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(54) **Fe-Si-Al alloy magnetic thin film and method of manufacturing the same.**

(57) A Fe-Si-Aℓ alloy magnetic thin film contains a limited oxygen content in the range 0.17 to 0.46 wt % and has excellent magnetic and mechanical properties.

The film is made by sputtering in an inert gas atmosphere containing a controlled concentration of oxygen amounting to 400 to 1500 volumetric ppm if the sputtering target is a cast film, while the oxygen content is reduced by an amount dependent on the initial concentration of oxygen in the sputtering target when the target is a sintered target containing oxygen.

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FE-SI-Aℓ ALLOY MAGNETIC THIN FILM AND METHOD OF MANUFACTURING THE SAME

The present invention relates to an Fe-Si-Aℓ alloy magnetic thin film and to a method of manufacturing this thin film. The film contains, as its main components, Fe Si and Aℓ, and additionally contains oxygen. The method manufactures such an Fe-Si-Aℓ alloy magnetic thin film by effecting sputtering in an inert gas-based atmosphere containing a regulated amount of oxygen gas.

Recently, in the field of magnetic recording technology, recording density has been improved remarkably. Improved recording density has led to increases in demand for track width reduction in a magnetic head such as a video head or computer head, for increased magnitization saturation of a core material, and for improved magnetic permeability in high-frequency areas.

One type of alloy magnetic thin film has been drawing attention as a magnetic thin film of a magnetic head capable of meeting such demands. This is a magnetic thin film of a Sendust alloy, an Fe-Si-Aℓ alloy containing Fe, Si and Aℓ as its main components.

A Sendust alloy magnetic thin film, i.e., an Fe-Si-Aℓ alloy magnetic thin film, generally has superior magnetic characteristics. However, the durability of such a magnetic thin film is inferior. Therefore, various proposals have been made to provide Fe-Si-Aℓ alloy magnetic thin films excellent in both magnetic characteristics and durability.

For instance, Japanese Patent Application Public Disclosure No. 220914/1985 discloses the art of adding 0.005 to 6% by weight (hereinafter abbreviated to "wt%") of oxygen to an Fe-Si-Aℓ alloy magnetic thin film, so as to obtain a magnetic thin film which has both excellent magnetic characteristics and high hardness.

The present inventors have conducted many studies and experiments in order to obtain an Fe-Si-Aℓ alloy magnetic thin film which has as excellent magnetic characteristics as that shown in the above-mentioned patent application, but which also has high hardness. As a result, the present inventors have found that, if the amount of oxygen contained in the magnetic thin film is within that wide range from 0.005 to 6 wt% specified in the patent application, the Fe-Si-Aℓ alloy magnetic thin film will not always exhibit excellence in both magnetic characteristics and durability.

Specifically, the present inventors have found that, in order to obtain an Fe-Si-Aℓ alloy magnetic thin film having excellent and superior magnetic characteristics and high hardness, it is of great importance that the amount of oxygen contained in the magnetic thin film be kept within a very limited range from 0.17 to 0.46 wt%.

In general, a Sendust alloy magnetic thin film, or an Fe-Si-Aℓ alloy magnetic thin film, is formed by sputtering an Fe-Si-Aℓ alloy onto a substrate of crystallized glass or ceramics in an inert gas atmosphere.

In the course of the present inventors' studies into manufacturing, by sputtering, an Fe-Si-Aℓ alloy magnetic thin film containing oxygen, they have found that, if an oxygen gas is introduced into the inert gas atmosphere and in an amount within a very limited range, it is possible suitably to manufacture an Fe-Si-Aℓ alloy magnetic thin film containing the above-specified amount of oxygen.

It has been found that the oxygen-containing Fe-Si-Aℓ alloy magnetic thin film manufactured by this method is capable of maintaining high magnetic permeability and high hardness while avoiding the risk of a drop in the saturation flux density, of maintaining a coercive force (Hc) of not more than 0.35 Oe, and of maintaining a value of less than 0.20 that is indicative of a change in the specific initial magnetic permeability at 1 MHz caused by the application of a certain strain.

The value indicating a change in the specific initial permeability at 1 MHz caused by the application of a certain strain (the value will hereinafter be symbolized as "η") is calculated, with the following formula (1) : $\eta = 20 \log (\mu/\mu_0)$ ..... (1) from (a) the specific initial permeability μ_0 at 1 MHZ when an Fe-Si-Aℓ alloy magnetic thin film sputtered onto a substrate is subjected to no strain and (b) the specific initial permeability μ at 1 MHz of smaller value when the magnetic thin film is subjected to either a tensile or a compressive strain of 1×10^{-4} corresponding to the strain that can be caused by the difference in thermal expansion coefficient between the substrate and the thin film as well as by deformation of the substrate. Thus, the value η indicates a certain quality of a magnetic film which is very important in determining whether the film is practically usable or not.

Whether or not the coercive force (Hc) is not more than 0.35 Oe, and whether or not the value η is less than 0.20 matters because if these conditions are not met, the magnetic head will not exhibit the performance levels required of a high-vision magnetic head (that is, the maximum value of the normalized output voltage for MP (Metal Powder) tape should exceed 90 [$nV_{0\text{-}p}/\mu m \cdot turn \cdot (m/sec)$], and the CN (Carrier to Noise) ratio at 19 MHz must be equal to or greater than 58 dB measured with 30 KHz resolution bandwidth).

Japanese Patent Application Public Disclosure No. 218821/1985 discloses a method of manufacturing an Fe-Si-Aℓ alloy magnetic thin film by effecting sputtering in an inert gas-based atmosphere containing oxygen. However, in the sputtering effected in that disclosed method, the atmosphere contains 0.01 to 40% by volume of oxygen.

According to the result of certain studies and experiments conducted by the present inventors, if the amount of oxygen contained in the inert gas-based atmosphere is less than 400 ppm by volume, there can be cases where the amount of oxygen contained in the resultant magnetic thin film is less than 0.17 wt%. In such cases, the coercive force will exceed 0.35 Oe. On the other hand, if the amount of oxygen contained in the inert gas-based atmosphere exceeds 1500 volumetric ppm, there can be cases where the amount of oxygen contained in the resultant magnetic thin film greatly exceeds 0.46 wt%. In such cases, the value η will be 0.20 or greater. The present inventors have also found that, if 3000 volumetric ppm of oxygen is contained in the inert gas-based atmosphere, the film will peel from the substrate, becoming unusable in practice.

In this way, the art disclosed in the above-mentioned publication specifies too wide a range of the amount of oxygen in the inert gas-based atmosphere to exclude a practically unusable range and to assure industrial utilization. In other words, the conventional art fails to teach or suggest that the oxygen content in the inert gas-based atmosphere must be within a very narrow range in order to effectively manufacture an Fe-Si-Aℓ alloy magnetic film.

As discussed above, the present inventors have found that it is possible to effectively manufacture an Fe-Si-Aℓ alloy magnetic thin film containing 0.17 to 0.46 wt% of oxygen only if the amount of oxygen contained in the inert gas-based atmosphere is within a very narrow and specific range.

This finding leads to the following. If the sputtering is to be effected by using, as the sputtering target, a cast target which contains substantially no oxygen (i.e., contains only 3 to 5 ppm by weight), the oxygen concentration in the inert gas-based atmosphere must be 400 to 1500 volumetric ppm. If a sintered target which contains a relatively large amount of oxygen is to be used, the oxygen concentration in the inert gas-based atmosphere must be adjusted in accordance with the quality of the target and set at a suitably low level because the oxygen already contained in the target can influence the inert gas-based atmosphere. For instance, if the target used consists of a normally used sintered target which contains 0.14 wt% of oxygen, the initial oxygen concentration of the inert gas-based atmosphere is set at about 500 volumetric ppm.

The present invention has been made on the basis of the above-described novel finding.

It is an object of the present invention to provide an oxygen-containing Fe-Si-Aℓ alloy magnetic thin film having high hardness and excellent durability, the amount of oxygen contained in the magnetic thin film being specified within a specific range. The magnetic thin film is capable of exhibiting a coercive force (Hc) of not more than 0.35 Oe, and the value η of less than 0.20.

It is another object of the present invention to provide a method of manufacturing such an oxygen-containing Fe-Si-Aℓ alloy magnetic thin film, the method being adapted strictly to regulate the oxygen concentration in the inert gas-based atmosphere to achieve a suitable oxygen concentration in the atmosphere during sputtering.

The above-stated objects are achieved by an Fe-Si-Aℓ alloy magnetic thin film and a method of manufacturing the thin film, both according to the present invention. In brief, the nub of the present invention resides in an Fe-Si-Aℓ alloy magnetic thin film containing, as its main components, Fe, Si and Aℓ, and additionally containing 0.17 to 0.46 wt% of oxygen.

The Fe-Si-Aℓ alloy magnetic thin film containing oxygen within the above-specified range can be very advantageously manufactured by first preparing a sputtering target and an inert gas-based atmosphere having a strictly regulated concentration of oxygen. The oxygen concentration in the inert gas-based atmosphere is set at 400 to 1500 volumetric ppm if the target is a cast product, whereas, if the target is a sintered product, the oxygen concentration is adjusted in accordance with the quality of the target and is set at a level lower than the above-mentioned range. For instance, if the sintered target contains 0.14 wt% of oxygen, the oxygen concentration in the inert gas-based atmosphere should preferably be set at about 500 volumetric ppm. Then, sputtering is effected employing the target and the inert gas-based atmosphere.

The invention will now be explained in more detail in the following description, which is given by way of example only, and with reference to the accompanying drawings in which:

Fig. 1 is a schematic illustration of a sputtering apparatus suitable for use in carrying out a manufacturing method according to the present invention;

Fig. 2 is a graph showing the coercive force and the value η indicative of a change in the specific initial permeability at 1 MHz caused by a strain, both in relation to the oxygen concentration in the inert gas-based atmosphere;

Fig. 3 is a graph showing the amount of oxygen contained in magnetic thin film in relation to the oxygen concentration in the inert gas-based atmosphere and;

Fig. 4 is a graph showing the coercive force and the value η in relation to the oxygen concentration in the film.

Detailed explanations will first be given of an Fe-Si-Aℓ alloy magnetic thin film according to the present invention. If the amount of oxygen contained in the magnetic thin film is less than 0.17 wt%, the coercive force will exceed 0.35 Oe. On the other hand, if the amount of oxygen contained in the magnetic thin film exceeds 0.46 wt%, the value η will be 0.20 or greater.

The proportion of the main components Fe, Si and Aℓ in the chemical composition is not particularly specified. However, the magnetic thin film should preferably contain 4 to 7 wt% of Aℓ, 8 to 12 wt% of Si, and the balance of Fe.

If desired, a part of Fe, more specifically, a part of Fe which is not more than 60 wt% thereof, may be substituted with such elements as Co and Ni. Further, in order to improve the corrosion resistance and the wear resistance of the magnetic thin film, various elements may be added as additives within a range of less than 10 wt% of the magnetic thin film. Examples which may be used as the additives include: Y and other elements in the IIIa group; Ti, Zr, Hf and other elements in the IVa group; V, Nb, Ta and other elements in the Va group; Cr, Mo, W and other elements in the VIa group; Mn, To, Re and other elements in the VIIa group; La, Ce, Nd, Gd and other elements in the lanthanum series; Cu, Ag, Au and other elements in the Ib group; Ga; In; Ge; Sn; Sb; and Bi. Other types of additives are possible, and such additives are selected in accordance with necessity and are added suitably.

Next, detailed explanations will be given of a method of manufacturing an Fe-Si-Aℓ alloy magnetic thin film containing a specified amount of oxygen according to the present invention.

In order to suitably manufacture the magnetic thin film by the method of the present invention, it is possible to adopt any of the normally conducted various types of sputtering. For instance, diode DC glow discharge sputtering, triode DC glow discharge sputtering, RF glow discharge sputtering, magnetron sputtering, or ion beam sputtering may be suitably employed.

Fig. 1 schematically shows a DC magnetron sputtering (RF bias application) apparatus suitable for use in carrying out the method according to the present invention.

DC sputtering apparatus 30 includes a cathode 32 connected to a high-voltage DC power source 31, and a substrate holder 34 connected to an RF bias power source 33 and electrically insulated. A target 35 is disposed on the cathode 32, while a substrate 11 is supported by the holder 34. The apparatus 30 has a first port 36 through which the interior of the apparatus is vacuum pumped by a vacuum pump (not shown), and a second port 37 through which an inert gas is introduced.

Such gas as He, Ne or Ar can be used as the inert gas. Normally, Ar is used. During sputtering, the pressure of the inert gas-based atmosphere is maintained within the range from 1×10^{-4} to 2.0×10^{-1} Torr. (1.33×10^{-4} to 2.67×10^{-1} hPa).

According to the present invention, oxygen gas is introduced into an inert gas atmosphere, and the oxygen concentration is strictly regulated in such a manner that the oxygen concentration in the inert gas-based atmosphere will be 400 to 1500 volumetric ppm during sputtering. If a casted target which contains only a very small amount of oxygen of the order of 3 to 5 ppm by weight is used as the target 35, the oxygen concentration in the inert gas-based atmosphere will, during sputtering, fall within the same range, i.e., from 400 to 1500 volumetric ppm. On the other hand, if a sintered target containing a not-negligible amount of oxygen is used, the oxygen in the target can, during sputtering, flow into the inert gas-based atmosphere and influence the same. Therefore, in this case, the concentration of oxygen contained in the atmosphere must be adjusted before sputtering in accordance with the quality of the target and set at a level lower than the above-described range. For instance, if a sintered target containing 0.14 wt% of oxygen is used, the concentration of the inert gas-based atmosphere is preferably set at about 500 volumetric ppm.

In practice, oxygen gas is introduced from the second port 37 of the sputtering apparatus 30 together with Ar gas. The present inventors have found as a result of their studies and experiments that, during the introduction, the oxygen-containing Ar gas should preferably be supplied as directed toward the substrate 11. If the oxygen-containing Ar gas is directed toward the target 35, this results in the following disadvantages. Oxide film may adhere to a shield (not shown), thereby making frequent cleaning of the shield necessary. Sputtering may become so unstable that a higher oxygen concentration is necessary to achieve the same effect as in the case where the gas supply is directed toward the substrate 11.

The present inventors have conducted various experiments to examine the relationship between the oxygen concentration in the sputtering atmosphere and the oxygen content in the deposited magnetic thin films. In those experiments, a sputtering apparatus, such as that shown in Fig. 1, was used, and a plurality of samples of Fe-Si-Aℓ alloy magnetic thin film were each formed with a thickness of 20 µm (i.e., the thickness corresponding to the total thickness of a magnetic film portion of an actual alloy magnetic film) on a high-purity (purity level: 99.9995%) Ni substrate having a thickness of 0.2 mm and a diameter of 50 mm. The film deposition conditions adopted in the experiments are as follows:

Film Deposition Conditions:

Inert gas: Ar gas
Oxygen concentration: 1500 ppm
Volume Rate of Flow of Inert Gas: 100 sccm
Sputtering Gas Pressure: 5.6×10^{-3} Torr(7.47×10^{-3} hPa)
Input power: 500 W
Substrate temperature: 60° C
Film Deposition Rate: 0.4 µm/min
Target: Cast target (Si: 11.2 wt%, Aℓ: 5.0 wt%, and Fe: the balance, oxygen content: 5 ppm by weight)

When the plurality of alloy magnetic thin film samples were deposited, the amount of oxygen contained in each Fe-Si-Aℓ alloy magnetic thin film sample deposited on the Ni substrate was examined by means of an oxygen-nitrogen analyzing apparatus (a product of LECO; trade name: LECO TC-36) by an inert gas fusion method.

As a result, the average of the amounts of oxygen contained in the Fe-Si-Aℓ alloy magnetic thin film samples was 0.40 wt%, and the relative error of analysis was within ±15%, accounting for 0.06 wt% at most.

Next, two other film samples were deposited by adopting the same film deposition conditions as above except that the oxygen concentration was changed to 400 ppm and 750 ppm. The formed film samples were analyzed in the same manner. As a result, the Fe-Si-Aℓ alloy magnetic thin film samples respectively contained 0.20 wt% of oxygen and 0.31 wt% of oxygen. The analysis relative error was estimated to be within ±15%.

The results of the above-described experiments were analyzed. As a result, it has been found that, as far as those experiments are concerned, the following formula best approximates the relationship between the oxygen content (expressed as y (wt%) in the formula) in the Fe-Si-Aℓ alloy magnetic thin film and the oxygen concentration (x (wt%)) in the sputtering atmosphere. This relationship is also shown in Fig. 3.

$y = -0.70 + 0.35 \log x$ ..... (2)
(coefficient of correlation = 0.99
the value of y has a variation range of ±15%)

From the above-described results of the experiments, it will be understood that, when the amount of oxygen contained in the inert gas-based sputtering atmosphere is 400 volumetric ppm, the amount of oxygen in the resultant magnetic thin film is 0.17 to 0.23 wt%, whereas when the amount of oxygen contained in the inert gas-based sputtering atmosphere is 1500 volumetric ppm, the amount of oxygen in the resultant magnetic thin film is 0.34 to 0.46 wt%. It has also been found that these results of the experiments can be sufficiently supported by a lot of other studies and experiments on alloy magnetic film conducted by the present inventors in view of practical use.

From the above-described studies and experiments of the present inventors, therefore, it has been found that when a cast target is used, it is of importance that the oxygen concentration in the inert gas-based atmosphere should be maintained within the range from 400 to 1500 volumetric ppm. This is because, as will be seen from Fig. 3, if the amount of oxygen contained in the inert gas-based atmosphere is less than 400 volumetric ppm, the amount of oxygen contained in the resultant magnetic thin film can be less than 0.17 wt%. In such cases, the coercive force will exceed 0.35 Oe. On the other hand, if the amount of oxygen contained in the inert gas-based atmosphere exceeds 1500 volumetric ppm, the amount of oxygen contained in the resultant magnetic thin film can greatly exceed 0.46 wt%. It is clear that, in such cases, the value η will be 0.20 or greater.

The present invention will now be described by way of the following non-limiting examples.

Example 1:

Various Fe-Si-Aℓ alloy magnetic thin film samples were each manufactured in the following manner by using the sputtering apparatus shown in Fig. 1.

Used as the target 35 was a cast target essentially consisting of Si: 11.2 wt%; Aℓ: 0.5 wt%, and Fe: the balance, and containing 5 ppm by weight of oxygen, which cast target had a diameter of 4 inches and a thickness of 4 mm. The substrate 11 consisted of a ceramic substrate containing, as its main components, manganese oxide and nickel oxide. The substrate had dimensions of 0.5 mm x 20 mm x 20 mm, and had mirror-finished surfaces. The substrate 11 and the target 35 were placed in the apparatus with a distance of 50 mm therebetween.

An oxygen-containing Ar gas was introduced from an oxygen-containing Ar gas container into the sputtering apparatus while the flow of gas was directed to a position which was 5 mm separated from the substrate 11. The concentration of oxygen in the gas within the apparatus was maintained at a predetermined value. At this time, the gas pressure was 5.6×10^{-3} Torr(7.47×10^{-3} hPa), and the volume rate of flow of the gas was 100 sccm.

Then, sputtering was done. The input power was 500 W, and the substrate was at 60° C. An Fe-Si-Aℓ alloy film was deposited on the substrate 11 at a film deposition rate of 0.4 µm/min through a thickness of 5 µm. The thus obtained alloy film had the composition of Si: 9.0 wt%, Aℓ: 5.0 wt%, and Fe: the balance. When the microstructure of the alloy film was examined, it was different from a columnar microstructure of an alloy film deposited in an atmosphere composed of pure Ar. When, in Example 1, the sputtering atmosphere contained 1500 ppm of oxygen, the resultant alloy film had a dense, fine-grained microstructure.

Thereafter, an inter-layer film (insulating film) was deposited on the Fe-Si-Aℓ alloy film. The interlayer film deposition was conducted by using the magnetron sputtering apparatus used in the Fe-Si-Aℓ alloy film deposition, in which an SiO_2 target having a diameter of 4 inches (10 cm) and a thickness of 5 mm was disposed. Ar gas alone was introduced into the sputtering apparatus. At this time, the Ar gas pressure was 4×10^{-3} Torr (5.33×10^{-3} hPa), and the input RF power was 300 W. Under these conditions, an SiO_2 film with a thickness of 0.3 µm was deposited on the alloy film on the substrate.

The above-described operations were repeatedly conducted four times so as to subsequently deposit alloy films overlying on and alternating with inter-layer insulating films. As a result, a soft magnetic film having a total thickness of 20 µm was obtained, which film was then heat treated.

Further, on the thus obtained soft magnetic film, a glass film was deposited by a normal method. The resultant film product was subjected to a forming process, and it was then used in the fabrication of a thin film stacked magnetic head.

Fig. 2 shows, in solid lines, changes in the coercive force (Hc) of the Fe-Si-Aℓ alloy magnetic thin film and in the value n which occurred when the oxygen concentration in the inert gas-based sputtering atmosphere was changed to various values. The coercive force was measured by means of a 50 Hz B-H tracer.

It will be understood from Fig. 2 that if the amount of oxygen contained in the inert-gas based atmosphere is less than 400 volumetric ppm, the coercive force exceeds 0.35 Oe, whereas if that amount of oxygen exceeds 1500 volumetric ppm, the value η becomes 0.20 or greater. When that amount of oxygen was 3000 volumetric ppm, the film peeled from the substrate.

The graph shown in Fig. 4 is the summary of the relationship of the coercive force and the value η with the oxygen concentration in the film. In the summarization, the recurrence formula obtained from Fig. 3 was used.

It will be understood from Fig. 4 that, if a range of ±15% is allowed for relative error in the analysis of the oxygen concentration in the film, the oxygen concentrations in the film that make the coercive force not more than 0.35 Oe and the value η less than 0.20 range from 0.17 to 0.46 wt%.

Fe-Si-Aℓ alloy magnetic thin film manufactured in an inert gas-based atmosphere having an oxygen concentration of 400 to 1500 volumetric ppm had good magnetic characteristics. In particular, the saturation flux density was 11 kilo-Gauss, and the specific initial permeability at 1 MHz was 3000. The thin film also had a Vickers hardness of 600 kg/mm², a sufficiently satisfactory level.

When the amount of oxygen contained in the Fe-Si-Aℓ alloy magnetic thin film manufactured in the sputtering atmosphere having an oxygen concentration of 400 to 1500 volumetric ppm was measured by means of the above-mentioned oxygen-nitrogen analyzing apparatus (a product of LECO; trade name: LECO TC-36), the oxygen concentration in the film ranged from 0.17 to 0.46 wt%.

Example 2:

Soft magnetic film samples and thin film stacked magnetic head samples were produced in the same manner as in Example 1 except that a sintered target was used as the target 35, the sintered target essentially consisting of Si: 11.2 wt%; Aℓ: 5.0 wt%; and Fe: the balance, and containing 0.14 wt% of oxygen. The coercive force and the value η of the resultant Fe-Si-Aℓ alloy magnetic thin film in relation to the oxygen concentration in the sputtering atmosphere is indicated by broken lines in Fig. 2.

It will be understood from Fig. 2 that if the amount of oxygen contained in the inert-gas based atmosphere is less than 300 volumetric ppm, the coercive force exceeds 0.35 Oe, whereas if that amount of oxygen exceeds 800 volumetric ppm, the value η becomes 0.20 or greater. When that amount of oxygen was 2000 volumetric ppm, the film peeled from the substrate.

Fe-Si-Aℓ alloy magnetic thin film manufactured in an inert gas-based atmosphere having an oxygen concentration of 300 to 800 volumetric ppm had good magnetic characteristics. In particular, the saturation flux density was 11.2 kilo-Gauss, and the specific initial permeability at 1 MHz was 3000. The thin film also had a Vickers hardness of 600 kg/mm², a sufficiently satisfactory level.

When, as in the case of Example 2, the target used is a sintered target containing a not-negligible amount of oxygen, because the oxygen in the target can, during sputtering, flow into the inert gas-based atmosphere and influence the same, the initial oxygen concentration in the inert gas-based atmosphere must be adjusted in accordance with the quality of the target and set to a level lower than the range adopted in Example 1 where a casted target was used.

The Fe-Si-Aℓ alloy magnetic thin film obtained in Example 2 and manufactured in a sputtering atmosphere having an oxygen concentration of 300 to 800 volumetric ppm had its oxygen concentration measured by means of the above-mentioned oxygen-nitrogen analyzing apparatus (a product of LECO; trade name: LECO TC-36). As a result, the oxygen concentration in the film ranged from 0.17 to 0.46 wt%.

Other experiments were conducted under the same condition as those in Example 2 except that a sintered target containing 0.10 wt% of oxygen was used. As a result, magnetic thin film which was manufactured in an inert gas-based atmosphere having an oxygen concentration of 550 to 1050 volumetric ppm had good magnetic characteristics. If a sintered target is used, the initial oxygen concentration Ca (in volumetric ppm) in the inert gas atmosphere is selected from the range expressed by the following formula:

$1175 - (5/8) \cdot Ct \leqq Ca \leqq 1675 - (5/8) \cdot Ct$ ..... (3)

where Ct represents oxygen concentration (ppm by weight) in the target.

As has been described above, an Fe-Si-Aℓ alloy magnetic thin film and a method of manufacturing the same, both according to the present invention, are characterized by the following: The oxygen concentration in the inert gas-based atmosphere during sputtering is strictly regulated so that the amount of oxygen in the resultant Fe-Si-Aℓ alloy magnetic thin film will be specified as being within a very limited range. This regulation enables the provision of an Fe-Si-Aℓ alloy magnetic thin film having a coercive force (Hc) of not more than 0.35 Oe and a value η of less than 0.20 that indicates a change in the specific initial permeability at 1 MHz caused by application of a certain strain. The thin film is also capable of maintaining high magnetic permeability and high hardness while avoiding the risk of a drop in saturation flux density.

Claims

1. An Fe-Si-A alloy magnetic thin film containing, as the main components thereof, Fe, Aℓ and Si, and additionally containing 0.17 to 0.46% by weight of oxygen.

2. A film according to claim 1, which contains 4 to 7 wt % Aℓ and 8 to 12% Si.

3. A film according to claim 1 or claim 2, which contains Co and/or Ni, for instance in an amount up to about 52 wt % of the film.

4. A film according to claim 1, 2 or 3, which contains in an amount of less than 10 wt % of the film, one or more elements selected from: Y; Ti, Zr, Hf; V, Nb, Ta; Cr, Mo, W; Mn, Tc, Re; La, Ce, Nd, Gd, Cu, Ag, Au; Ga; In; Ge; Sn; Sb; Bi.

5. A method of manufacturing an Fe-Si-Aℓ alloy magnetic thin film comprising the steps of:
preparing a sputtering target and an inert gas-based atmosphere having a strictly regulated concentration of oxygen, the oxygen concentration of said inert gas-based atmosphere being set at 400 to 1500 volumetric ppm if said target is a cast target, whereas, if said target is a sintered target, said oxygen concentration is adjusted in accordance with the quality of said target and set at a level lower than the above-mentioned range; and
effecting sputtering employing said target and said inert gas-based atmosphere.

6. A method according to claim 5, wherein the target is a sintered target and the initial oxygen concentration in the inert atmosphere (Ca) in volumetric ppm is set such that:

$1175 - (5/8) \times Ct \leqq Ca \leqq 1675 - (5/8) \times Ct$

where Ct is the oxygen concentration in the target in ppm by weight.

7. A method according to claim 5, wherein the target is a sintered target having an initial oxygen concentration of 0.14 wt % and the oxygen concentration in the inert atmosphere is set to 300 to 800 volumetric ppm.

FIG. 1

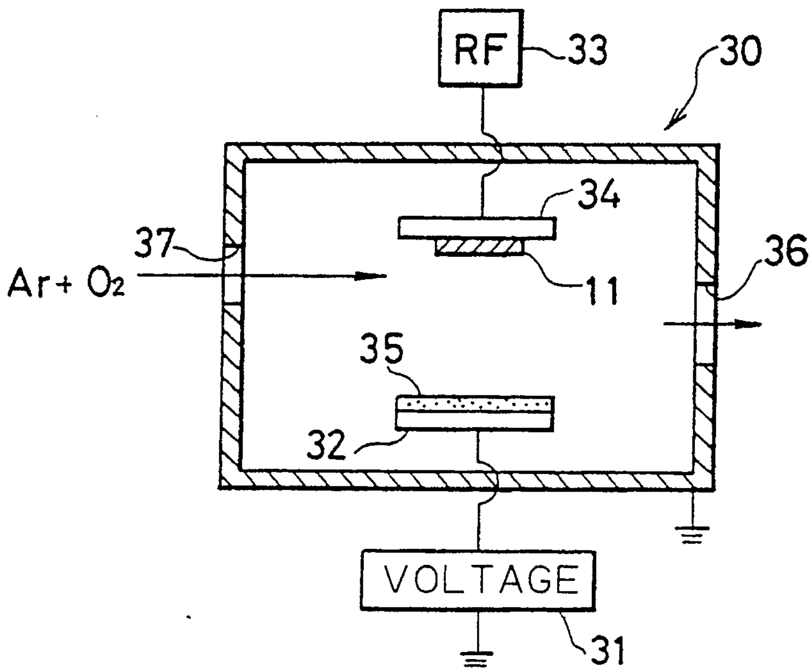


FIG.2

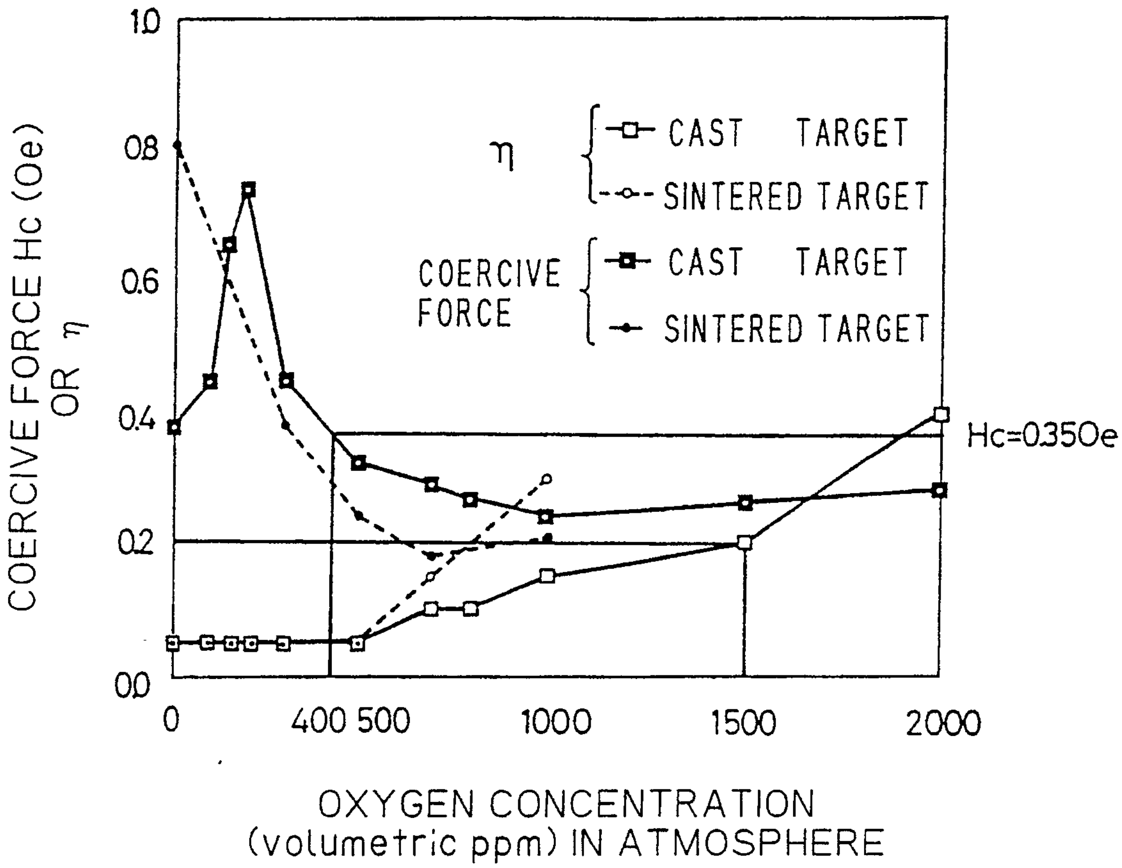

COERCIVE FORCE Hc (Oe)
OR η
1.0
0.8
0.6
0.4
0.2
0.0
η
CAST TARGET
SINTERED TARGET
COERCIVE FORCE
CAST TARGET
SINTERED TARGET
Hc=0.35Oe
0
400 500
1000
1500
2000
OXYGEN CONCENTRATION
(volumetric ppm) IN ATMOSPHERE

FIG.3

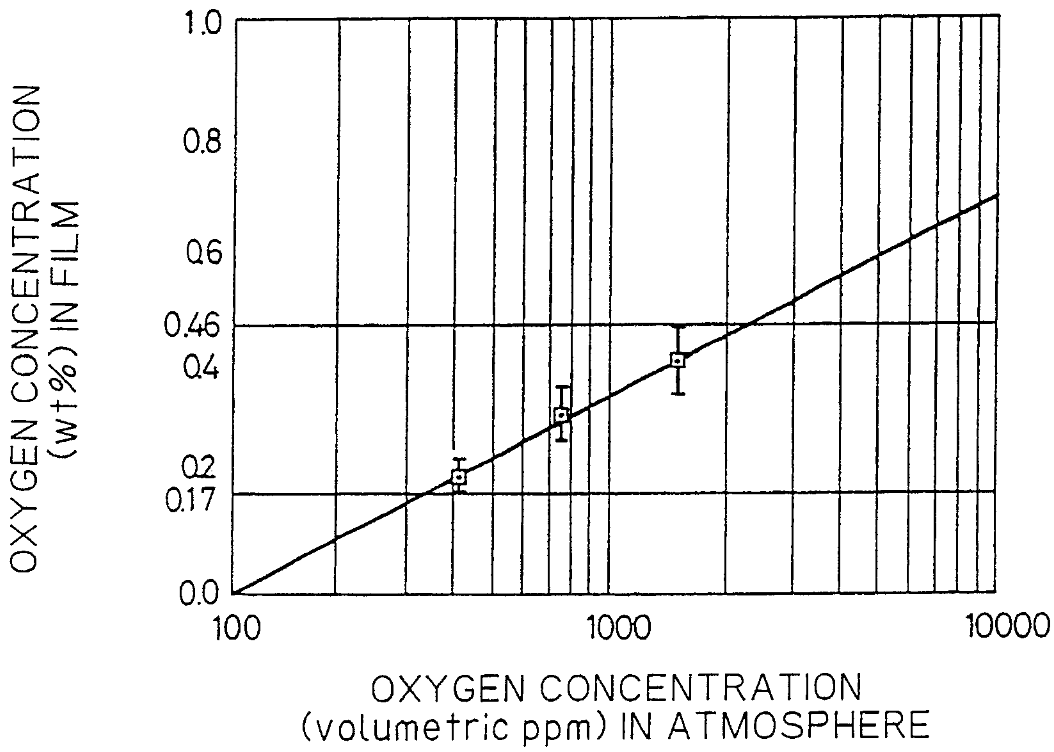
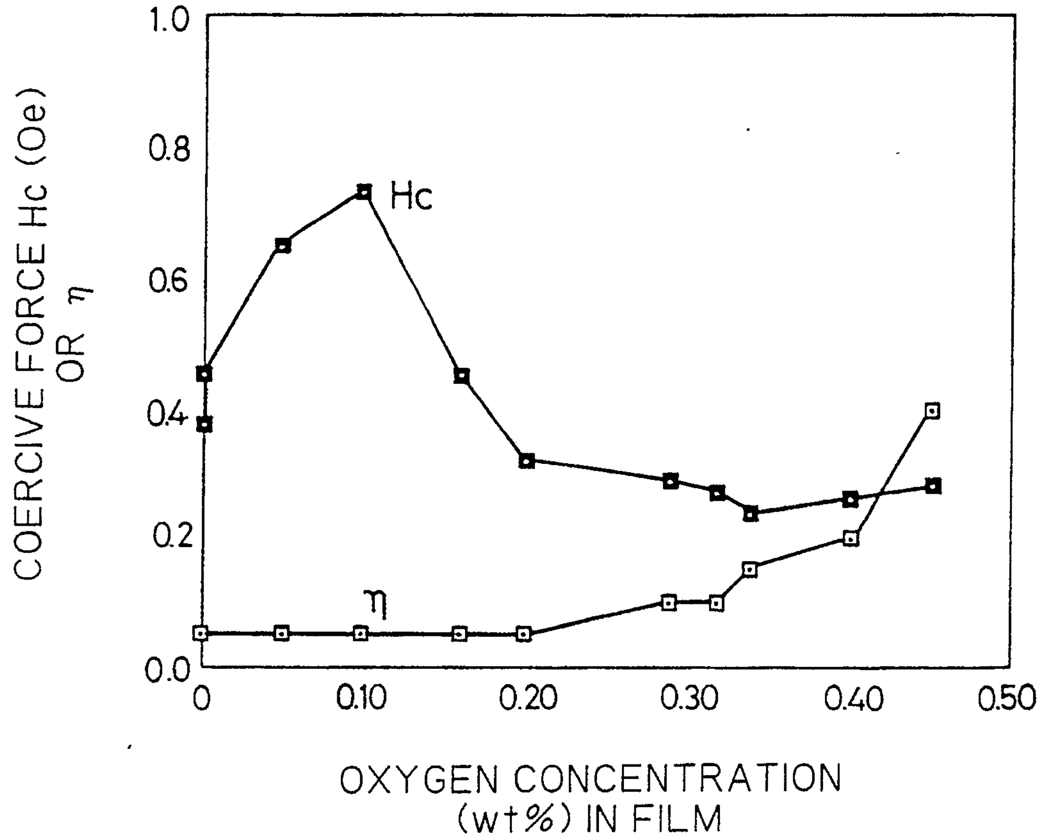

1.0
0.8
0.6
0.46
0.4
0.2
0.17
0.0
OXYGEN CONCENTRATION
(wt%) IN FILM
100
1000
10000
OXYGEN CONCENTRATION
(volumetric ppm) IN ATMOSPHERE

FIG.4


1.0
0.8
0.6
0.4
0.2
0.0
COERCIVE FORCE Hc (Oe) OR η
Hc
η
0
0.10
0.20
0.30
0.40
0.50
OXYGEN CONCENTRATION (wt%) IN FILM