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(54) **Silicon steel having low residual magnetic flux density**

Siliziumstahl mit niedrigem Restgehalt an magnetische Flussdichte

Acier au silicium ayant une basse teneur en densité de flux magnétique résiduel

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DescriptionBACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The present invention relates to a silicon steel sheet having low residual magnetic flux density, which is used as a core of distribution transformers, electric power and industrial equipment transformers, direct current sensors, and current transformers.

10 2. Description of the Related Arts

[0002] Generally, distribution transformers use grain-oriented silicon steel sheets because that type of sheets allow the design of high magnetic flux density while suppressing the iron loss to a low level. The grain-oriented silicon steel sheets have, however, a drawback of residual induction owing to their high residual magnetic flux density. When residual induction exists, distribution transformers in buildings and in an environment that widely uses inverter power source may induce overcurrent in case of power failure or in case of reclosing of power because of the saturation of magnetic flux, and may finally result in the occurrence of iron loss in the power source equipment of power distribution system and further the generation of serious damages on other power system. To prevent such defects, distribution transformers are designed to reduce residual magnetic flux density by placing a gap in magnetic path to avoid the occurrence of residual induction.

[0003] Owing to the design, the characteristic of high magnetic flux density which is an inherent feature of grain-oriented silicon steel sheets cannot be utilized, and the transformer becomes large. In addition, existence of gap increases iron loss at the gap portion.

[0004] Direct current sensors have a gap in magnetic path, and detects the magnetic flux crossing the gap. Also the direct current sensors have similar problem as the distribution transformers have. That is, owing to the high residual magnetic flux density in core, the sensor cannot function in detecting current during a period of decreasing the current from a high level to a low level because of the residual magnetism in the core.

[0005] For power and transmission current transformers, cutting may be applied thereto for preventing error in evaluation of break of transmission line induced by the occurrence of residual induction under accidental overcurrent resulted from lightening or the like.

SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to provide a silicon steel sheet having low residual magnetic flux density, which is able to prevent the occurrence of residual induction without giving gap thereto.

[0007] To attain the object, the present invention provides a silicon steel sheet having low residual magnetic flux density. The silicon steel sheet comprises Fe of a base element, Si of an alloying element, a concentration gradient of Si over the entire thickness direction of the steel sheet. The concentration gradient has a maximum Si concentration and a minimum Si concentration. An average Si concentration is at most 7 wt.%. A difference between the maximum Si concentration and the minimum Si concentration is at least 0.5 wt.%.

[0008] The difference between the maximum Si concentration and the minimum Si concentration may be at least 5.5 wt.%.

[0009] The difference between the maximum Si concentration and the minimum Si concentration may be from 0.5 to 5.5 wt.%.

[0010] The average Si concentration may be at most 3.5 wt.%.

[0011] It is preferable that the silicon steel sheet is a grain-oriented silicon steel sheet having a Goss Orientation $\{110\langle 001 \rangle\}$. The silicon steel sheet has a surface layer and a central portion in a thickness direction, a Si concentration in the surface layer is higher than a Si concentration in the central portion. A difference in Si concentration between the surface layer and the central portion is at least 0.5 wt.%.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Fig. 1 is a graph showing the values of residual magnetic flux density B_r with several levels of average Si concentration and ΔSi under magnetization up to the maximum magnetization level of $B_m = 1.4T$.

[0013] Fig. 2 is a graph showing a relation between the average Si concentration and the saturation magnetic flux density.

[0014] Fig. 3 is a graph showing the values of iron loss $W_{12/50}$ with several levels of average Si concentration and

of ΔSi under a condition of 50 Hz AC and $B_m=1.2\text{T}$.

[0015] Fig. 4 is a graph showing a relation between the ΔSi and residual magnetic flux density

DESCRIPTION OF THE EMBODIMENTS

Embodiment 1

[0016] The specification of average Si concentration in a silicon steel sheet and the creation of a specific concentration gradient of Si therein in sheet thickness direction thereof significantly decreases the residual magnetic flux density without increasing iron loss. The specification of Si concentration and Si concentration gradient further decreases the residual magnetic flux density, decreases the iron loss, or increases the saturation magnetic flux density.

[0017] As described above, the silicon steel sheet according to Embodiment 1 is basically the one comprising 7 wt.% or less of Si at an average, wherein the sheet has a Si concentration gradient in thickness direction thereof, while the difference in Si concentration between the maximum and the minimum thereof is 0.5 wt.% or more.

[0018] Fig. 1 shows the values of residual magnetic flux density (B_r) in the case that a Si concentration gradient is created in sheet thickness direction. The samples used were taken from a steel sheet having a thickness of 0.3 mm prepared by rolling method, followed by siliconizing in a SiCl_4 atmosphere at 1200°C and then by diffusion treatment in a N_2 atmosphere at 1200°C to create various kinds of Si content and Si concentration gradient in sheet thickness direction. The horizontal axis is the average Si content, and the vertical axis is the difference of Si concentration between the maximum and the minimum, or ΔSi . Fig. 1 indicates the residual magnetic flux density B_r on each of the direct current BH curves under magnetization of individual points up to the maximum magnetization $B_m = 1.4\text{T}$. The values of ΔSi are the result of EPMA (electron probe microanalyzer) on a cross section of each sample.

[0019] Fig. 1 suggests that the creation of Si concentration gradient in sheet thickness direction and the increase in ΔSi monotonously decrease the residual magnetic flux density. If the value of ΔSi is selected to 0.5% or more, then sufficiently low residual magnetic flux density is obtained.

[0020] Therefore, Embodiment 1 includes the requirements to create a Si concentration gradient and to adjust the difference of Si concentration between the maximum and the minimum thereof, or ΔSi , to 0.5 wt.% or more. More preferably, ΔSi is 0.7 wt.% or more to obtain stably a low residual magnetic flux density.

[0021] As seen in Fig. 1, when the value of ΔSi is 5.5 wt.% or more, a very low residual magnetic flux density as low as 0.1T or less is obtained. Consequently, the present invention includes a requirement of 5.5 wt.% or more of ΔSi for decreasing the residual magnetic flux density.

[0022] In that case, the method to determine Si concentration in sheet thickness direction is not specifically limited, and an X-ray microanalyzer such as EPMA is preferred.

[0023] The concept to create a Si concentration gradient in thickness direction of steel sheet is disclosed in Japanese Patent Publication Laid-Open Nos. 62-227033 through 62-227036, Japanese Patent Publication Laid-Open No. 62-227077, and Japanese Patent Publication Laid-Open No. 4-246157. The object of the disclosed patent publications is to shorten the diffusion treatment time by an intermission of diffusion treatment during the manufacturing process of high silicon steel sheet using siliconizing process. The Si concentration gradient is created simply as a result of the treatment. Accordingly, these patent publications do not imply a concept to positively create a Si concentration gradient.

According to these patent publications, the period of intermission of diffusion treatment is determined in a range not to degrade iron loss. The iron loss is determined by various variables, and the reduction of iron loss needs to increase the residual magnetic flux density. Consequently, the technology disclosed in the above-described patent publications can be said to determine the allowable limit of Si concentration gradient within a range not to excessively reduce the residual magnetic flux density. To the contrary, Embodiment 1 creates positively a Si concentration gradient to reduce the residual magnetic flux density, so that the technical concept according to Embodiment 1 completely differs from that in the above-described patent publications.

[0024] Inrush current induced by residual induction relates to a saturation magnetic flux density as well as the residual magnetic flux density, and the inrush current decreases with increase in the saturation magnetic flux density. To this point, even when a concentration gradient is created in sheet thickness direction to decrease the residual magnetic flux density, sufficient effect cannot be expected if the saturation magnetic flux density decreases. Since, as seen in Fig. 2, the saturation magnetic flux density is inversely proportional to an average Si amount added, excessive Si content is unfavorable. When, the average Si concentration exceeds 7%, the workability is degraded, and punching performance is significantly degraded. Therefore, the present invention includes a requirement to secure the Si concentration to 7 wt.% or less as an average.

[0025] Decrease in Si content increases the saturation magnetic flux density. Particularly when the Si content becomes to 3.5 wt.% or less, the saturation magnetic flux density becomes remarkably high value, or 2.0T or more. Consequently, the present invention sets a condition to particularly increase the saturation magnetic flux density by specifying the Si concentration to 3.5 wt.% or less, the creation of Si concentration gradient in sheet thickness direction,

and the difference of concentration between the maximum and the minimum thereof to 0.5 wt.% or more.

[0026] The average Si concentration referred in Embodiment 1 is the one obtained by chemical analysis.

[0027] Regarding the concentration gradient of alloying element according to the present invention, there is no condition on the profile of gradient, whether the central part in the sheet thickness direction has higher or lower level than that in the edge parts, and, the only requirement is to have a concentration gradient in the sheet thickness direction. The case that a continuous concentration gradient exists from the surface of one side to the surface of other side is also included. The method to create that type of concentration gradient is not specifically limited, and a preferred method is siliconizing in a SiCl_4 atmosphere as described above, followed by diffusion treatment.

[0028] As a feature of the hysteresis curve of the soft magnetic alloy according to the present invention, there is a B_m dependency of B_r/B_m which is the ratio of the residual magnetic flux density B_r to the maximum magnetic flux density B_m . That is, increase in B_m saturates B_r , so the increase in B_m lowers the value of B_r/B_m . Accordingly, there is an advantage of attaining a high level of magnetic flux density in practical application.

[0029] Regarding the iron loss, Fig. 3 shows the data of iron loss $W_{12/50}$ observed in the steel sheet used in the analysis of Fig. 1 under a condition of 50 Hz AC and 1.2T of B_m . The figure shows that, by satisfying the basic requirements of the present invention, or by specifying the Si concentration to 7 wt.% or less, the creation of Si concentration gradient in sheet thickness direction, and the difference of concentration between the maximum and the minimum thereof to 0.5 wt.% or more, a practically applicable silicon steel sheet having less residual magnetic flux density and low iron loss is obtained.

[0030] Fig. 3 also indicates that, within a range of ΔSi from 0.5 to 5.5 wt.%, the iron loss becomes very low, or $W_{12/50}$ being 2.0W/kg or less. Therefore, the present invention specifies the Si concentration to 7 wt.% or less as an average, the creation of a Si concentration gradient in sheet thickness direction, and the difference of concentration between the maximum and the minimum thereof to a range of from 0.5 to 0.5 wt.%, for particularly decreasing the iron loss while maintaining the residual magnetic flux density at a low level.

[0031] According to Embodiment 1, elements other than Si are not specifically specified, and the other elements are acceptable if only they are at a level existing in ordinary silicon steel sheets.

Example

[0032] A steel sheet having a thickness of 0.3 mm and having a composition given in Table 1 was prepared by rolling process. The sheet was subjected to siliconizing in a SiCl_4 atmosphere at 1200°C, followed by diffusion treatment in a N_2 atmosphere at 1200°C to produce a silicon steel sheet having a Si concentration gradient in sheet thickness direction.

Table 1

	wt. %						
	C	Si	Mn	P	S	sol.Al	N
Steel sheet A	0.002	<0.1	0.01	0.003	0.0009	0.001	0.001
Steel sheet B	0.003	2.86	0.01	0.003	0.0003	0.001	0.002

[0033] The average Si concentration of the prepared sample was determined by wet analysis, and the difference of Si concentration between the maximum and the minimum thereof, or ΔSi , was determined by EPMA. As for the steel sheet A in Table 1, the average Si concentration of prepared sample was in a range of from 0.4 to 3.0 wt.%. For the steel sheet B in Table 1, the average Si concentration of prepared sample was in a range of from 3.5 to 6.8 wt.%. The content of elements other than Si showed very little change before and after the siliconizing.

[0034] From thus prepared steel sheet, specimens in ring shape having the dimensions of 31 mm in outer diameter and 19 mm in inner diameter were cut to prepare. These specimens were subjected to determination of direct current BH curves and 50 Hz Ac magnetic characteristics.

[0035] Fig. 1 shows the values of residual magnetic flux density B_r on direct current BH curves under magnetization up to the maximum magnetization level $B_m = 1.4\text{T}$. As seen in Fig. 1, it was proved that the silicon steel sheet having low residual magnetic flux density B_r is obtained by creating a Si concentration gradient in sheet thickness direction at a Si concentration level of this example and by selecting the value of ΔSi to 0.5 wt.% or more. Furthermore, by bringing the value of ΔSi to 5.5 wt.% or more, a very low B_r value as low as 0.1T or less was realized. The relation between the average Si concentration and the saturation magnetic flux density is given in Fig. 2. As shown in Fig. 2, the saturation magnetic flux density became extremely high level, or 2.0T or more, at an average Si concentration of 3.5 wt.% or more.

[0036] Fig. 3 shows the values of iron loss $W_{12/50}$ observed under a condition of 50 Hz AC and 1.2T of B_m . As seen

in Fig. 3, it was proved that the practically applicable silicon steel sheet having low residual magnetic flux density and low iron loss is obtained by creating a Si concentration gradient in sheet thickness direction at a Si concentration level of this example and by selecting the value of ΔSi to 0.5 wt. % or more. In addition, under a condition of ΔSi in a range of from 0.5 to 5.5 wt.%, an extremely low iron loss, or $W_{12/50}$ being 2.0W/kg or less, was obtained.

Embodiment 2

[0037] The inventors found that the creation of a Si concentration gradient in sheet thickness direction significantly decreases the residual magnetic flux density.

[0038] Embodiment 2 was completed based on the above-described findings. Embodiment 2 provides a grain-oriented silicon steel sheet having low residual magnetic flux density, having a Si concentration gradient in sheet thickness direction thereof, wherein a Si concentration in a surface layer is higher than that at a central portion of the sheet thickness thereof, and wherein the difference in Si concentration between the surface layer and the central portion of the sheet thickness is 0.5 wt. % or more.

[0039] It is preferable that an average Si concentration over the total sheet thickness is in a range of from 3 to 7 wt. %. It is desirable that the Si concentration in the surface layer is 7.5 wt. % or less.

[0040] Fig. 4 shows the change of values of residual magnetic flux density (Br) in the case that a Si concentration gradient is created in sheet thickness direction of the grain-oriented silicon steel sheet. The sample used was prepared by siliconizing a grain-oriented silicon steel sheet containing 3.1 wt.% of Si and having a thickness of 0.3 mm. The siliconization was carried out by reacting the steel sheet heated to 1200°C with a mixed gas of 20 vol.% of SiCl_4 and 80 vol.% of N_2 , thus penetrating Si from the surface of the steel sheet, followed by soaking the steel sheet in N_2 atmosphere to perform diffusion to a central portion of the sheet thickness. Various kinds of samples having different Si concentration gradients were prepared by changing the Si penetration time and the diffusion time. The magnetic characteristics of thus prepared samples were determined.

[0041] Fig. 4 shows data of residual magnetic flux density observed under a condition of 50 Hz and magnetization up to 1.4T. The horizontal axis is the difference of Si concentration between the maximum and the minimum thereof, or ΔSi , derived from quantitative analysis of Si on a cross section of sample using EPMA.

[0042] Fig. 4 shows that the creation of Si concentration gradient in sheet thickness direction and the increase in ΔSi monotonously decrease the residual magnetic flux density. Fig. 4 also suggests that, to decrease the residual magnetic flux density by 10% or more, the value of ΔSi is necessary to be selected to 0.5% or more.

[0043] Therefore, Embodiment 2 includes the requirements to create a Si concentration gradient and to establish a minimum Si concentration at near the center of the sheet thickness lower than the Si concentration in the surface layer by 0.5 wt. % or more.

[0044] In that case, the method to determine Si concentration in sheet thickness direction is not specifically limited, and a EPMA is preferred.

[0045] The grain-oriented silicon steel sheet according to Embodiment 2 is typically the one having one orientation such as the Goss orientation. Nevertheless, Embodiment 2 is not limited to the one having one orientation.

[0046] Since a Goss-oriented silicon steel sheet as the base material becomes difficult to form Goss orientation if the average Si concentration over the total sheet thickness is 3 wt. % or less, the average Si concentration thereover is preferably at 3 wt. % or more. On the other hand, if the average Si concentration thereover increases, the Si content in the surface layer increases to degrade workability. From the standpoint of workability, the surface Si concentration is preferably at 7.5 wt. % or less, thus the average Si concentration is preferably at 7 wt. % or less. Accordingly, the present invention specifies a preferred value of average Si concentration to a range of from 3 to 7 wt. %, and, further specifies a preferred Si concentration in the surface layer to 7.5 wt. % or less.

[0047] According to Embodiment 2, contained elements other than Si are not specifically specified, and these other elements are acceptable if only they are at a level appeared in ordinary grain-oriented silicon steel sheets.

Example

[0048] A grain-oriented silicon steel sheet having a thickness of 0.3 mm, having a Goss orientation, and having a composition given in Table 1 was treated by siliconizing and diffusion in a continuous siliconizing line to create a Si concentration in sheet thickness direction. The applied siliconizing line comprised heating, siliconizing, diffusing, and cooling zones, and an insulation film coating unit. In the siliconizing line, the sheet was heated to 1200°C, then reacted with SiCl_4 gas to form Fe_3Si on the surface of the steel sheet, followed by diffusion-soaking to let Si diffuse into the central portion of the sheet thickness to create a Si concentration gradient. During the treatment, the concentration of SiCl_4 gas and the soaking time were changed to prepare steel sheets having different Si profile to each other. All the steel sheets contained similar composition of elements other than Si before and after the siliconization to each other.

Table 2

WT%					
C	Si	Mn	S	sol. Al	N
0.002	3.25	0.074	0.024	0.029	0.0086

[0049] From each of thus prepared silicon sheets, a transformer with 50 Hz, single phase, and 1 kVA of capacity was fabricated, and the inrush current was determined under a phase control. The observed values of residual magnetic flux density, magnetic flux density B₈, and inrush current are shown in Table 2. The residual magnetic flux density was the value determined under a condition of 50 Hz and magnetization up to 1.4T. The inrush current was the value determined under a condition that the transformer was magnetized up to 1.4T, and was expressed by a ratio to the rated current. Table 3 shows the observed values of Δ Si, Si concentration in the surface layer, average Si concentration, residual magnetic flux density, magnetic flux density B₈, and inrush current ratio.

Table 3

No.	Sample	Δ Si (wt%)	Si content in surface layer (wt%)	Average Si content (wt%)	Residual magnetic flux density (T)	Magnetic flux density B ₈ (T)	Inrush current ratio
1	Comparative material	0.3	6.65	6.43	1.02	1.74	23
2	Material of the invention	1.6	6.61	5.64	0.70	1.80	7
3	Material of the invention	2.1	7.93	6.78	0.59	1.78	5
4	Material of the invention	2.0	6.01	4.96	0.60	1.86	5
5	Material of the invention	0.6	5.31	4.96	0.93	1.87	11

[0050] Table 3 proved that the conditions satisfying the range of the present invention give low residual magnetic flux density so that the inrush current characteristics are superior. Consequently, it was proved that the present invention provides a grain-oriented silicon steel sheet for transformers giving low inrush current. The sample No. 3 in Table 2 was inferior in workability owing to large Si content.

Claims

1. A silicon steel sheet having low residual magnetic flux density, the silicon steel sheet comprising:

Fe of a base element;
 Si of an alloying element;
 a concentration gradient of Si over the entire thickness direction of the steel sheet, the concentration gradient having a maximum Si concentration and a minimum Si concentration;
 an average Si concentration of at most 7 wt.%; and
 a difference between the maximum Si concentration and the minimum Si concentration being at least 0.5 wt. %.

2. The silicon steel sheet of claim 1, wherein the difference between the maximum Si concentration and the minimum Si concentration is at least 5.5 wt. %.

3. The silicon steel sheet of claim 1, wherein the average Si concentration is at most 3.5 wt. %.

4. The silicon steel sheet of claim 1, wherein the difference between the maximum Si concentration and the minimum Si concentration is from 0.5 to 5.5 wt. %.

5. The silicon steel sheet of claim 1, wherein

the silicon steel sheet is a grain-oriented silicon steel sheet having a Goss Orientation $\{(110)\langle 001 \rangle\}$;
 the silicon steel sheet has a surface layer and a central portion in a thickness direction, a Si concentration in
 the surface layer is higher than a Si concentration in the central portion; and
 a difference in Si concentration between the surface layer and the central portion is at least 0.5 wt.%.
 5

6. The silicon steel sheet of claim 5, wherein the Si concentration in the surface layer is at most 7.5 wt.%.

7. The silicon steel sheet of claim 5, wherein the average Si concentration in the thickness direction is from 3 to 7 wt.%.
 10

Patentansprüche

1. Siliziumstahlblech mit einer geringen restlichen magnetischen Flußdichte, wobei das Siliziumstahlblech umfaßt:

Fe als Basiselement;
 Si als Legierungselement;
 einen Konzentrationsgradienten des Si über die gesamte Dickenrichtung des Stahlblechs, wobei der Gradient
 eine maximale Si-Konzentration und eine minimale Si-Konzentration aufweist;
 eine mittlere Si-Konzentration von maximal 7 Gew.%; und
 einen Unterschied zwischen der maximalen Si-Konzentration und der minimalen Si-Konzentration von min-
 destens 0,5 Gew.%.
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2. Siliziumstahlblech gemäß Anspruch 1, worin der Unterschied zwischen der maximalen Si-Konzentration und der
 minimalen Si-Konzentration mindestens 5,5 Gew.% beträgt.
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3. Siliziumstahlblech gemäß Anspruch 1, worin die mittlere Si-Konzentration maximal 3,5 Gew.% beträgt.

4. Siliziumstahlblech gemäß Anspruch 1, worin der Unterschied zwischen der maximalen Si-Konzentration und der
 minimalen Si-Konzentration von 0,5 bis 5,5 Gew.% beträgt.
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5. Siliziumstahlblech gemäß Anspruch 1, worin
 das Siliziumstahlblech ein Korn-orientiertes Siliziumstahlblech mit einer Goss-Orientierung $\{(110)\langle 001 \rangle\}$ ist;
 das Siliziumstahlblech eine Oberflächenschicht und einen Zentralabschnitt in Dickenrichtung aufweist, wobei die
 Si-Konzentration in der Oberflächenschicht höher ist als die Si-Konzentration im Zentralabschnitt; und
 der Unterschied in der Si-Konzentration zwischen der Oberflächenschicht und dem Zentralabschnitt mindestens
 0,5 Gew.% beträgt.
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6. Siliziumstahlblech gemäß Anspruch 5, worin die Si-Konzentration in der Oberflächenschicht maximal 7,5 Gew.%
 beträgt.
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7. Siliziumstahlblech gemäß Anspruch 5, worin die mittlere Si-Konzentration in der Dickenrichtung von 3 bis 7 Gew.
 % beträgt.
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Revendications

1. Tôle d'acier au silicium ayant une faible densité de flux magnétique résiduel, la tôle d'acier au silicium comprenant :

- du Fe en élément de base ;
- du Si en élément d'alliage ;
- du Si présentant un gradient de concentration en épaisseur de la tôle d'acier, le gradient de concentration
 ayant une concentration en Si maximale et une concentration en Si minimale ;
 50

une concentration en Si moyenne au maximum de 7 % en poids ; et
 une différence entre la concentration en Si maximale et la concentration en Si minimale étant au moins de
 0,5 % en poids.
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2. Tôle d'acier au silicium selon la revendication 1, dans laquelle la différence entre la concentration en Si maximale et la concentration en Si minimale est au moins de 5,5 % en poids.
- 5 3. Tôle d'acier au silicium selon la revendication 1, dans laquelle la concentration en Si moyenne est au maximum de 3,5 % en poids.
4. Tôle d'acier au silicium selon la revendication 1, dans laquelle la différence entre la concentration en Si maximale et la concentration en Si minimale est de 0,5 à 5,5 % en poids.
- 10 5. Tôle d'acier au silicium selon la revendication 1, dans laquelle
la tôle d'acier au silicium est une tôle d'acier au silicium à grains orientés ayant une orientation Goss $\{(110) <001>\}$;
la tôle d'acier au silicium a une couche superficielle et une partie centrale dans la direction de son épaisseur, une concentration en Si dans la couche superficielle est supérieure à une concentration en Si dans la partie
15 centrale ; et
une différence dans la concentration en Si entre la couche superficielle et la partie centrale est au moins de 0,5 % en poids.
- 20 6. Tôle d'acier au silicium selon la revendication 5, dans laquelle la concentration en Si dans la couche superficielle est au moins de 7,5 % en poids.
7. Tôle d'acier au silicium selon la revendication 5, dans laquelle la concentration en Si moyenne dans la direction de son épaisseur est de 3 à 7 % en poids.

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FIG. 1

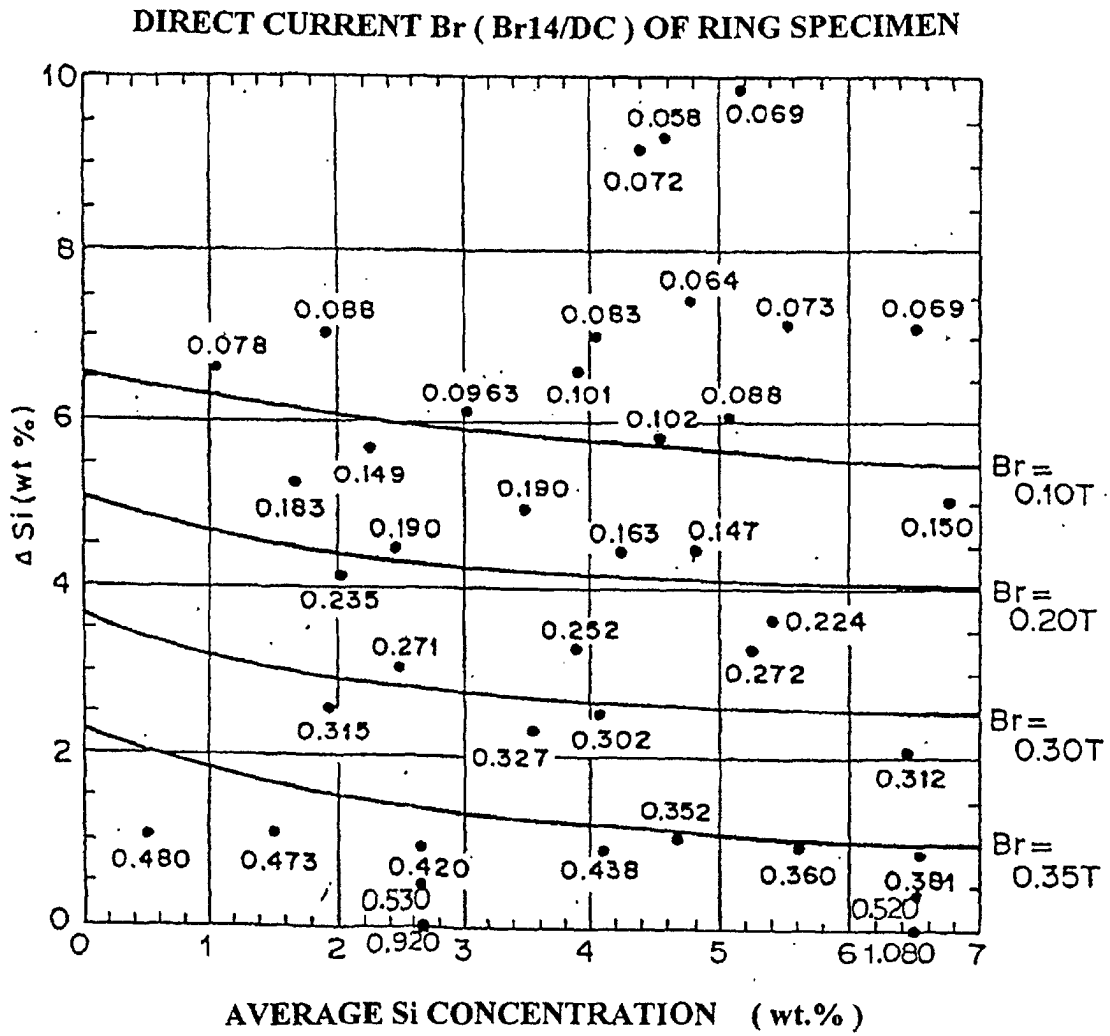


FIG. 2

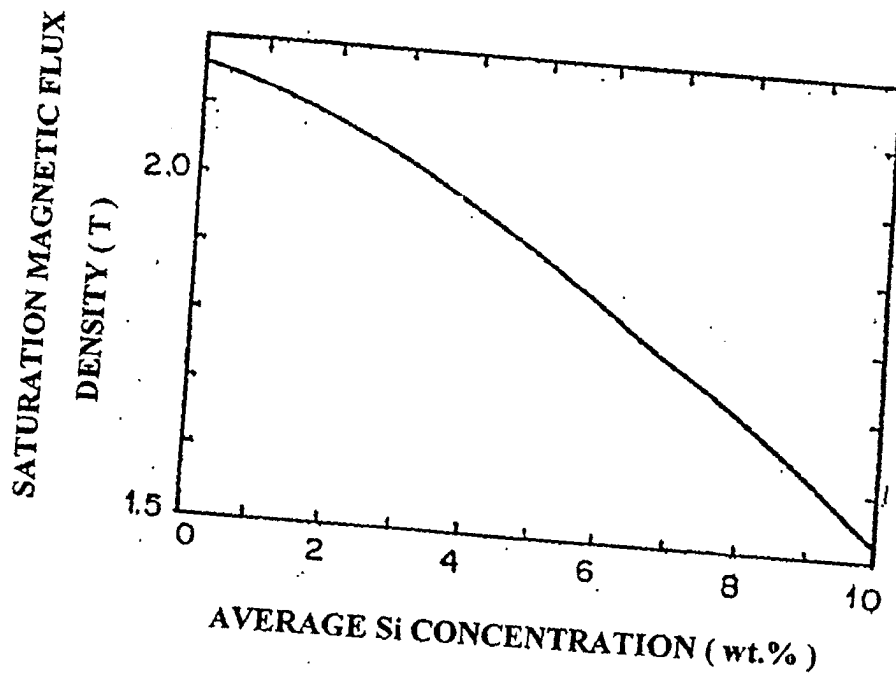


FIG. 3

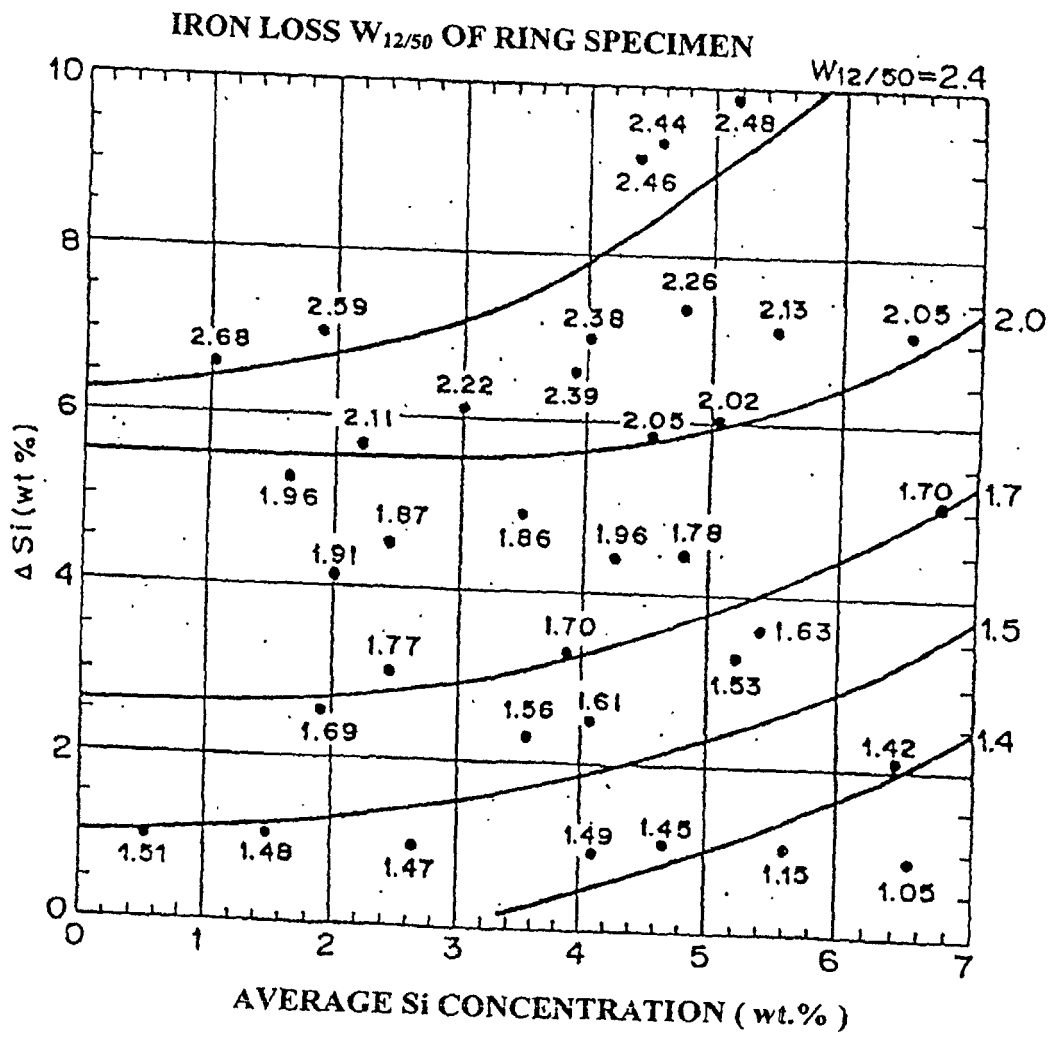


FIG. 4

