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⑤④ **Wound iron core.**

⑤⑦ A wound iron core formed by winding a thin strip of a soft magnetic alloy into a triodal form, characterized in that a Co-base amorphous magnetic alloy is used as the thin strip and that the thin strip is annealed in a magnetic field in the direction of excitation, so that the core exhibits a rectangle ratio B_r/B_{10} of 85% or higher in D.C. hysteresis curve. The Co-base amorphous magnetic alloy has a composition substantially expressed by: $Co_{100-a-b}X_aY_b$ where X represents one, two or more elements selected from a group consisting of Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, while Y represents one, two or more elements selected from a group consisting of B, C, Al, Si, P and Ge, and wherein the following conditions are met: $0 \leq a \leq 15$ (atom%) and $14 \leq b \leq 30$ (atom%).

WOUND IRON CORE

1 BACKGROUND OF THE INVENTION

The present invention relates to a wound iron core made of a Co-base amorphous alloy and exhibiting a rectangular hysteresis property, as well as a superior
5 soft magnetic property.

Wound iron cores made of, for example, anisotropic 50% Ni permalloy, supermalloy, directional silicon steel or the like material are finding use in magnetic phase shifters, magnetic amplifiers, D.C.
10 current detectors, magnetic modulators and nowadays in S. W and R of magnetic amplifier control system. As is well known, these conventional wound iron cores have a large rectangle ratio Br/B_{10} in the B-H hysteresis curve. Recently, however, there is an increasing demand
15 for a wound iron core which exhibits not only a large rectangle ratio Br/B_{10} but also a small coercive force H_c .

In S. W and R of magnetic amplifier control system, the wound iron core is used at a high frequency
20 of an order of several tens of kilohertz (KHz) or higher. The 50% Ni permalloy, which is one of the conventionally used materials, exhibits a coercive force H_c which is as large as 0.1 Oe to cause a large loss in the core resulting in a large heat generation. This gives a

1 rise to a demand for a wound iron core having a rectangle ratio B_r/B_{10} equivalent to that of the 50% Ni permalloy and a coercive force H_c smaller than that of the same.

5 Among the wound iron cores used hitherto, the core of permalloy system such as of 50% Ni permalloy, supermalloy and so forth has a high sensitivity to strain of the magnetic material, so that the magnetic property is deteriorated seriously due to mechanical
10 strain incurred during handling, transportation and winding or coiling thereby making it impossible to attain the expected performance of the wound iron core and the electric balance. In addition, these conventional materials for forming the wound iron core are
15 produceable only through a careful and complicated process having the steps such as melting, ingot making, hot rolling, pickling, cold rolling and so forth, so that the production cost is raised uneconomically.

SUMMARY OF THE INVENTION

20 Accordingly, an object of the invention is to provide a less-expensive wound iron core having a rectangle ratio B_r/B_{10} equivalent to that of ordinarily used 50% Ni permalloy and smaller coercive force than the same, while offering various advantages such as
25 superior stability against strain and a high impact resistance, as well as easiness in heat treatment for

1 attaining the rectangular hysteresis property, thereby
to overcome the above-described problems of the prior
art.

To this end, according to the invention, a
5 thin sheet of Co-base amorphous alloy is used as the
thin sheet having high magnetic permeability for consti-
tuting the wound iron core, and this sheet is subjected
to an annealing in a magnetic field in the direction of
excitation.

10 Above and other objects, features and advan-
tages of the invention will become clear from the
following description of the preferred embodiment of the
invention taken in conjunction with the attached
drawing.

15 BRIEF DESCRIPTION OF THE DRAWING

The attached sole Figure shows a D.C. hystere-
sis curve as obtained with a wound iron core of the
invention formed from a Co-base amorphous alloy strip,
in comparison with that exhibited by a wound iron core
20 made from a conventional Fe-base material.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Generally, a Co-base amorphous alloy exhibits
a magnetostriction of zero or substantially zero and,
hence, a small magnetic anisotropy in the quenched
25 state, which in turn facilitates the uniform and uni-

1 directional magnetization by an external magnetic field
during the annealing which is conducted under the
influence of the magnetic field to attain a superior
rectangular hysteresis property. It is, therefore,
5 possible to attain a distinguished rectangular hystere-
sis property much more easily than in the case where
an amorphous Fe-base alloy which tends to exhibit a
large magnetostriction is used as the material. The
small magnetostriction permits also a reduction in the
10 coercive force down to a level below 1/10 of that pre-
sented by ordinarily used 50% Ni permalloy and below 1/2
of that presented by ordinarily used amorphous Fe-base
alloy.

Hitherto, the Co-base amorphous alloy has been
15 used mainly as the material of magnetic heads. No pro-
posal nor attempt has been made up to now as to the use
of the Co-base amorphous alloy in place of the 50% Ni
permalloy as the magnetic core for would iron core, by
realizing a rectangular hysteresis property through an
20 annealing in a magnetic field parallel to the direction
of the exciting current.

The present inventors have found that a wound
iron core simultaneously exhibiting a large value of the
rectangle ratio Br/B_{10} and a low coercive force H_c is
25 obtainable by a process which has the steps of preparing
an amorphous alloy having a composition expressed by
 $Co_{100-a-a}X_aY_b$, where X represents one, two or more ele-

1 ments selected from a group consisting of Ti, Zr, Hf, V,
Nb, Ta, Cr, Mo, W, Mn, Fe, Ni, Ru, Y, Ce, Pr, Nd, Sm,
Eu, Gd, Tb and Dy, while Y represents one, two or more
elements selected from a group consisting of B, C, Al,
5 Si, P and Ge, particularly an amorphous alloy specified
above satisfying the conditions of $0 \leq a \leq 15$ and
 $14 \leq b \leq 30$, annealing the amorphous alloy in a magnetic
field and, after a cooling, winding the alloy into the
form of an iron core.

10 In the composition of the amorphous alloy used
in the invention, the total content of the element or
elements Y serving as an amorphous structure former
should range between 14 and 30 atom %, because the
amorphous structure cannot be formed when the Y content
15 is less than 14 atom % and when the same is 30 atom % or
greater. Metalloid or semimetal elements such as C, Si,
B, P, Ge and Al are known as elements for forming
amorphous structure. However, for attaining a high
thermal stability and toughness, it is preferred to use
20 a combination of Si and B. Although the effect of the
invention is not affected seriously by the presence of
C, P, Ge or Al, the content of such elements is pre-
ferably not greater than 5 atom %. When a specifically
high resistance to environmental condition, e.g. a spe-
25 cifically high moisture proof or anti-alkali property is
required, the B content should be selected to be not
greater than 10 atom % but the B content should not be

1 reduced down below 7 atom % for otherwise the amorphous
structure will not be obtained. Any Si content less
than 10 atom % and not smaller than 20 atom % is not
preferred because such an Si content will seriously
5 deteriorate the thermal stability and increase the coercive force undesirably.

The content of the element X which serves as the transition metal element should be selected to be not greater than 15 atom %, because X content above 15 %
10 undesirably increases the magnetostriction λ_s to a level of 10×10^{-6} or greater. Elements other than Fe, Ni and Mn, when added by an amount smaller than 15 atom %, reduces the magnetostriction nearly to zero and improves the ability for forming the amorphous structure advantageously.
15 The elements X, particularly Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, improves the hardness and, in addition, provides a higher thermal stability through raising the crystallization temperature.

The expected rectangular hysteresis property
20 can be obtained also when the Co-base amorphous alloy strip of above-specified composition is annealed in a magnetic field in the direction of excitation which usually coincides with the longitudinal direction of the strip followed by an annealing in a magnetic field.
25 Although direct electric current has been used hitherto for forming the external magnetic field during the annealing, an effect almost equivalent to that produced

1 by the direct electric current is obtainable when an
electric current obtained by a half-wave rectification
or even alternating current (commercial frequency) is
used for the formation of the magnetic field.

5 The advantage of the invention will be fully
realized from the following description of example.

Example 1

A Co-base amorphous alloy strip of 55 mm wide
was prepared to have a composition expressed by
10 $(\text{Co}_{0.94}\text{Fe}_{0.06})_{76.5}\text{Si}_{14}\text{B}_{9.5}$. The strip was wound in a
substantially troidal form into a wound iron core having
an outside diameter of 35 mm and an inside diameter of
25 mm. The wound iron core was subjected to an
annealing which was conducted at 320°C for 1 hour in a
15 circumferentially directed magnetic field of 50 Oe. The
properties of the thus produced wound iron core are
shown in Table 1 and Fig. 1 in comparison with those of
wound iron cores produced from conventionally used 50 %
Ni permalloy and supermalloy. The wound iron core of
20 Fe-base amorphous alloy appearing in Table 1 and
Fig. 1 was made from an alloy having a composition
expressed by $\text{Fe}_{71}\text{Ni}_{10}\text{Si}_{10}\text{B}_9$ and had been subjected to an
optimum annealing conducted in a magnetic field of 50 Oe
as in the case of the iron core of the invention.

Table 1

No.		material	$B_{10}(G)$	Br/B_{10} (%)	$H_c(Oe)$
1	*	supermalloy (5Mo-79Ni-Fe)	8,000	85	0.015
2		50% Ni permalloy (50Ni-Fe)	15,500	93	0.120
3	**	$Fe_{71}Ni_{10}Si_{10}B_9$	14,500	85	0.050
4		$(Co_{0.94}Fe_{0.06})_{76.5}Si_{14}B_{9.5}$	9,000	96	0.010
5	Amorphous Material	$(Co_{0.92}Mn_{0.06}Fe_{0.02})_{76}Si_{15}B_9$	9,200	94	0.005
6		$(Co_{0.92}Mn_{0.07}Fe_{0.01})_{76}Cr_1Si_{14}B_9$	8,900	95	0.014
7		$(Co_{0.90}Fe_{0.05}Ni_{0.05})_{77}Si_{14}B_9$	9,400	96	0.004
8		$(Co_{0.80}Fe_{0.05}Ni_{0.15})_{78}Si_{12.5}B_{9.5}$	8,000	97	0.005
9		$(Co_{0.92}Fe_{0.05}Zr_{0.03})_{76}Si_{12}B_{12}$	8,100	92	0.016
10		$(Co_{0.90}Fe_{0.04}Ti_{0.01}-Nb_{0.05})_{76}Si_{10}B_{14}$	7,800	91	0.020
11		$(Co_{0.92}Fe_{0.05}Mo_{0.02}-Ti_{0.01})_{76}Si_{10}C_2B_{12}$	7,900	93	0.040
12		$(Co_{0.90}Fe_{0.04}Ru_{0.06})_{75}Cr_2Si_{14}B_9$	7,800	95	0.020

... continued.

13	Amorphous Material	$(\text{Co}_{0.91}\text{Fe}_{0.04}\text{W}_{0.03}\text{Y}_{0.01}\text{Ce}_{0.01})_{76}\text{Si}_{15}\text{B}_9$	8,200	96	0.030
14		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{75}\text{V}_{10}\text{Y}_{0.5}\text{Nb}_{0.5}\text{Si}_{14}\text{B}_9$	8,700	97	0.020
15		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{75}\text{Cr}_2\text{Hf}_{0.5}\text{Dy}_{0.5}\text{Si}_{13}\text{B}_9$	8,800	96	0.025
16		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{74}\text{Cr}_2\text{Pr}_{0.5}\text{Sm}_{0.5}\text{Si}_{13}\text{B}_{10}$	8,600	95	0.022
17		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{75}\text{Mo}_1\text{Eu}_{0.2}\text{Gd}_{0.3}\text{Tb}_{0.5}\text{Si}_{12}\text{B}_{11}$	8,500	96	0.025
18		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{79}\text{Zr}_1\text{Ta}_2\text{B}_{18}$	9,900	97	0.045
19		$(\text{Co}_{0.94}\text{Mn}_{0.05}\text{Cr}_{0.01})_{72}\text{Al}_2\text{Si}_{14}\text{B}_{12}$	9,600	95	0.047
20		$(\text{Co}_{0.94}\text{Fe}_{0.06})_{75}\text{P}_2\text{Ge}_3\text{Si}_8\text{B}_{12}$	9,400	97	0.048

* conventionally used crystalline material

** comparative amorphous material

1 From Table 1, it will be seen that the wound
iron core of the invention formed from Co-base amorphous
alloy exhibits a superior rectangle ratio Br/B_{10} of 96%,
and a coercive force which is as small as less than 1/10
5 of that exhibited by the iron core formed from conven-
tionally used 50% Ni permalloy.

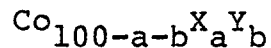
1 The wound iron core made from the strip of Fe-
is quite superior to the known wound iron core made from
an Fe-base amorphous alloy.

5 As has been described, according to the inven-
tion, it is possible to produce easily a wound iron core
having a distinguished performance over known wound iron
cores, thereby to offer a great advantage in the field
of industry concerned.

WHAT IS CLAIMED IS:

1. A wound iron core formed by winding a thin strip of a soft magnetic alloy into a troidal form, characterized in that a Co-base amorphous magnetic alloy is used as said thin strip and that said thin strip is annealed in a magnetic field in the direction of excitation, so that said core exhibits a rectangle ratio B_r/B_{10} of 85% or higher in D.C. hysteresis curve.

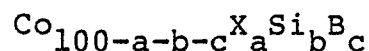
2. A wound iron core according to claim 1, wherein said Co-base amorphous magnetic alloy has a composition substantially expressed by:



where, X represents one, two or more elements selected from a group consisting of Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, while Y represents one, two or more elements selected from a group consisting of B, C, Al, Si, P and Ge, and wherein the following conditions are met:

$$0 \leq a \leq 15 \text{ (atom\%)} \text{ and } 14 \leq b \leq 30 \text{ (atom\%)}. \text{}$$

3. A wound iron core according to claim 1, wherein said Co-base amorphous magnetic alloy has a composition substantially expressed by:



where, X represents one, two or more elements selected from a group consisting of Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, and wherein the following conditions are met:

$0 \leq a \leq 15$ (atom%), $10 \leq b \leq 20$ (atom%)
and $7 \leq c < 10$.

