

NICKEL-BASED ALLOY SPUTTERING TARGET AND NICKEL-BASED ALLOY LAYER

1. Field of the Invention

The present invention relates to a sputtering target and a material of a
5 magnetic recording medium, and particularly to a nickel-based alloy sputtering
target and a nickel-based alloy layer suitable as a seed layer of a perpendicular
magnetic recording medium.

2. Description of the Related Art

With the increasing requirement of the information storage capacity of
10 the magnetic recording media, how to promote the recording quality of the
magnetic recording media is still an important issue to be developed. According
to the orientation of the magnetization, the magnetic recording media are
classified into longitudinal magnetic recording media and perpendicular
magnetic recording media. The longitudinal magnetic recording media have
15 been developed to reach the limit; therefore, the research turns to throw in the
perpendicular magnetic recording media. By minimizing the recording units and
laminating the layers in perpendicular structure, the recording density of the
perpendicular magnetic recording media can be further promoted.

The lamellar structure of the general perpendicular magnetic recording
20 media comprises a substrate, an adhesive layer, a soft underlayer, a seed layer, an
intermediate layer, a magnetic recording layer, a covering layer, and a lubricative
layer from bottom to top.

To ensure that the seed layer is formed of a single face-centered cubic
structure, the seed layer is mainly composed of nickel in the prior art. However,

the seed layer sputtered from the nickel sputtering target has the problems of coarse grain sizes and low uniformity of grain sizes. Also, the magnetic recording layer formed on the seed layer also has the problems of coarse grain sizes and low uniformity of grain sizes thereof, thus failing to promote the recording density of the magnetic recording media.

According to the problems above, the objective of the present invention is to refine the grain sizes and uniform the grain distribution of the nickel-based alloy sputtering target, and thus allowing the nickel-based alloy layer sputtered by the target has effects of refined and uniform distribution as well.

Another objective of the present invention is to control the nickel-based alloy sputtering target formed of a single face-centered cubic structure, and make the nickel-based alloy layer sputtered by the nickel-based alloy sputtering target also formed of a single face-centered cubic structure thereby.

In order to achieve the objective, the present invention provides a nickel-based alloy sputtering target, characterized in that the nickel-based alloy sputtering target comprises nickel and a refining metal. The total amount of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy sputtering target, and the refining metal comprises rhenium.

According to the appropriate addition of rhenium in the nickel-based alloy sputtering target, the nickel-based alloy sputtering target is not only determined to be formed of a single face-centered cubic structure but also beneficial to refine and uniform the grain sizes. Specifically, the average grain sizes of the nickel-based alloy sputtering target is smaller than 100 μm and the

uniformity of the grain sizes of the nickel-based alloy sputtering target is lower than 20%.

In the nickel-based alloy sputtering target, the amount of the rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at% based on
5 the total atoms of the nickel-based alloy sputtering target.

According to the present invention, besides the rhenium, the refining metal further comprises ruthenium, tungsten, tantalum, niobium, molybdenum, titanium, or any combinations thereof.

In an embodiment, the refining metal can be, but not limited to, a
10 combination of rhenium and ruthenium, a combination of rhenium and tungsten, or a combination of rhenium, ruthenium, and tungsten. In the embodiment, the total amount of the refining metal is higher than or equal to 10 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy sputtering target, the amount of rhenium is higher than 0 at% and less than or equal to 10
15 at% based on the total atoms of the nickel-based alloy sputtering target.

Preferably, the total amount of atoms of the refining metal is higher than or equal to 10 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy sputtering target, and the amount of rhenium is higher than 0 at% and less than or equal to 8 at% based on the total atoms of the nickel-based
20 alloy sputtering target.

In another embodiment, the refining metal comprises rhenium; the amount of rhenium is higher than or equal to 6 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy sputtering target.

Preferably, the nickel-based alloy sputtering target comprises iron. In the

embodiment, the amount of iron is higher than 0 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target. More preferably, the amount of iron is higher than or equal to 15 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target. Much more preferably, the amount of iron is higher than or equal to 25 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target.

Preferably, the amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy sputtering target. The amount of iron atoms is higher than or equal to 15 at% and less than or equal to 28 at% based on the total atoms of the nickel-based alloy sputtering target.

In another embodiment, the nickel-based alloy sputtering target comprises iron. The refining metal is, but not limited to, a combination of rhenium and ruthenium, a combination of rhenium and tungsten, or a combination of rhenium, ruthenium, and tungsten. In the embodiment, the total amount of atoms of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at%, and the amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy sputtering target. The amount of the iron atoms contained in the total atoms in the nickel-based alloy sputtering target is similar as mentioned above.

In further another embodiment, the nickel-based alloy sputtering target comprises iron. The refining metal comprises rhenium. In the embodiment, the

amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy sputtering target.

The amount of the iron atoms contained in the total atoms in the nickel-based alloy sputtering target is similar as mentioned above.

5 Preferably, a microstructure of the nickel-based alloy sputtering target consists of a face-centered cubic structure so the nickel-based alloy sputtering target is suitable to be sputtered to form a seed layer applied in perpendicular magnetic recording media.

 Preferably, the average grain sizes of the nickel-based alloy sputtering
10 target is smaller than or equal to 100 μm . Comparing to the pure nickel sputtering target in the prior art, the present invention can solve the problem of coarse grain sizes. Therefore, the nickel-based alloy layer sputtered by the nickel-based alloy sputtering target of the present invention is suitable to apply in the perpendicular magnetic recording media to promote the recording density of the perpendicular
15 magnetic recording media.

 In order to achieve the objective, the present invention provides a nickel-based alloy layer, characterized in that the nickel-based alloy layer is formed from the nickel-based alloy sputtering target mentioned above. Specifically, the nickel-based alloy layer comprises nickel and a refining metal.
20 The total amount of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy layer, and the refining metal comprises rhenium.

 By controlling the composition of the nickel-based alloy layer, the nickel-based alloy layer can be suitable as a seed layer of the perpendicular

magnetic recording media, thereby promoting the recording density of the perpendicular magnetic recording media.

In the nickel-based alloy layer, the amount of the rhenium is higher than or equal to 5 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy layer.

In an embodiment, the refining metal can be, but not limited to, a combination of rhenium and ruthenium, a combination of rhenium and tungsten, or a combination of rhenium, ruthenium, and tungsten. In the embodiment, the total amount of atoms of the refining metal is higher than or equal to 10 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy layer. The amount of rhenium atoms is higher than 0 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy layer. Preferably, the total amount of atoms of the refining metal is higher than or equal to 10 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy layer. The amount of rhenium atoms is higher than 0 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy layer.

The amount of rhenium atoms is higher than or equal to 6 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy layer.

Preferably, the nickel-based alloy layer comprises iron. In the embodiment, the amount of iron atoms is higher than 0 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy layer. More preferably, the amount of iron atoms is higher than or equal to 15 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy layer. Much more preferably, the amount of iron is higher than or equal to 25 at% and

less than or equal to 30 at% based on the total atoms of the nickel-based alloy layer.

Preferably, the amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy layer. The amount of iron atoms is higher than or equal to 15 at% and less than or equal to 28 at% based on the total atoms of the nickel-based alloy layer.

In another embodiment, the nickel-based alloy layer comprises iron. The refining metal is, but not limited to, a combination of rhenium and ruthenium, a combination of rhenium and tungsten, or a combination of rhenium, ruthenium, and tungsten. In the embodiment, the total amount of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy layer. The amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy layer. The amount of the iron atoms contained in the total atoms in the nickel-based alloy layer is similar as mentioned above.

In another embodiment, the nickel-based alloy layer comprises iron. The refining metal comprises rhenium. In the embodiment, the amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy layer. The amount of the iron atoms contained in the total atoms in the nickel-based alloy layer is similar as mentioned above.

Preferably, a microstructure of the nickel-based alloy layer consists of a face-centered cubic structure so the nickel-based alloy layer is suitable as a seed layer applied in perpendicular magnetic recording media.

Preferably, the average grain size of the nickel-based alloy layer is smaller than or equal to 100 μm . Comparing to the seed layer in the prior art, the present invention can solve the problem of coarse grain sizes, thereby promoting the recording density of the perpendicular magnetic recording media.

5 IN THE DRAWINGS:

Figs. 1A to 1E are respectively optical microscope images of Ni-Re-W alloy sputtering targets of Examples 3 and 4, of Ni-Re-Ru alloy sputtering target of Example 6, of Ni-Re-W-Ru alloy sputtering target of Example 7, and of Ni-Fe-Re-W alloy sputtering target of Example 16, and all of them were
10 observed at the half radius of the nickel-based alloy sputtering targets;

Figs. 2A to 2D are respectively optical microscope images of pure nickel sputtering target in Comparative Example 1, of Ni-Re alloy sputtering targets in Comparative Examples 2 and 3, and of Ni-Fe alloy sputtering target in Comparative Example 4, and all of them were observed at the half radius of the
15 nickel-based alloy sputtering targets;

Fig. 3A is XRD spectra of Ni-Re alloy sputtering targets of Examples 1 and 2 and Comparative Example 3, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3B is XRD spectra of Ni-Re-W alloy sputtering targets of Examples
20 3 to 5 and Comparative Example 5, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3C is XRD spectra of Ni-Re-Ru alloy sputtering targets of Example 6 and Comparative Example 6, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3D is XRD spectra of Ni-Re-W-Ru alloy sputtering targets of Example 7 and Comparative Example 7, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3E is XRD spectra of Ni-Fe-Re alloy sputtering targets of Examples 8 to 10, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3F is XRD spectra of Ni-Fe-Re-W-Ru alloy sputtering targets of Examples 11 and 12 and Comparative Examples 10 and 11, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3G is XRD spectra of Ni-Fe-Re-Ru alloy sputtering targets of Examples 13 to 15 and Comparative Example 12, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Fig. 3H is XRD spectra of Ni-Fe-Re-W alloy sputtering targets of Examples 16 to 21, of nickel metal with a standard FCC structure, and of rhenium metal with a standard HCP structure;

Figs. 4A to 4C are optical microscope images of Ni-Re-W alloy sputtering target of Example 16, each of them respectively observed at center, half radius, and edge of the Ni-Re-W alloy sputtering target.

Examples were made to prove the influence of the compositions of nickel-based alloy sputtering targets on the grain sizes, the uniformity of grain sizes, and the crystal structure and to illustrate the detailed description of the present invention. Comparative Examples of nickel-based alloy sputtering targets were made to compare with the Examples. One skilled in the arts can easily realize the advantages and effects of the nickel-based alloy sputtering

target in accordance with the present invention from the Examples and Comparative examples. The descriptions proposed herein are just for the purpose of illustrations only, not intended to limit the scope of the invention.

Various modifications and variations could be made in order to practice or apply the present invention without departing from the spirit and scope of the invention.

Examples 1 and 2: Ni-Re alloy sputtering target

The nickel-based alloy sputtering targets of Examples 1 and 2 were each prepared by a similar method as follows.

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material and a rhenium material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. Each of the round nickel-based alloy sputtering targets of Examples 1 and 2 was formed with a diameter of 165 mm and a thickness of 4 mm, and abbreviated as Ni-Re alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based alloy sputtering targets of Examples 1 and 2 was expressed by a formula “aNi-b1Re”. In the formula, “a” and “b1” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets

and the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Examples 3 to 5: Ni-Re-W alloy sputtering target

The nickel-based alloy sputtering targets of Examples 3 to 5 were each prepared by the similar method as follows.

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, a rhenium material, and a tungsten material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. Each of the round nickel-based alloy sputtering targets of Examples 3 to 5 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Re-W alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based alloy sputtering targets of Examples 3 to 5 was expressed by a formula “aNi-b1Re-b2W”. In the formula, “a”, “b1”, and “b2” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, and the amount of the tungsten atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Example 6: Ni-Re-Ru alloy sputtering target

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, a rhenium material, and a ruthenium material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C , and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. The round nickel-based alloy sputtering target of Example 6 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Re-Ru alloy sputtering target.

As shown in Table 1, the composition of the nickel-based sputtering target of Example 6 was expressed by a formula “ $a\text{Ni}-b_1\text{Re}-b_3\text{Ru}$ ”. In the formula, “ a ”, “ b_1 ”, and “ b_3 ” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, and the amount of the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Example 7: Ni-Re-W-Ru alloy sputtering target

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, a rhenium material, a tungsten material, and a ruthenium material were vacuum induction melted under 5×10^{-2} torr and at a

melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge
 5 machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. The round nickel-based alloy sputtering target of Example 7 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Re-W-Ru alloy sputtering target.

As shown in Table 1, the composition of the nickel-based sputtering
 10 target of Example 7 was expressed by a formula “aNi-b1Re-b2W-b3Ru”. In the formula, “a”, “b1”, “b2”, and “b3” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the tungsten atoms contained
 15 in the total atoms of the nickel-based alloy sputtering targets, and the amount of the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Examples 8 to 10: Ni-Fe-Re alloy sputtering target

The nickel-based alloy sputtering targets of Examples 8 to 10 were each
 20 prepared by the method as follows.

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, an iron material, and a rhenium material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a

green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. Each of the
 5 round nickel-based alloy sputtering targets of Examples 8 to 10 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Fe-Re alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based sputtering targets of Examples 8 to 10 was expressed by a formula
 10 “aNi-cFe-b1Re”. In the formula, “a”, “b1”, and “c” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, and the amount of the iron atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose
 15 units were atomic percentage (at%).

Examples 11 to 12: Ni-Fe-Re-W-Ru alloy sputtering target

The nickel-based alloy sputtering targets of Examples 11 to 12 were each prepared by the method as follows.

According to the composition of the nickel-based alloy sputtering target
 20 listed in Table 1, a nickel material, an iron material, a rhenium material, a tungsten material, and a ruthenium material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher

than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. Each of the round nickel-based alloy sputtering targets of Examples 11 to 12 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Fe-Re-W-Ru alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based sputtering targets of Examples 11 to 12 was expressed by a formula “aNi-cFe-b1Re-b2W-b3Ru”. In the formula, “a”, “b1”, “b2”, “b3”, and “c” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the tungsten atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, and the amount of the iron atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Examples 13 to 15: Ni-Fe-Re-Ru alloy sputtering target

The nickel-based alloy sputtering targets of Examples 13 to 15 were each prepared by the method as follows.

According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, an iron material, a rhenium material, and a ruthenium material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for

casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round

- 5 nickel-based alloy sputtering target. Each of the round nickel-based alloy sputtering targets of Examples 13 to 15 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Fe-Re-Ru alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based sputtering targets of Examples 13 to 15 was expressed by a formula “a
10 Ni-cFe-b1Re-b3Ru”. In the formula, “a”, “b1”, “b3”, and “c” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering
15 targets, and the amount of the iron atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Examples 16 to 21: Ni-Fe-Re-W alloy sputtering target

The nickel-based alloy sputtering targets of Examples 16 to 21 were each prepared by the method as follows.

- 20 According to the composition of the nickel-based alloy sputtering target listed in Table 1, a nickel material, an iron material, a rhenium material, and a tungsten material were vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was

1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy sputtering target. Each of the round nickel-based alloy sputtering targets of Examples 16 to 21 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Fe-Re-W alloy sputtering target.

As shown in Table 1, the composition of each of the nickel-based sputtering targets of Examples 16 to 21 was expressed by a formula “a Ni-cFe-b1Re-b2W”. In the formula, “a”, “b1”, “b2”, and “c” respectively represented the amount of the nickel atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets, the amount of the tungsten atoms contained in the total atoms of the nickel-based alloy sputtering targets, and the amount of the iron atoms contained in the total atoms of the nickel-based alloy sputtering targets, whose units were atomic percentage (at%).

Comparative Example 1: pure nickel sputtering target

No refining metal material, such as rhenium, ruthenium, or tungsten, was used to prepare the nickel-based alloy sputtering target of Comparative Example 1. Only nickel material was vacuum induction melted under 5×10^{-2} torr and at a melting temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round

pure nickel sputtering target of Comparative Example 1. The round pure nickel sputtering target of Comparative Example 1 was formed with a diameter of 165 mm and a thickness of 4 mm.

Comparative Examples 2 and 3: Ni-Re alloy sputtering target

5 The nickel-based alloy sputtering targets of Comparative Examples 2 and 3 were each prepared by the method as follows.

 The nickel-based alloy sputtering targets of Comparative Examples 2 and 3 (abbreviated as Ni-Re alloy sputtering target) were each compared with the Ni-Re alloy sputtering target of Examples 1 and 2 and were prepared by a similar
10 method as Examples 1 and 2. The difference among Comparative Examples 2 and 3 and Examples 1 and 2 was that the amounts of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets of Comparative Examples 2 and 3 were out of the range of 6 at% to 8 at%. The specific compositions of the nickel-based alloy sputtering targets of
15 Comparative Examples 2 and 3 were listed in Table 1.

Comparative Example 4: Ni-Fe alloy sputtering target

 No refining metal material was used to prepare the nickel-based alloy sputtering target of Comparative Example 4. A nickel material and an iron material were vacuum induction melted under 5×10^{-2} torr and at a melting
20 temperature, and then poured into a mold at a casting temperature for casting, so as to obtain a green compact. Herein, the casting temperature was 1750°C, and the melting temperature was 100°C higher than the casting temperature. The green compact was processed by wire electrical discharge machining and computer numerical control lathe to obtain the round nickel-based alloy

sputtering target of Comparative Example 4. The nickel-based alloy sputtering target of Comparative Example 4 was formed with a diameter of 165 mm and a thickness of 4 mm and abbreviated as Ni-Fe alloy sputtering target. The specific composition of the nickel-based alloy sputtering target was listed in Table 1.

5 **Comparative Example 5: Ni-Re-W alloy sputtering target**

The nickel-based alloy sputtering target of Comparative Example 5 (abbreviated as Ni-Re-W alloy sputtering target) was compared with the Ni-Re-W alloy sputtering targets of Examples 3 to 5 and was prepared by the similar method as Examples 3 to 5. The difference among Comparative Example
10 5 and Examples 3 to 5 was that the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering target of Comparative Example 5 was higher than 8 at%. The specific composition of the nickel-based alloy sputtering target was listed in Table 1.

Comparative Example 6: Ni-Re-Ru alloy sputtering target

15 The nickel-based alloy sputtering target of Comparative Example 6 (abbreviated as Ni-Re-Ru alloy sputtering target) was compared with the Ni-Re-Ru alloy sputtering target of Example 6 and was prepared by the similar method as Example 6. The difference between Comparative Example 6 and Example 6 was that the amount of the rhenium atoms contained in the total
20 atoms of the nickel-based alloy sputtering target of Comparative Example 6 was higher than 8 at%. The specific composition of the nickel-based alloy sputtering target was listed in Table 1.

Comparative Example 7: Ni-Re-W-Ru alloy sputtering target

The nickel-based alloy sputtering target of Comparative Example 7

(abbreviated as Ni-Re-W-Ru alloy sputtering target) was compared with the Ni-Re-W-Ru alloy sputtering target of Example 7 and was prepared by the similar method as Example 7. The difference between Comparative Example 7 and Example 7 was that the total amount of the rhenium atoms, the tungsten atoms, and the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering target of Comparative Example 7 was higher than 15 at%. The specific composition of the nickel-based alloy sputtering target was listed in Table 1.

Comparative Examples 8 and 9: Ni-Fe-Re alloy sputtering target

The nickel-based alloy sputtering targets of Comparative Examples 8 and 9 were each prepared by the method as follows.

The nickel-based alloy sputtering targets of Comparative Examples 8 and 9 (abbreviated as Ni-Fe-Re alloy sputtering target) were each compared with the Ni-Fe-Re alloy sputtering targets of Examples 8 to 10 and each was prepared by the similar method as Examples 8 to 10. The difference among Comparative Examples 8 and 9 and Examples 8 to 10 was that the amounts of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering targets of Comparative Examples 8 and 9 were higher than 8 at%. The specific compositions of the nickel-based alloy sputtering targets were listed in Table 1.

Comparative Examples 10 and 11: Ni-Fe-Re-W-Ru alloy sputtering target

The nickel-based alloy sputtering targets of Comparative Examples 10 and 11 were each prepared by the method as follows.

The nickel-based alloy sputtering targets of Comparative Examples 10

and 11 (abbreviated as Ni-Fe-Re-W-Ru alloy sputtering target) were each compared with the Ni-Fe-Re-W-Ru alloy sputtering target of Examples 11 and 12 and were each prepared by the similar method as Examples 11 and 12. The difference among Comparative Examples 10 and 11 and Examples 11 and 12 was that the total amounts of the rhenium atoms, the tungsten atoms, and the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering targets of Comparative Examples 10 and 11 were higher than 15 at%. The specific compositions of the nickel-based alloy sputtering targets were listed in Table 1.

10 **Comparative Example 12: Ni-Fe-Re-Ru alloy sputtering target**

 The nickel-based alloy sputtering target of Comparative Example 12 (abbreviated as Ni-Fe-Re-Ru alloy sputtering target) was compared with the Ni-Fe-Re-Ru alloy sputtering targets of Examples 13 to 15 and was prepared by the similar method as Examples 13 to 15. The difference among Comparative Example 12 and Examples 13 to 15 was that the total amount of the rhenium atoms and the ruthenium atoms contained in the total atoms of the nickel-based alloy sputtering target of Comparative Example 12 was higher than 15 at%. The specific composition of the nickel-based alloy sputtering target was listed in Table 1.

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Table 1: the compositions, the average grain sizes (μm), the normalized uniformities of grain sizes (%), and the crystal structures of the nickel-based alloy sputtering targets of the Examples 1 to 21 (abbreviated as E1 to E21) and Comparative Examples 2 to 12 (abbreviated as C2 to C12), and those of the pure

nickel sputtering target of Comparative Example 1 (abbreviated as C1).

	Composition	Average grain size	Normalized uniformity of grain sizes	Crystal structure
E1	93.5Ni-6.5Re	95.82	18.84	FCC
E2	92Ni-8Re	89.37	14.33	FCC
E3	88Ni-8Re-4W	61.34	19.36	FCC
E4	87Ni-5Re-8W	59.78	17.11	FCC
E5	85Ni-7Re-8W	58.43	17.74	FCC
E6	87Ni-8Re-5Ru	51.09	19.43	FCC
E7	86Ni-5Re-4W-5Ru	14.45	16.68	FCC
E8	70Ni-25Fe-5Re	59.39	19.80	FCC
E9	74Ni-18Fe-8Re	53.64	14.41	FCC
E10	67Ni-25Fe-8Re	33.48	13.85	FCC
E11	61Ni-25Fe-5Re-4W-5Ru	19.43	14.58	FCC
E12	60Ni-25Fe-6Re-4W-5Ru	23.23	15.90	FCC
E13	62Ni-25Fe-8Re-5Ru	18.55	17.69	FCC
E14	60Ni-25Fe-10Re-5Ru	14.14	5.72	FCC
E15	55Ni-30Fe-5Re-10Ru	16.52	17.51	FCC
E16	66Ni-25Fe-5Re-4W	21.46	14.76	FCC
E17	63Ni-25Fe-8Re-4W	28.80	18.34	FCC
E18	62Ni-25Fe-5Re-8W	27.24	13.29	FCC
E19	60Ni-25Fe-7Re-8W	25.89	13.92	FCC
E20	58Ni-30Fe-8Re-4W	28.80	18.34	FCC
E21	56Ni-30Fe-10Re-4W	14.31	8.85	FCC
C1	Ni	724.00	64.30	FCC
C2	95Ni-5Re	131.38	24.77	FCC
C3	90Ni-10Re	88.20	22.79	FCC/HCP
C4	75Ni-25Fe	385.47	15.85	FCC
C5	86Ni-10Re-4W	46.86	12.68	FCC/HCP
C6	85Ni-10Re-5Ru	46.68	21.52	FCC/HCP
C7	72Ni-10Re-8W-10Ru	30.44	21.51	FCC/HCP
C8	72Ni-18Fe-10Re	41.99	10.73	FCC/HCP
C9	65Ni-25Fe-10Re	16.20	7.89	FCC/HCP
C10	58Ni-25Fe-8Re-4W-5Ru	30.83	18.52	FCC/HCP
C11	57Ni-25Fe-5Re-8W-5Ru	20.31	11.48	FCC/HCP
C12	58Ni-25Fe-12Re-5Ru	33.75	22.94	FCC/HCP

Test Example 1: microstructure of the sputtering target

The foresaid sputtering targets of Examples 1 to 21 and Comparative

Examples 1 to 12 were observed by an optical microscope to determine whether the nickel-based alloy sputtering targets could be refined and uniformed in grain size by controlling their compositions.

Take the optical microscope images of the nickel-based alloy sputtering targets of Examples 3, 4, 6, 7, 16 and Comparative Examples 2 to 4, and the pure nickel sputtering target of Comparative Example 1 for example, according to Figs. 1A to 1E and Figs. 2A to 2D, controlling the compositions of the nickel-based alloy sputtering targets was beneficial to refine and uniform the grain sizes of the nickel-based alloy sputtering targets. In contrast, the pure nickel sputtering target of Comparative Example 1 and the nickel-based alloy sputtering targets of Comparative Examples 2 and 4 each had coarser grain sizes, and the pure nickel sputtering target of Comparative Example 1 also had less uniform distribution in grain size.

In short, the nickel-based alloy sputtering target of the present invention, such as those of Examples 3, 4, 6, 7, and 16, can be sputtered to form a nickel-based alloy layer with more refined and uniform grain sizes. When the nickel-based alloy layer is applied in the perpendicular magnetic recording media and acts as a seed layer, a magnetic recording layer formed on the seed layer can have a refined and uniform grain size accordingly, thereby promoting the recording density of the perpendicular magnetic recording media.

Test Example 2: crystal structure of the sputtering targets

The nickel-based alloy sputtering targets of Examples 1 to 21 and Comparative Examples 2 to 12 and the pure nickel sputtering target of Comparative Example 1 were respectively scanned by x-ray diffractometer to

obtain x-ray diffraction spectra (abbreviated as XRD spectra). Besides, the XRD spectra of Examples 1 to 21 and Comparative Examples 1 to 12 were compared with XRD patterns of nickel metal with a standard face-centered cubic structure (abbreviated as FCC structure) and rhenium metal with a standard hexagonal close-packed structure (abbreviated as HCP structure) to determine their crystal structures, and the results were listed in Table 1 above.

According to the XRD pattern of nickel metal with a standard FCC structure, the characteristic peaks of (111), (200), and (220) planes were respectively located at 2θ of 44.58° , 51.89° , and 76.61° . According to the XRD pattern of rhenium metal with a standard HCP structure, the characteristic peaks of (002), (101), (102), (103), (112), and (202) planes were respectively located at 2θ of 37.46° , 40.24° , 42.64° , 56.05° , 67.34° , and 75.38° .

With reference to Fig. 3A, in addition to the characteristic peaks as shown in the XRD spectra of the Ni-Re alloy sputtering targets of Examples 1 and 2, a characteristic peak of (002) plane, corresponding to HCP structure, was further observed in the XRD spectrum of the Ni-Re alloy sputtering target of Comparative Example 3. It indicated that the Ni-Re alloy sputtering target of Comparative Example 3 was formed of a combination of FCC and HCP structure instead of a single FCC structure.

In Ni-Re alloy material system, when the amount of the rhenium atoms is in a range of 6 at% to 8 at% based on the total atoms of nickel-based alloy sputtering target, the crystal structure of such nickel-based alloy sputtering target, for example, Examples 1 and 2, consists of a single FCC structure, and thus the nickel-based alloy sputtering target can be sputtered to form a nickel-based alloy

layer of a single FCC structure and allows such nickel-based alloy layer to be suitable as a seed layer of the perpendicular magnetic recording media.

With reference to Fig. 3B, in addition to the characteristic peaks as shown in the XRD spectra of the Ni-Re-W alloy sputtering targets of Examples 3 to 5, characteristic peaks of (002) and (101) planes, corresponding to HCP structure, were further observed in the XRD spectrum of the Ni-Re-W alloy sputtering target of Comparative Example 5. It indicated that the Ni-Re-W alloy sputtering target of Comparative Example 5 was formed of a combination of FCC and HCP structure instead of a single FCC structure.

With reference to Fig. 3C, in addition to the characteristic peaks as shown in the XRD spectrum of the Ni-Re-Ru alloy sputtering target of Example 6, characteristic peaks of (002) and (103) planes, corresponding to HCP structure, were further observed in the XRD spectrum of the Ni-Re-Ru alloy sputtering target of Comparative Example 6. It indicated that the Ni-Re-Ru alloy sputtering target of Comparative Example 6 was formed of a combination of FCC and HCP structure instead of a single FCC structure.

With reference to Fig. 3D, in addition to the characteristic peaks as shown in the XRD spectrum of the Ni-Re-W-Ru alloy sputtering target of Example 7, a characteristic peak of (101) plane, corresponding to HCP structure, was further observed in the XRD spectrum of the Ni-Re-W-Ru alloy sputtering target of Comparative Example 7. It indicated that the Ni-Re-W-Ru alloy sputtering target of Comparative Example 7 was formed of a combination of FCC and HCP structures instead of a single FCC structure.

Based on the results in Figs. 3B to 3D, no matter in Ni-Re-W alloy

material system, Ni-Re-Ru alloy material system, or Ni-Re-W-Ru alloy material system, the nickel-based alloy sputtering targets (such as Examples 3 to 7) are each formed of a single FCC structure when the total amount of the refining metal, *e.g.*, rhenium and tungsten in Examples 3 to 5, rhenium and ruthenium in
5 Example 6, or rhenium, ruthenium, and tungsten in Example 7, is less than or equal to 15 at% and the amount of rhenium atoms is less than or equal to 8 at% based on the total atoms of the nickel-based alloy sputtering target.

Besides, with reference to Fig. 3F, in addition to the characteristic peaks as shown in the XRD spectra of the Ni-Fe-Re-W-Ru alloy sputtering targets of
10 Examples 11 and 12, a characteristic peak of (002) plane, corresponding to HCP structure, was further observed in the XRD spectra of the Ni-Fe-Re-W-Ru alloy sputtering targets of Comparative Examples 10 and 11. It indicated that the Ni-Fe-Re-W-Ru alloy sputtering targets of Comparative Examples 10 and 11 both were formed of a combination of FCC and HCP structure instead of a single
15 FCC structure.

With reference to Fig. 3G, in addition to the characteristic peaks as shown in the XRD spectra of the Ni-Fe-Re-Ru alloy sputtering targets of Examples 13 to 15, characteristic peaks of (002) and (112) planes, corresponding to HCP structure, were further observed in the XRD spectrum of the
20 Ni-Fe-Re-Ru alloy sputtering target of Comparative Example 12. It indicated that the Ni-Fe-Re-Ru alloy sputtering target of Comparative Example 12 was also formed of a combination of FCC and HCP structure instead of a single FCC structure.

With reference to Fig. 3E, only the characteristic peaks corresponding to

FCC structure were observed in the XRD spectra of the Ni-Fe-Re alloy sputtering targets of Examples 8 to 10. That is, no characteristic peaks corresponding to HCP structure were observed in the XRD spectra of the Ni-Fe-Re alloy sputtering targets of Examples 8 to 10. With reference to Fig. 3H, the XRD spectra of the Ni-Fe-Re-W alloy sputtering targets of Examples 16 to 21 indicated a result similar with those of Examples 8 to 10.

Based on the results as shown in Figs. 3E to 3H, no matter in Ni-Fe-Re alloy material system, Ni-Fe-Re-W alloy material system, Ni-Fe-Re-Ru alloy material system, or Ni-Fe-Re-W-Ru alloy material system, the nickel-based alloy sputtering targets (such as Examples 8 to 21) are each formed of a single FCC structure when the total amount of the refining metal is less than or equal to 15 at% and the amount of the rhenium atoms is less than or equal to 10 at% based on the total atoms of the nickel-based alloy sputtering targets.

Controlling the composition of the nickel-based alloy sputtering target can determine the nickel-based alloy sputtering target being formed of a single FCC structure without any HCP structure. Therefore, the nickel-based alloy sputtering target prepared by the present invention can be sputtered to form the nickel-based alloy layer formed of a single FCC structure, thereby being suitable as a seed layer of the perpendicular magnetic recording media.

Test example 3: average grain size and uniformity of grain sizes

To prove the technical features in the present invention could refine and uniform the grain sizes again, each of the nickel-based alloy sputtering targets of Examples and Comparative Examples was analyzed by a similar method as follows.

Each nickel-based alloy sputtering target was cut at its center, half-radius ($r/2$), and edge (r) by wire electrical discharge machining, so as to obtain the samples sized in 10 mm × 10 mm. The top surface of each sample was washed by an etching solution containing water, hydrochloric acid, nitric acid, and hydrogen peroxide. Each of the three samples was observed by an optical microscope at 500 times magnification and snapped at 10 to 12 different locations, so as to obtain 30 to 36 optical microscope images in total.

Then each optical microscope image was marked with four auxiliary lines. Two auxiliary lines respectively were diagonals on the optical microscope image. The other two auxiliary lines were centerlines respectively parallel to the length and to the width of the optical microscope image. Specifically, the four auxiliary lines respectively connected the opposite sides and opposite points of the optical microscope image.

After that, the total amount of grains on the four auxiliary lines was counted by simple random sampling. A length of each auxiliary line was divided by the amount of the grains on the respective auxiliary line to obtain a partial average grain size. Then all the partial average grain sizes on auxiliary lines were calculated to obtain an average grain size and a standard deviation. A normalized uniformity of grain sizes was calculated by dividing the average grain size by the standard deviation and multiplying 100%. A higher value of the normalized uniformity of grain sizes implied a more significant variation and a less uniform distribution in grain size. The average grain size and the uniformity of grain sizes of each Example and each Comparative Example were listed in Table 1 above.

To further illustrate the analysis in Test Example 3, the nickel-based

alloy sputtering target of Example 16 and its optical microscope images were taken as an example for illustration.

The Ni-Fe-Re-W alloy sputtering target of Example 16 was cut at locations of center, half-radius, and edge to obtain samples sized in 10 mm × 10 mm by wire electrical discharge machining. The samples were observed and snapped by the optical microscope at 500 times magnification as shown in Figs. 4A to 4C.

Take the center sample of the Ni-Fe-Re-W alloy sputtering target for example, the optical microscope image of Fig. 4A (observed region 1) was marked with four auxiliary lines “L1”, “L2”, “L3”, and “L4”. The lengths of the auxiliary lines of “L1” and “L2” were 325 μm; the length of the auxiliary line “L3” was 195 μm; and the length of the auxiliary line “L4” was 260 μm. The amount of the grains counted on each auxiliary line and the partial average grain size calculated on each auxiliary line of the sample at observed region 1 were listed in Table 2.

Subsequently, the center sample of the nickel-based alloy sputtering target was repeatedly observed, snapped, and analyzed at the other eleven observed regions (observed regions 2 to 12) by the similar method aforementioned. All lengths of the auxiliary lines of “L1”, “L2”, “L3”, and “L4” at observed regions 1 to 12 were the same.

According to the results of the partial average grain sizes on each auxiliary line of “L1”, “L2”, “L3”, and “L4” obtained by simple random sampling, a local average grain size of each auxiliary line could be obtained by averaging the partial average grain sizes on each same auxiliary line at observed

regions 1 to 12 as shown in Table 3. According to the local average grain sizes of each auxiliary line, the average grain size could be obtained by averaging the local average grain sizes of the four auxiliary lines. The average grain size of the center sample of the nickel-based alloy sputtering target of Example 16 was 21.6 μm ; the standard deviation of the center sample of the nickel-based alloy sputtering target of Example 16 was 1.458; the uniformity of grain sizes of the center sample of the nickel-based alloy sputtering target of Example 16 was 6.75%.

After that, the half-radius sample and the edge sample of the nickel-based alloy sputtering target of Example 16 were repeatedly measured by the similar method aforementioned. The average grain size of the half-radius sample of the nickel-based alloy sputtering target of Example 16 was 21.1 μm . The average grain size of the edge sample of the nickel-based alloy sputtering target of Example 16 was 21.5 μm .

According to the measured results, the average grain size of the overall nickel-based alloy sputtering target of Example 16 was 21.46 μm ; the standard deviation of the overall nickel-based alloy sputtering target of Example 16 was 1.454; the uniformity of grain sizes of the overall nickel-based alloy sputtering target of Example 16 was 6.77%.

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Table 2: the amount of the grains and the partial average grain sizes (μm) on each auxiliary line (L1 to L4) at different observed regions (abbreviated as R1 to R12) of the center sample of the nickel-based alloy sputtering target of Example 16.

	L1		L2		L3		L4	
	Amt. of grains	Partial avg. grain size	Amt. of grains	Partial avg. grain size	Amt. of grains	Partial avg. grain size	Amt. of grains	Partial avg. grain size
R1	14	23.4	19	16.7	8	25.0	9	30.0
R2	15	21.9	20	15.9	9	21.9	11	23.4
R3	15	21.9	15	21.9	10	19.5	10	25.0
R4	14	23.4	15	21.9	12	16.7	10	25.0
R5	13	25.0	14	23.4	12	15.9	12	21.9
R6	13	25.0	13	25.0	9	21.9	13	19.5
R7	15	21.9	15	21.9	9	21.9	16	16.7
R8	17	19.5	14	23.4	8	23.4	16	15.9
R9	19	16.7	13	25.0	9	21.9	12	21.9
R10	20	15.9	13	25.0	9	21.9	13	19.5
R11	15	21.9	15	21.9	9	21.9	11	23.4
R12	15	21.9	17	19.5	8	25.0	16	15.9

Table 3: the local average grain sizes (μm) of each auxiliary line (L1 to L4) averaged from the partial average grain sizes on each auxiliary line (L1 to L4) at different observed regions listed in Table 2.

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	L1	L2	L3	L4
Local average grain size	21.5	21.8	21.4	21.5

As shown in Table 1, the average grain sizes and the uniformities of grain sizes of the nickel-based alloy sputtering targets of Examples 1 to 21 could be respectively controlled under less than $100\ \mu\text{m}$ and less than 20% to refine and uniform the grain sizes of the nickel-based alloy sputtering targets.

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Specifically, in Ni-Re alloy material system, when the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering target is in the range of 6 at% to 8 at%, the nickel-based alloy sputtering target can have refined and uniform grain sizes (such as Examples 1 and 2). In the

contrary, the pure nickel sputtering target of Comparative Example 1 does not contain any refining metal material so the pure nickel sputtering target has the problems of coarser grain sizes and less uniform distribution in grain size. Also, if the amount of rhenium material is not enough, the nickel-based alloy

5 sputtering target of Comparative Example 2 still has the problems of the coarser grain sizes and less uniform distribution in grain size. On the other hand, if the amount of rhenium material is excessive, the nickel-based alloy sputtering target of Comparative Example 3 still fails to have an uniform distribution in grain size, causing the nickel-based alloy sputtering target not suitable for sputtering to
10 form a nickel-based alloy layer with refined and uniform grain sizes. Even the iron material in an appropriate amount is contained in the nickel-based alloy sputtering target, the iron material still cannot effectively refine the grain size, such that the average grain size of the nickel-based alloy sputtering target of Comparative Example 4 is still up to 385 μm .

15 Besides, in Ni-Re-Ru alloy material system or Ni-Re-W-Ru alloy material system, when the amount of atoms of the refining metal contained in the total atoms of the nickel-based alloy sputtering target is in the range of 10 at% to 15 at% and the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering target is less than or equal to 8 at%, the
20 nickel-based alloy sputtering target (such as Examples 6 and 7) will have refined and uniform grain sizes. In the contrary, the nickel-based alloy sputtering targets of Comparative Examples 6 and 7 have the problems of coarser grain sizes and less uniform distribution in grain size respectively due to the excessive rhenium metal material (Comparative Example 6) and excessive refining metal material

(Comparative Example 7).

In Ni-Fe-Re-Ru alloy material system, when the amount of atoms of the refining metal contained in the total atoms of the nickel-based alloy sputtering target is in the range of 10 at% to 15 at% and the amount of the rhenium atoms
 5 contained in the total atoms of the nickel-based alloy sputtering target is less than or equal to 10 at%, the nickel-based alloy sputtering target (such as Examples 13 to 15) will have refined and uniform grain sizes. In the contrary, the nickel-based alloy sputtering target of Comparative Example 12 has the problems of coarser grain sizes and less uniform distribution in grain size due to the excessive
 10 refining metal and excessive rhenium metal.

Comparing the results of Examples 2, 3, and 6, when the amount of the rhenium atoms contained in the total atoms of the nickel-based alloy sputtering target was equal to 8 at%, an addition of the tungsten material or ruthenium material was beneficial to refine and uniform the grain sizes so the grain sizes of
 15 the nickel-based alloy sputtering targets of Examples 3 and 6 were smaller than that of Example 2. Similarly, further comparing the results of Examples 9 and 10 with Examples 13, 17, and 20, or comparing the results of Example 8 with Examples 11, 15, 16, and 18 could get similar deductions.

According to the results of Test Examples 1 to 3, controlling the
 20 composition of the nickel-based alloy sputtering target can not only determine the nickel-based alloy sputtering target formed of a single FCC structure but also refine and uniform the grain sizes of the nickel-based alloy sputtering target. Further, the nickel-based alloy sputtering target can be sputtered to form the nickel-based alloy layer with a single FCC structure, refined grain sizes, and

uniform distribution in grain size. Therefore, the nickel-based alloy layer is suitable as the seed layer of the perpendicular magnetic recording media and can promote the recording density of the perpendicular magnetic recording media.

CLAIMS

1. A nickel-based alloy sputtering target, characterized in that the nickel-based alloy sputtering target comprises nickel and a refining metal; the
5 total amount of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at% based on the total atoms of the nickel-based alloy sputtering target, and the refining metal comprises rhenium.

2. The nickel-based alloy sputtering target as claimed in claim 1,
10 wherein the refining metal comprises ruthenium, tungsten, tantalum, niobium, molybdenum, titanium, or any combinations thereof.

3. The nickel-based alloy sputtering target as claimed in claim 2,
wherein the total amount of the refining metal is higher than or equal to 10 at%
15 and less than or equal to 15 at% and the amount of rhenium atoms is higher than 0 at% and less than or equal to 10 at% based on the total atoms of the nickel-based alloy sputtering target.

4. The nickel-based alloy sputtering target as claimed in claim 3,
20 wherein the total amount of the refining metal is higher than or equal to 10 at% and less than or equal to 15 at% and the amount of rhenium atoms is higher than 0 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy sputtering target.

5. The nickel-based alloy sputtering target as claimed in claim 1, wherein the amount of rhenium atoms is higher than or equal to 6 at% and less than or equal to 8 at% based on the total atoms of the nickel-based alloy sputtering target.

5

6. The nickel-based alloy sputtering target as claimed in any one of claims 1 to 5, wherein the nickel-based alloy sputtering target comprises iron; the amount of iron atoms is higher than 0 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target.

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7. The nickel-based alloy sputtering target as claimed in claim 2, wherein the nickel-based alloy sputtering target comprises iron; the total amount of the refining metal is higher than or equal to 5 at% and less than or equal to 15 at%, the amount of rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at%, and the amount of iron atoms is higher than 0 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target.

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8. The nickel-based alloy sputtering target as claimed in claim 7, wherein the amount of iron atoms is higher than or equal to 25 at% and less than or equal to 30 at% based on the total atoms of the nickel-based alloy sputtering target.

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9. The nickel-based alloy sputtering target as claimed in claim 1,
wherein the nickel-based alloy sputtering target comprises iron; the amount of
rhenium atoms is higher than or equal to 5 at% and less than or equal to 10 at%
and the amount of iron atoms is higher than 0 at% and less than or equal to 30
5 at% based on the total atoms of the nickel-based alloy sputtering target.

10 The nickel-based alloy sputtering target as claimed in claim 7,
wherein the amount of rhenium atoms is higher than or equal to 5 at% and less
than or equal to 8 at% and the amount of iron atoms is higher than or equal to 15
10 at% and less than or equal to 28 at% based on the total atoms of the nickel-based
alloy sputtering target.

11. The nickel-based alloy sputtering target as claimed in any one of
claims 1 to 5 and 7 to 10, wherein a microstructure of the nickel-based alloy
15 sputtering target consists of a face-centered cubic structure.

12. The nickel-based alloy sputtering target as claimed in claim 6,
wherein a microstructure of the nickel-based alloy sputtering target consists of a
face-centered cubic structure.

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13. The nickel-based alloy sputtering target as claimed in any one of
claims 1 to 5 and 7 to 10, wherein the average grain size of the nickel-based alloy
sputtering target is smaller than or equal to 100 μm .

14. The nickel-based alloy sputtering target as claimed in claim 6, wherein the average grain size of the nickel-based alloy sputtering target is smaller than or equal to 100 μm .

5 15. The nickel-based alloy sputtering target as claimed in claim 1, wherein the refining metal is selected from the group consisting of a combination of rhenium and ruthenium, a combination of rhenium and tungsten, and a combination of rhenium, ruthenium, and tungsten.

10 16. A nickel-based alloy layer, characterized in that the nickel-based alloy layer is formed by sputtering the nickel-based alloy sputtering target as claimed in any one of claims 1 to 15.