, leaving little room for an improvement in SNR.

And hence, an object of the present invention is to offer a new layer composition in a magnetic recording medium. Another object of the present invention is to offer a manufacturing process of the magnetic recording medium. New layer composition provides cobalt alloy crystal grains in a magnetic recording layer with more uniform diameters with other characteristics intact. This improves the SNR of the magnetic recording medium.

Means to Solve the Problems

The inventors have devoted themselves to the study to solve the problems
5 set forth earlier. Non-magnetic ground layer was double-layered. One of
the two layers closer to a substrate was made of pure chromium metal.
Further, the other of the two layers positioned closer to a magnetic
recording layer was made of chromium-molybdenum-tungsten ternary alloy.
The experiment has shown the possibility that the cobalt alloy magnetic
10 recording layer with more uniform crystal grain dimensions be formed on
the ground layer.

The present invention was performed in accordance with the findings.
The following describes the characteristics of a magnetic recording medium
15 of the present invention. Magnetic recording medium of the present
invention comprises a non-magnetic substrate, a non-magnetic ground
layer, a magnetic recording layer, and a protecting layer. Non-magnetic
ground layer and the magnetic recording layer are formed consecutively on
the non-magnetic substrate one on top of another. Non-magnetic ground layer
20 and the magnetic recording layer are formed with a sputtering technique.
Consecutively formed on those layers is the protecting layer with a
sputtering technique or a CVD technique. Thus, the magnetic recording
medium of the present invention has the layered structure of three thin
films or more. Non-magnetic ground layer has a layered structure consisting
25 of two non-magnetic metal layers of a different composition. In addition,
the non-magnetic metal layer closer to the substrate is made of pure
chromium. Non-magnetic metal layer closer to the magnetic recording layer
is made of chromium-molybdenum-tungsten ternary alloy.

30 Manufacturing process of the present invention comprises the steps of
forming at least a pure chromium ground layer, a ternary chromium alloy
ground layer consisting of chromium, molybdenum, and tungsten, and a
magnetic recording layer, and a protecting layer consecutively on a
non-magnetic substrate one on top of another. Pure chromium ground layer,
35 the ternary chromium alloy ground layer, and the magnetic recording layer
are formed with a sputtering technique. Protecting layer is formed with

a sputtering technique or a CVD technique. Thus, the magnetic recording medium with high SNR is manufactured.

Brief Description of The Drawings

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Figure 1 is a view in cross section of a conventional multi-layered magnetic recording medium.

Figure 2 is a view in cross section of a magnetic recording medium of the present invention referred to in an example.

Figure 3 is a diagram plotting SNR of a magnetic recording medium of the present invention referred to in an example against pure chromium layer thickness ratio in a ground layer consisting of a pure chromium and chromium alloy layers.

Preferred Embodiment of the Invention

Magnetic recording medium of the present invention has the double-layered non-magnetic ground layer. One of the two layers positioned closer to the substrate is made of pure chromium. The other of the two layers positioned closer to the magnetic recording layer is made of ternary alloy consisting of chromium, molybdenum, and tungsten. Thus, the magnetic recording medium of the present invention is characterized by its magnetic recording layer formed on the ground layer with the dimensions of cobalt alloy grains grown more uniformly.

Desirably the pure chromium layer, the closer one of the two layers to the substrate in the double-layered non-magnetic ground layer, has layer thickness not less than 20% and not more than 80% of the total thickness of the non-magnetic ground layer. Further desired is the total layer thickness of the non-magnetic ground layer not more than 20nm.

Furthermore desired is the ternary alloy layer consisting of chromium, molybdenum, and tungsten, the closer one of the two layers to the magnetic recording layer, to satisfy the following composition:

- (a) 5 to 30 at% molybdenum and tungsten;
- (b) 4 to 29 at% molybdenum;
- (c) 1 to 15 at% tungsten; and
- 5 (d) the balance chromium.

Grain dimensions of 12nm or less is suitable to achieve the recording densities 10 Gbit/in² or more. Preferred total layer thickness of 20nm or less in the ground layer satisfies the grain dimensions.

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Possibility to coordinate the lattice constant of the ground layer crystal with that of the recording layer crystal places a lower limit on the range of chromium-molybdenum-tungsten alloy. Deterioration in the crystallinity of a chromium matrix places an upper limit on the range of
15 cobalt-molybdenum-tungsten alloy. Experiment sets the appropriate total contents of molybdenum and tungsten for five to 30 at%. Each content of molybdenum and tungsten is determined appropriately so that the lattice constant of the chromium alloy crystal in the ground layer matches that of cobalt alloy crystal in the magnetic recording layer. Tungsten content,
20 however, is specified within 15 at %, since tungsten contents exceeding 15 at % cause the grains to enlarge. It is desired that the composition formulae set forth earlier be satisfied in terms of requirement for the coexistence of chromium, molybdenum, and tungsten.

25 Magnetic recording medium of the present invention is characterized by realizing minute and uniformly sized grains in the ground layer, thereby causing minute and uniformly sized grains to grow on those in the ground layer. Growing minute and uniformly sized crystal grains in the ground layer is affected neither by the kind nor the layer-forming
30 condition of the layer formed thereon. And hence, realizing minute and uniformly sized grains in the ground layer of the present invention causes those in the magnetic recording layer to grow effectively, provided that an epitaxial growth of the magnetic recording layer is allowed to proceed on the ground layer. Neither the chemical composition nor the constitution
35 of the magnetic recording layer is accordingly specified in the magnetic recording medium of the present invention.

Besides, an intermediate layer is sometimes formed between the non-magnetic ground layer and the magnetic recording layer to improve such a quality as magnetic recording density. Intermediate layer is made of a non-magnetic or a magnetic cobalt alloy. Minute and uniformly sized grains in the ground layer of the present invention helps grow those in the magnetic recording layer, provided that the intermediate layer and the magnetic recording layer is allowed to grow epitaxially on the ground layer and the intermediate layer respectively.

10 Example

The following describes the example of the present invention.

Figure 2 is a sectional view of a magnetic recording medium referred to in the example.

Magnetic recording medium of the example comprises an aluminum alloy substrate 10, a pure chromium ground layer 11, a chromium alloy ground layer 12, a cobalt alloy magnetic recording layer 13, and a carbon protecting layer 14. Pure chromium ground layer 11, the chromium alloy ground layer 12, the cobalt alloy magnetic recording layer 13, and the carbon protecting layer 14 are formed consecutively on a aluminum alloy substrate 10 one on top another with a DC magnetron sputtering technique. Aluminum alloy substrate 10 is textured circumferentially and plated with Ni-P. Magnetic layer 13 was made of cobalt alloy having the composition of cobalt-24chromium-10platinum-2boron (at%). It is confirmed that the layers formed have almost equal composition with the target used in the DC magnetron sputtering.

Substrate 10 has a doughnut-shaped outward appearance, an external circumference of 95mm, an internal circumference of 25mm, and a thickness of 1.0 mm. Carbon protecting layer 14 has a layer thickness of 8nm.

Even argon pressure of 5 mTorr was maintained in sputtering. Substrate 10 was heated at about 250 °C just before the formation of the ground layer 11.

Table 1 shows the result of the measurements concerning grain dimensions and grain dimensions variance in the cobalt magnetic recording layer. Five kinds of magnetic recording media referring to Example 1 and Comparative Example 1, 2, 3, and 4 were measured. Four kinds of magnetic recording media referring to Comparative Example 1, 2, 3, 4 have different ground layer constitution with each other. Even total thickness of 18 nm was maintained in the ground layer. Grain dimensions and the grain dimensions variance was calculated according to micrograph data measured with a TEM.

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Ground layer referring to the Comparative Example 1 is made of pure chromium. Cobalt alloy referring to Comparative Example 1 has the minimum grain dimensions and grain dimensions variance among five magnetic recording media. Conventional ground layer referring to Comparative Example 2 is single-layered and made of chromium-molybdenum alloy. Conventional ground layer referring to Comparative Example 3 is double-layered and consists of a pure chromium layer and a chromium-molybdenum alloy layer. Cobalt alloy referring to Comparative Example 2 and Comparative Example 3 has almost equal grain dimensions. Cobalt alloy referring to Comparative Example 2 and Comparative Example 3 has almost equal grain dimensions variance. Ground layer referring to Comparative Example 4 is single-layered and made of chromium-molybdenum-tungsten alloy. Cobalt alloy referring to Comparative Example 4 is almost equal to that referring to Comparative Example 2 and Comparative Example 3 in terms of grain dimensions variance. Cobalt alloy referring to Comparative Example 4 is larger than that referring to Comparative Example 2 and Comparative Example 3 in terms of grain dimensions, predicting difficulty in forming more minute recording bits in the magnetic recording layer.

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In contrast, the ground layer referring to Example 1 is double-layered and consists of a pure chromium layer and a chromium-molybdenum-tungsten alloy layer. Cobalt alloy referring to Example 1 is almost equal to that referring to Comparative Example 2 and Comparative Example 3 in terms of grain dimensions. Cobalt alloy referring to Example 1 is about 15% smaller than that referring to Comparative Example 2 and Comparative Example 3 in

grain dimensions. Cobalt alloy referring to Example 1 is about 15% smaller than that referring to Comparative Example 2 and Comparative Example 3 in terms of grain dimensions variance, And hence, it is anticipated that the double-layered ground layer referring to Example 1 gives excellent SNR.

Table 1

Cobalt Crystal Grain Dimensions and Variance Calculated According to Micrograph Data of TEM versus Ground Layer Constitution of Magnetic Recording Media

Basic Layer Constitution: Carbon Coating Layer/Co-24Cr-10Pt-2B Magnetic Recording Layer /Ground layer/Aluminum Substrate

Figure 3 is a diagram plotting SNR against pure chromium layer thickness ratio in a ground layer. Ground layer referred to herein has a double-layered structure consisting of a pure chromium layer and a chromium alloy layer.

Even total layer thickness of 18 nm was maintained in the ground layer. Spinning stand type tester was used for measuring SNR. SNR was measured at a linear density of 308 kfc/i with a GMR head. Varying electric powers at respective layer formation controlled thickness ratio of pure chromium layers to chromium alloy layers. Hence, layer formation has all the conditions in common except electric powers required to form a pure chromium layer and a chromium alloy layer. Layer thickness of a magnetic layer is adjusted so that the magnetic recording medium manufactured has a residual magnetization multiplied by magnetic layer thickness (Mrt) of 0.45 memu/cm². Layer thickness of a magnetic layer is in the range of 17 nm and 20 nm. Varying the product of residual magnetization by magnetic layer thickness (Mrt) affects a R/W characteristic, thereby making it difficult to evaluate the result brought by the example. Even product of residual magnetization by magnetic layer thickness (Mrt) was maintained to avoid the difficulty.

One magnetic recording medium measured has the ground layer of a multi-layered structure consisting of a pure chromium and a chromium-15molybdenum-5tungsten alloy layer. The other magnetic recording medium measured has the ground layer of a multi-layered structure consisting of a pure chromium and chromium-20molybdenum alloy layers. Findings reveal that forming the respective ground layers of a multi-layered structure provides an increase in SNR over single-layered ground layers represented in the diagram by points on a left and right ends. Magnetic recording medium with the ground layer consisting of a pure chromium and a chromium-molybdenum-tungsten alloy layer yields larger SNR than the one consisting of a pure chromium and a chromium-molybdenum alloy layer. This indicates that the former ground layer consisting of a pure chromium and a chromium-molybdenum-tungsten alloy layer provides an improvement in SNR over the latter one, the chromium-molybdenum-tungsten alloy layer improving SNR more effectively when it forms a multi-layered ground layer. Conventional magnetic recording medium with a single-layered ground layer consisting of chromium-20molybdenum is described by the mark $\diamond$ on a left end in the diagram. The magnetic recording medium is set for a reference and hereinafter referred to as ref. Use is made of the pure chromium layer thickness ratio that exhibits higher SNR than the ref. The magnetic recording medium with the ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers has a wider range in the pure chromium layer thickness ratio stated earlier than that consisting of a pure chromium and chromium-molybdenum alloy layers. This demonstrates that the ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers is superior to that consisting of a pure chromium and chromium-molybdenum alloy layers. This is ascribed to the effect that a multi-layered ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers has on the uniform formation of grain dimensions. Thickness ratio of pure chromium layers to chromium-molybdenum-tungsten alloy layers is maintained within the range that exhibits higher SNR than that of the ref. Pure chromium layer thickness ratio is maintained over the range 20% to 80% in the magnetic recording medium of the present invention. Magnetic recording medium with a single-layered pure chromium ground layer has minimum grain dimensions and grain dimensions variance as shown in Table 1. The

magnetic recording medium exhibits the poorest SNR among the sample media as shown by the point on the right end in the diagram. As mentioned earlier, the epitaxial growth of cobalt alloy on a pure chromium crystal is poor, since the lattice spacing of a pure chromium crystal is smaller
5 than that of a cobalt alloy crystal. This deteriorates the grain characteristics of a cobalt alloy magnetic layer.

Table 2 shows the variation of SNR and pulse width at half maximum (Pw 50) when the ground layer thickness is reduced. The Pw50 refers to
10 half-width of the solitary playback output waveform in R/W measurement. The Pw50 gives a criterion to determine magnetization reversal transition width. The smaller the Pw50, the higher the recording density. The narrower the magnetization reversal transition width is, the less the playback output signal interferes with each other on increasing the recording
15 density of the medium. Narrow magnetization reversal transition width enables the medium to have high recording density. Moreover, thickness ratio of 25 to 75 in terms of pure chromium layers to chromium alloy layers was maintained in magnetic recording media with a multi-layered ground layer referring to Comparative Example 7, 8 and Example 2, 3.

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Magnetic recording media referring to Comparative Example 5 and 6 have a single-layered chromium-molybdenum ground layer. Reducing the ground layer thickness of these media from 18nm to 13.5nm tends to improve both SNR and Pw50 to little purpose. Magnetic recording media referring to
25 Comparative Example 7 and 8 have a multi-layered ground layer consisting of a pure chromium and chromium-20molybdenum alloy layers. Reduced ground layer thickness in these media affects SNR adversely. It is a common knowledge that reducing ground layer thickness, on one hand, provides reduced grain dimensions in the ground layer, improving SNR and Pw50. On
30 the other hand, reducing a chromium and chromium alloy layers thickness worsens crystallizability in these layers, deteriorating SNR and Pw50. That is, equilibrium between the formation of minute grains and deterioration in crystallinity varies SNR and Pw50 on reducing ground layer thickness. Deducibly magnetic recording medium with the
35 single-layered chromium-molybdenum ground layer finds the equilibrium in favor of deterioration in crystallinity over the formation of minute grains,

providing no sufficient improvement in SNR and Pw50 on reducing ground layer thickness. The same deduction holds true for the magnetic recording medium with a multi-layered ground layer consisting of a pure chromium and chromium-molybdenum alloy layers.

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Magnetic recording media referring to Comparative Example 9 and 10 have a single-layered chromium-molybdenum-tungsten alloy ground layer. Magnetic recording media referring to Example 2 and 3 have a ground layer of a multi-layered structure consisting of a pure chromium and a chromium-molybdenum-tungsten alloy layer. Reducing ground layer thickness of these media from 18 nm to 13.5 nm, however, improves effectively SNR by 0.7 to 0.9dB and Pw50 by 0.2 nsec over the media referring to Comparative Example 5, 6, 7, and 8. It is deduced that the magnetic recording medium with the chromium-molybdenum-tungsten layer in the ground layer finds the equilibrium in favor of the formation of minute grains far over deterioration in crystallinity on reducing the layer thickness. Hence, use of chromium-molybdenum-tungsten alloy in a ground layer enables the ground layer to have smaller thickness without great deterioration in crystallinity. Thus, it is possible to manufacture a magnetic recording medium with minute grains, and excellent SNR and Pw50. In addition, comparison of the media referring to Comparative Example 10 and Example 3 indicates that a multi-layered ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers effectively improves SNR, even when the ground layer has reduced thickness.

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Table 2

Variation of SNR and Pw50 on Reducing Ground Layer Thickness

Basic Layer Constitution:

30 Carbon Protecting Layer/Co-24Cr-10Pt-2B Magnetic layer/Ground
Layer/Aluminum Substrate

As set forth earlier, a magnetic recording medium of the present invention has a multi-layered ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers. Multi-layered ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy

layers forms cobalt grains with uniform dimensions, thereby improving in SNR. Further, the multi-layered ground layer consisting of a pure chromium and chromium-molybdenum-tungsten alloy layers enables the ground layer to have reduced thickness with no loss in crystallinity. Reduced ground layer thickness facilitates the formation of minute grains in the ground layer, thereby enabling an improvement in SNR.

Advantageous Effect of the Invention

As mentioned above, the magnetic recording medium of the present invention has a double-layered non-magnetic ground layer. Non-magnetic ground layer consists of a pure chromium layer positioned closer to a substrate, and a chromium-molybdenum-tungsten ternary alloy layer positioned closer to a magnetic recording layer. Specifying thickness ratio of the two layers and the composition of chromium-molybdenum-tungsten alloy within an appropriate range forms cobalt alloy grains with uniform dimensions in the recording layer formed on the ground layer, thereby enabling an improvement in SNR of a magnetic recording medium.



Claims

1. A multi-layered magnetic recording medium of three thin films or
5 more comprising:

- (a) a non-magnetic substrate;
- (b) a non-magnetic ground layer;
- (c) a magnetic recording layer; and
- 10 (d) a protecting layer.

said non-magnetic ground layer, magnetic recording layer and
protecting layer being formed sequentially on said non-magnetic
substrate one on top of another, said non-magnetic ground layer and
15 magnetic recording layer being formed with a sputtering technique, said
protecting layer being formed with a sputtering technique or a CVD
technique, said non-magnetic ground layer being double-layered,
consisting of two non-magnetic metal layers of different composition, and
said two non-magnetic metal layers being a pure chromium layer positioned
20 closer to said substrate and a chromium-molybdenum-tungsten ternary alloy
layer positioned closer to said magnetic recording layer.

2. A magnetic recording medium as set forth in claim 1, wherein a pure
chromium layer has thickness from 20% to 80% of the total thickness of a
25 non-magnetic ground layer and said non-magnetic ground layer has total
thickness of 20 nm or less.

3. A magnetic recording medium as set forth in claim 1, wherein a
chromium-molybdenum-tungsten ternary alloy layer satisfies the following
30 composition:

- (a) 5 to 30 at% molybdenum and tungsten;
- (b) 4 to 29 at% molybdenum;
- (c) 1 to 15 at% tungsten; and
- 35 (d) the balance chromium.



4. A manufacturing process of a magnetic recording medium with a high SNR characteristic comprising the steps of:

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(a) forming at least a pure chromium ground layer, a chromium-molybdenum-tungsten ternary chromium alloy ground layer, and a magnetic recording layer sequentially on a non-magnetic substrate one on top of another with a sputtering technique; and

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(b) forming a protecting layer consecutively on said layers with a sputtering technique or a CVD technique.

5. A manufacturing process of a magnetic recording medium as set forth in claim 4, wherein a pure chromium ground layer has thickness from 20% to 80% of the total thickness of said pure chromium ground layer and a chromium alloy ground layer, and said total thickness is 20 nm or less.

6. A manufacturing process of a magnetic recording medium as set forth in claim 4, wherein a chromium-molybdenum-tungsten ternary alloy ground layer satisfies the following composition:

(a) 5 to 30 at% molybdenum and tungsten;

(b) 4 to 29 at% molybdenum;

25 (c) 1 to 15 at% tungsten; and

(d) the balance chromium.

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