

Sept. 5, 1972

KIYOSHI INOUE ET AL

3,689,254

MAGNETIC MATERIAL

Filed April 28, 1971

2 Sheets-Sheet 1

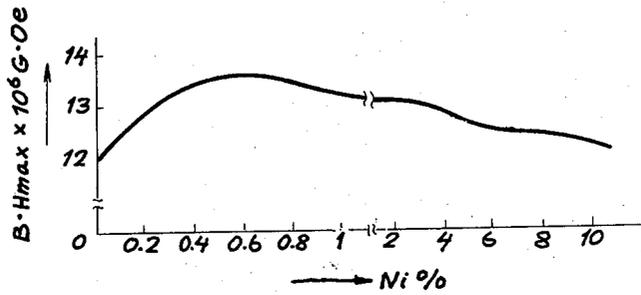


FIG. 1

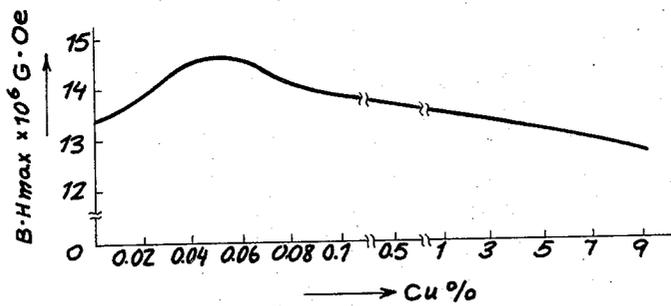


FIG. 2

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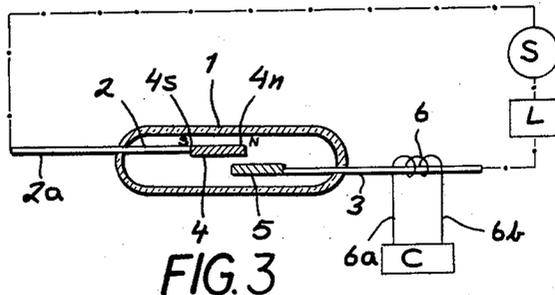


FIG. 3

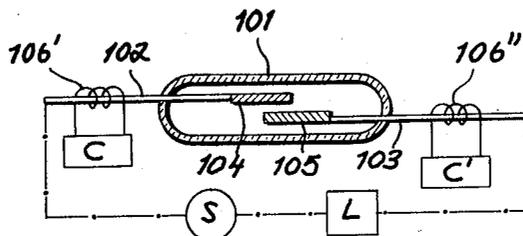


FIG. 4

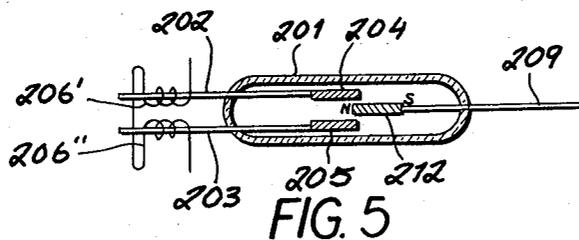


FIG. 5

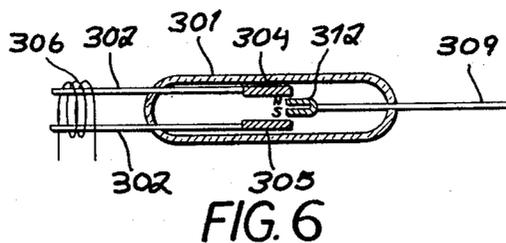


FIG. 6

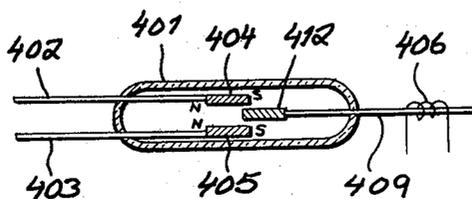


FIG. 7

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3,689,254

MAGNETIC MATERIAL

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 Continuation-in-part of application Ser. No. 859,354, Sept. 19, 1969, which is a continuation-in-part of application Ser. No. 628,086, Apr. 3, 1967, both now abandoned. This application Apr. 28, 1971, Ser. No. 138,081

Claims priority, application Japan, Apr. 14, 1966, 41/23,707

Int. Cl. H01f 1/04; C22c 5/00

U.S. Cl. 75—172

8 Claims

ABSTRACT OF THE DISCLOSURE

A magnetic material of high retentive capacity consisting essentially of 40 to 60 atomic percent platinum with good results when the Pt proportion is 45 to 55 atomic percent, balance cobalt (preferably 50 atomic percent ± 1 atomic percent platinum and 50 atomic percent ± 1 atomic percent cobalt), constituting a platinum/cobalt component and present as the balance of the magnetic material with between 4 and 15 atomic percent iron alone or with up to 5 atomic percent nickel (preferably above 0.1 atomic percent), the latter being present with or without copper in an amount up to 5 atomic percent copper (preferably at least 0.01 atomic percent) in the magnetic alloy. The cobalt proportion is in excess of the iron (in terms of atomic percent).

CROSS-REFERENCE TO COPENDING APPLICATION

This application is a continuation-in-part of application Ser. No. 859,354, filed Sept. 19, 1969, now abandoned, which in turn is a continuation-in-part of application Ser. No. 628,086, filed Apr. 3, 1967, now abandoned.

FIELD OF THE INVENTION

Our present invention relates to improvements in platinum-cobalt-iron magnetic materials and, more particularly, to permanent-magnetic substances consisting at least in major part of nonferrous materials.

BACKGROUND OF THE INVENTION

Recent investigations into binary, ternary and other multicomponent metallic alloys have revealed that many of these alloys have magnetic properties in terms of magnetic retentivity and permeability (magnetic field strength H and magnetic flux density B) far exceeding those of ferromagnetic materials in spite of the fact that such materials have long been considered the mainstay of permanent-magnet substances and compositions.

For example, it has been observed that iron/cobalt alloys, in which part of the iron of the metallurgical crystal structure is replaced by cobalt, have greater retentive powers than the pure iron. This is indeed surprising in view of the fact that cobalt has substantially less magnetic character than iron in its elemental state. Investigations have also shown that manganese/bismuth and manganese/aluminum alloys likewise have magnetic properties resembling to a large measure alloys contain-

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ing iron. It has been determined that platinum-containing bodies with metals of the iron group likewise have good magnetic properties although when platinum is substituted for cobalt in combination with iron, the magnetic properties are only slightly better than those of the iron/cobalt alloys.

OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide magnetic materials and bodies composed therefrom having high magnetic remanence and magnetic retentivity as well as exceptionally strong magnetic field strength.

Another object of this invention is to provide a magnetic material and method of working same which will impart a high magnetic energy product (BxH) thereto.

SUMMARY OF THE INVENTION

We have now found that an improved magnetic material consists predominantly of a platinum/cobalt/iron component containing 40 to 60 atomic percent platinum and in combination therewith a relatively high atomic proportion of iron, i.e. at least 4 atomic percent and up to 15 atomic percent with up to 5 atomic percent each of copper and/or nickel, the balance being cobalt in an amount in atomic percent greater than that of the iron (i.e. at least 4 atomic percent and up to 56 atomic percent).

Surprisingly, while iron/platinum alloys have only slightly better magnetic characteristics than iron/cobalt alloys and iron is vastly superior to cobalt in the unalloyed state with respect to the magnetic-field strength H of permanent magnets made from the respective materials, a platinum/cobalt/iron alloy has a magnetic field strength generally several times greater than that of corresponding platinum/iron alloys and the corresponding iron/cobalt alloy, the magnetic field characteristics being improved still more when the platinum/cobalt/iron component is combined with copper or nickel or both in the proportions set forth below.

According to an important feature of this invention therefore, a magnetic alloy having a field strength many times greater than that which would be expected from iron/cobalt, platinum/iron and even platinum/cobalt alloys, can be obtained by combining in the alloy from 96 to 70 atomic percent of a platinum/cobalt component with 4 to 30 atomic percent of iron and advantageously from 0 to 5 atomic percent nickel and/or 0 to 5 atomic percent copper. The platinum may be present in an amount of 40 to 60 atomic percent, preferably 45 to 55 atomic percent while cobalt makes up the balance.

The platinum/cobalt component can, moreover, consist essentially of 50% (atomic) platinum and 50% (atomic) cobalt, corresponding to substantially equal amounts of platinum and cobalt atoms in the final alloy. Within the platinum/cobalt component, the limitation of the variation to $\pm 1\%$ (atomic) by weight of Pt and Co is found to provide best results. We have found, furthermore, that when nickel is used in the alloy, excellent results are obtained when it is employed along with 0.01 to 5 atomic percent copper. Thus, according to this invention, a platinum/cobalt/iron/nickel copper alloy can be made with up to 5 atomic percent nickel, up to 5 atomic percent copper, up to 30 atomic percent iron and

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as little as 60 atomic percent of the platinum/cobalt component.

On the other hand, the alloy can be free from copper and nickel while containing up to 30 atomic percent iron and up to 70 atomic percent of the platinum/cobalt component. Platinum/cobalt/nickel alloys can range between compositions containing 99.9 atomic percent of the platinum/cobalt component and iron (at least 4 atomic percent) and 0.1 atomic percent nickel (no copper) to compositions containing 94.9% platinum/cobalt component and at least 4 atomic percent iron, 0.1 atomic percent nickel and 5 atomic percent copper, and to compositions consisting of 90 atomic percent platinum/cobalt component and iron at least 4 atomic percent, 5 atomic percent nickel and 5 atomic percent copper. An excellent magnetic material consists essentially of 50 atomic percent Pt, 4 to 15 atomic percent iron, 0 to 5 atomic percent Ni, 0 to 5 atomic percent copper and the balance cobalt.

The term "atomic percent" and those of similar import are used to indicate concentration in the metal alloy lattice in terms of the proportions of atoms rather than weight proportions. The atomic percent is, of course, proportional to the value of the weight concentration (percent by weight) divided by the atomic weight of the substance; thus,

$$\text{Atomic percent} = \frac{\text{percent by weight}}{\text{atomic weight}}$$

According to a further feature of this invention, the proportion of iron should be approximately ten times greater than the proportion of nickel present in the alloy and indeed it has been found that best results are obtained with alloys of this type wherein the proportion of copper is about one-tenth that of the nickel.

In a nickel/iron containing composition of the type constituting the present invention, the platinum/cobalt component can consist of 94.4 atomic percent of the platinum/cobalt component (say, 50 atomic percent platinum and 50 atomic percent cobalt or about 77% by weight cobalt), 5 atomic percent iron, 0.5 atomic percent nickel and 0.05 atomic percent copper. (Trace amounts of the usual impurities which do not affect magnetic properties may also be present along with residual quantities of deoxidation or desulfurization metals.) These metals are manganese, aluminum and titanium; up to 0.1 to 5% by weight in total of the desulfurization and deoxidation agent, added to the powdered alloying metals prior to melting to form the alloy, gives good results.

According to another feature of this invention, the alloys are cast and then heat-treated at an elevated temperature from 900° C. to 1400° C., preferably between 1000° C. and 1200° C., for a period in excess of one hour. After this initial treatment, the body is swaged preferably to rod or needle-shape in from 2 to 5 stages to a diameter of approximately one-fourth the diameter of the cast body and a cross-section of about one-sixteenth. This swaging step is followed by a further heat treatment at the aforementioned elevated temperatures for a period of between 15 minutes and two hours and preferably about ½ hour, the body then being cooled in steps of 200° C. to 300° C. in intervals of from 5 to 20 minutes until a temperature in the range of 500° C. to 800° C., preferably 550° C. to 700° C., is attained and, at this temperature, prolonged cooling is advantageous (e.g. to 15 hours).

DESCRIPTION OF THE DRAWING

The invention will be described in greater detail below with reference to specific examples and the accompanying drawing in which:

FIGS. 1 and 2 are graphs illustrating the present invention; and

FIGS. 3-7 are axial cross-sectional views through mag-

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netically operable reed-type relays illustrating typical uses for the magnetic material of the present invention.

SPECIFIC DESCRIPTION

In FIG. 1, we show the magnetic properties (plotted along the ordinate in units of 10⁶ gauss-oersted) of compositions identical to that of Example I but containing varying amounts of nickel (plotted along the abscissa in atomic percent). From this figure, it will be apparent that the properties rise rapidly as the nickel proportion is increased from 0 to 0.5 atomic percent and remains substantially constant through a range of 0.5 to 5% (atomic) before falling off to a material extent. The copper proportion is somewhat more critical as can be seen from FIG. 2 in which a graph of the system of Example II is presented illustrating the effect of various concentrations of copper (plotted along the abscissa in atomic percent). From this graph it is apparent that even traces of copper will improve the magnetic properties and indeed that these properties improve through a copper concentration of trace amounts to 10 atomic percent. Best results have been found with copper concentrations between 0.01 and 5% (atomic), the magnetic properties being more stable at these concentrations.

In FIG. 3, we show an embodiment of a reed-type switch or relay in which one contact is formed by a bar 4 of the magnetic material made as described in Examples I and II and magnetized by conventional techniques so as to have a north-magnetic pole 4_n at the free end of the bar and a south-magnetic pole 4_s at the end of the bar 4 connected to a flexible-reed terminal 2. The latter extends at 2_a from the hermetically sealed evacuated glass tube 1, while a magnetically permeable (e.g. iron) body 5 is disposed proximal to the north-magnetic pole 4_n upon a flexible magnetizable reed 3 to which the magnetically permeable rod 5 is attached. When an electric current is passed through the coil 6 in one sense, the free end of the bar 5 is temporarily magnetized to a south-magnetic polarity and the free ends of the bars 4 and 5 are drawn together by attractive magnetic forces and a circuit is closed through the switch of FIG. 3. When the current flow through the coil is terminated, the permanent-magnet force of bar 4 is sufficient to retain the bar 5 in the closed condition of the switch. Upon reversal of the current flow through the coil 6, the polarity at the free end of bar 5 is reversed (e.g. changes to north) so that repulsive forces separate the contact and open-circuit the switch. Since the bar 4 is composed in major part of platinum and cobalt (see Example I and II), it also sets as a corrosion-and-pitting-resistant contact material and has little tendency to spark.

In FIG. 4, we show a modification of the system of FIG. 3 wherein neither of the magnetizable contacts 104 and 105 within the hermetically sealed evacuated glass capsule 10 is permanently magnetic. In this case, the reed-type terminals 102 and 103 extending longitudinally into the glass tube 101 are composed of magnetically permeable material and are respectively surrounded by energization of de-energization coils 106', 106''.

These coils may respectively be "make" and "break" coils operable by controlled circuits represented at C and C', respectively, while the terminals 102 and 103 are connected between a source S and its load L. The coil 106' is so poled as to magnetize the contact 104 which, like the contact 105, is composed of the magnetic material of Example I or Example II.

When the coil 106'' is energized simultaneously to impart opposite magnetic polarity to the free end of contact 105, the magnetic attractive forces close the contact and complete the circuit.

When the coils are de-energized without polarity reversal, sufficient magnetic remanence may hold the circuit closed until one or the other of the coils is energized to produce a repulsive force. In this case, the switch can act as a memory in the manner of a bistable elec-

tronic device. More generally, however, the magnetic energization of the contacts 104 and 105 will be each insufficient to impart sufficient residual magnetic force to keep the contacts closed and upon de-energization of one or both coils, the contacts will spring apart under the resilience of the respective reeds.

In the modification of FIG. 5, the glass tube 201 surrounds a permanently magnetized contact 212 whose terminal 209 is connected in an external circuit. A pair of nonmagnetic but magnetically permeable rod contacts 204 and 205 respectively extend into the tube 210 from the other end and have terminals 202 and 203, respectively. These terminals 202 and 203 may be energized to opposite magnetic polarities by the oppositely wound coils 206' and 206'' which are here shown to be connected in series. When the control signal is a rapid train of signals, the contacts 204 and 205 will be alternately make and break electrical connections with the contact 212. Should the signal cease while one of the contacts 204, 205 is engaged with the permanent magnetic contact 212, the magnetic field of the latter will retain the contacts in closed circuit until a reverse polarity is applied.

In the modification of FIG. 6, a single coil 306 energizes a pair of reed contacts 302 and 303 whose magnetically permeable contact bodies 304 and 305 are respectively engageable with opposite magnetic poles of a U-shaped or horseshoe magnetic contact 312. The latter is carried out by a reed 309 extending into the glass tube 301. When the coil 306 is energized, therefore, one of the contacts 304, 305 will receive a polarity identical to that of the respective pole of the permanent magnet 312 and be repelled while the other is attracted. Reversal of the current flow through the coil 305 will release the previously attracted contact 304, 305 and make contact with the other. The system of FIG. 7 provides a pair of permanently magnetic contacts 404 and 405 whose reeds 402 and 403 extend into the glass tube 401 in the manner previously described. In this case, the countercontact 412 is magnetically permeable but not permanently magnetic and is carried by the magnetically permeable reed 409 which is surrounded by the energizing coil 406. In the embodiments of FIGS. 3-7, the permanently magnetized and magnetically permeable bodies may each be composed of the material described in connection with Examples I and II.

Alternatively, it is possible to use, as to magnetically permeable contact body in a reed-type switch illustrated in FIGS. 3-7, i.e. indicated as numerals 5; 104, 105; 204, 205; 304, 305; 404, 405, a semi-hard magnet, i.e. having a high residual flux density and relatively low coercive force.

SPECIFIC EXAMPLES

Example I

The magnetic alloy contained (excluding traces of impurities which did not affect the magnetic properties) approximately 5 atomic percent iron, 0.5 atomic percent nickel, the balance platinum and cobalt in equal amounts (i.e. the platinum/cobalt component being composed of 50 atomic percent platinum and 50 atomic percent cobalt); this component is present in substantially 94.5 atomic percent. The alloy was prepared by dissolving or melting an admixture of platinum, cobalt, iron and nickel powders in the above atomic proportions, in a magnesia crucible by high-frequency induction heating in an inert atmosphere (argon) for limiting oxidation of the admixture being dissolved.

Prior to melting, we incorporate into the admixture about 0.1 to 5% by weight of an additive consisting of equal parts by weight of manganese aluminum and titanium powders as a deoxidizing and de-sulfurizing agent; when such agent is omitted cobalt and iron form oxides and sulfides thereof at boundaries of the powders, and these oxides and sulfides are detrimental to the machina-

bility of the resultant alloy as well as the magnetic properties thereof.

The alloy contained 5 atomic percent iron, 0.5 atomic percent nickel, the balance platinum and cobalt in equal amounts (i.e. the platinum/cobalt component being composed of 50 atomic percent platinum and 50 atomic percent cobalt, $\pm 1\%$) and present in substantially 94.5 atomic percent. The alloy is cast into rods having a diameter of 8 mm., the rods being heat-treated at a temperature of 1000° C. to 1200° C. for 2 hours to disorderization of the alloy lattice. Thereafter, the rods are swaged to a circular diameter of 2 mm. in four steps of 6, 4, 3 and 2 mm. diameter respectively, each of these steps except the last being flowed by heat-treatment at this temperature for a period of ½ hour. After the final swaging step, the rods are held at a temperature between 1000° C. and 800° C. for 20 minutes. Thereafter, the rods are brought to a reduced temperature of 600° C. to 700° C. for 5 minutes and, after (or without) a water-cooling treatment, are maintained at an aging temperature between 500° and 700° C. for 5 hours for reordering of the alloy lattice.

NOTE: The maximum in the order-disorder transition curve of the platinum/cobalt component alloy of the super-lattice type lies at 50 atomic percent and 825° C. The rods showed a maximum energy product (BsH) max. = 13.5×10^6 gauss·oersted.

Example II

An alloy was prepared in which 0.05 atomic percent copper, 0.5 atomic percent nickel, 5 atomic percent iron, the balance a platinum/cobalt component as described in Example I and the usual impurities in trace amounts, by the method of this example, and are cast into rods or needles of 8 mm. diameter. The rods were heat-treated at a temperature of 1000° C. to 1200° C. for 2 hours to disorderization of the alloy lattice. Thereafter, the rods are swaged to a circular diameter of 2 mm. in four steps of 6, 4, 3 and 2 mm. diameter respectively, each of these steps except the last being followed by heat-treatment at this temperature for a period of ½ hour. After the final swaging step, the rods are held at a temperature between 1000° C. and 800° C. for 20 minutes. Thereafter the rods are brought to a reduced temperature of 600° C. to 700° C. for 5 minutes. After aging at a temperature of 550° C. to 700° C. over a period of 5 hours, the magnetic-energy product $B \times H$ (max.) of the needles was evaluated and found to be 14.8×10^6 gauss·oersted.

Example III

The semi-hard magnet composed of Pt/Co, Pt/Co/Fe, Pt/Co/Fe/Ni or Pt/Co/Fe/Ni/Cu in the proportions described above can be produced as follows:

The alloy is formed and cast as described in Example I into a body, which is heated to a temperature of about 830° C. to 1200° C. to disorder of the alloy lattice; thereafter the body is rapidly cooled to the aging temperature of about 550° C. to 750° C. and maintained at this temperature for about 20 to 400 minutes for ordering of the alloy lattice.

The resulting body, depending on the length of the aging treatment has a residual flux density of about 6000 to 7500 gauss and a coercive force of about 200 to 1000 oersted.

Example IV

Alloys containing 50 atomic percent platinum, varying amounts of iron (4 to 30 atomic percent iron, preferably 4 to 15 or 20 atomic percent), varying amounts of nickel (i.e. 0 to 5 atomic percent nickel) and as the balance cobalt were prepared. In each preparation, a mixture of these powders in a total quantity of 40 grams was melted by high-frequency induction heating in an argon atmosphere and after incorporating 0.1% by weight manganese

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serving as a deoxidation and desulfurization agent and cast into a mold having a diameter of 6 mm.

The ingot, after annealing at a temperature above the disorder-order transition of the alloy (i.e. at a temperature generally in a range between 900° C. and 1400° C.), was swaged and drawn. These annealing and cold working operations were repeated alternately until the body was reduced in diameter to 2.5 mm. Then the body was cut into lengths of 20 mm.

The body was then subjected to a heat treatment in an evacuated chamber at a temperature of 1300° C. (generally between 900° C. and 1400° C.) for 2 hours (generally up to 1 hour). This heat treatment was intended to primarily effect solid-state solvolization of the alloy or dissolving alloy constituents so that the iron atoms (and nickel atoms if also present) homogeneously merge in platinum and cobalt phases possibly form iron cobalt and iron platinum (the latter predominating and the former in relatively low proportion) within the platinum-cobalt matrix. Then the alloy was quenched (or otherwise controlledly cooled).

The quenched body was returned to a heat treatment in an argon atmosphere at a temperature of 1200° C. (generally between 900° C. and 1400° C.) for 2 hours which purposed accomplishment of disorder reaction and then brought to room temperature.

(Note: the post-swaging heat treatment may be eliminated and the swaging, heat-treatment and reheating steps may be interchanged in sequence.)

Finally the alloy was subjected to aging treatment in a temperature range between 500° C. and 800° C. (i.e. in the ordering-reaction range of the alloy) to yield the magnetic alloy.

This final stage preferably includes two or more steps. By way of example, the first aging step was at a temperature between 730° C. and 810° C. for a period of 10 to 300 seconds followed by quenching to room temperature and the second step was at a temperature between 500° C. and 600° C. for a period of 0.5 to 35 hours.

Example V

With a composition (prepared and treated as outlined above) of 50% Pt, 45% Co and 5% Fe (in atomic proportion) and when aged at a temperature of 750° C. for 60 seconds in the first step and at 550° C. for 1 hour in the second step, the alloy showed a maximum energy product 12.1 million gauss-oersted with a coercive force 4.9 kilo-oersted and a residual flux density of 7.3 kilo-gauss.

Example VI

With a composition (prepared and treated as outlined above) of 50% Pt, 42% Co and 8% Fe and when first-aged at 780° C. for 30 seconds and second-aged at 550° C. for 1 hour, the alloy showed a maximum energy product of 12.3M g.o.e. with a coercive force of 4.7K oe. and a residual flux density of 7.5 kg.

Example VII

With a composition (prepared and treated as outlined above) of 50% Pt, 40% Co and 10% Fe when first-aged at 790° C. for 20 seconds and second-aged at 550° C. for 1 hour, the alloy showed a maximum energy product of 12.2M g.o.e. with a coercive force of 4.2K oe. and a residual flux density of 7.6 kg.

Example VIII

With a composition (prepared and treated as outlined above) of 50% Pt, 41% Co, 8% Fe and 1% Ni and when first-aged at 780° C. for 20 seconds and second-aged at 550° C. for 1 hour, the alloy showed a maximum energy product of 13.9M g.o.e. with a coercive force of 5.0K oe. and a residual flux density of 7.7 kg.

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Example IX

With a composition of 50% Pt, 40% Co, 8% Fe and 2% Ni when first-aged at 780° C. for 20 seconds and second-aged at 550° C. for 1 hour, the alloy exhibited a maximum energy product of 14.6M g.o.e. with a coercive force of 5.0K oe. and a residual flux density of 7.9 kg.

Example XA

A composition of 50 atomic percent platinum, 45 atomic percent cobalt and 5 atomic percent iron was made as described in Example III and treated in a similar manner, aging the product in the first step at a temperature of 750° C. for 60 seconds and at a temperature of 550° C. for one hour in the second step. The composition corresponded to that of Example IV and the product had a maximum energy product of 12.1M g.o.e., a coercive force of 4.9K oe. and a residual flux density of 7.4 kg.

Example XB

With a composition corresponding to that of Example V and constituting of 50 atomic percent platinum, 42 percent cobalt and 8 atomic percent iron, aged in the first step at 780° C. for 30 seconds and at 550° C. for one hour in the second step, the maximum energy product was 12.3M g.o.e., the coercive force was 4.7K oe. and the residual flux density was 7.5 kg.

Example XC

A composition of 50 atomic percent platinum, 40 atomic percent cobalt and 10 atomic percent iron was prepared as set forth in Example III and corresponded to Example VI thereof. The composition was aged in the first step at 790° C. for 20 seconds and aged in the second step at 550° C. for one hour. The alloy had a maximum energy product of 12.3M g.o.e. with a coercive force of 4.2K oe. and a residual flux density of 7.6 kg.

Example XD

Alloys were made with compositions of 50 atomic percent platinum, 0 to 3 atomic percent iron in 0.5 atomic percent increments and cobalt (balance). The highest maximum energy product obtained was 9.2M g.o.e. with a coercive force of 4.8K oe. and a residual flux density of 6.4 kg. The improvement found with a minimum of 4% by weight iron as detailed in Examples XA-XC above, was a minimum of 20.6%.

Example XE

When the iron proportion (Example XD) was increased to 4% (atomic) with corresponding decrease of cobalt, the maximum energy product was 11.0M g.o.e. with a coercive force of 4.9K oe. and residual flux density of 7.0 kg. Abruptly in the region of 4% atomic iron, there appears, therefore, to be a 10% jump in the maximum energy product.

Example XF

A composition was prepared as described consisting of 50 atomic percent platinum, 35 atomic percent cobalt and 15 atomic percent iron. The alloy had a maximum energy product of 12.2M g.o.e. with a coercive force of 4.2K oe. and a residual flux density of 7.6 kg. This test demonstrated that substantially at the midpoint of the range of iron in the alloy, according to the above-identified application, there is basically no variation in the maximum energy product when the latter is compared with the average of Examples XA-XC corresponding to Examples IV-VI of the application.

Example XG

Further increase in the iron proportion showed that beyond approximately 30 atomic percent iron and, more particularly, in the range of 15 atomic percent iron and above, the magnetic energy product falls off sharply to

3M g.oe. with a coercive force of 1.6K oe. and a residual flux density of 3.0 kg.

Example XH

A composition corresponding to Example VII of the aforesaid application was prepared as described in Example III thereof and consisted of 50 atomic percent platinum, 41 atomic percent cobalt, 8 atomic percent iron and 1 atomic percent nickel. First step aging was carried out at 780° C. for 20 seconds and second step aging was carried out at 550° C. for one hour. The maximum energy product was 13.9M g.oe. with a coercive force of 5.0K oe. and a residual flux density of 7.7 kh.

Example XI

A composition corresponding to that of Example VIII of the patent application was prepared with 50 atomic percent platinum, 40 atomic percent cobalt, 8 atomic percent iron and 2 atomic percent nickel. The composition was initially aged at 780° C. for 20 seconds and subsequently aged at 550° C. for one hour. The maximum energy product was 14.6M g.oe. with a coercive force of 5.0K oe. and a residual flux density of 7.9 kg. A comparison of Example XH and XI with Example XB shows that the addition of nickel is able to increase the magnetic energy product over the same system without nickel by approximately 18%.

Example XJ

Tests were made to show the relationship of inclusion of iron to the effect of nickel in improving the magnetic energy product as described in connection with Examples XH and XI. With iron inclusions of less than 4% (atomic) and more than 20 atomic percent, no appreciable improvement in the maximum magnetic energy product was obtained by incorporation of nickel. When the iron proportion was in the range of 4 atomic percent to 15 atomic percent, however, substantial improvement in the maximum magnetic energy product was obtained when nickel was added in the amounts ranging from 0.1 atomic percent to 5 atomic percent in increments of 0.1 atomic percent. The average improvement was between 10 and 25%.

Example XK

Investigations were made into the effect of nickel on the lattice structure of the alloy by photomicrography. It was found that addition of nickel in an amount ranging 0.1 atomic percent and 5 atomic percent effectively retards the disorder-order transition rate of the alloy to provide superior magnetic properties even under severe heat treatment.

Example XL

A system was prepared as described in Example I, the rods having a maximum energy product of 13.5M g.oe. The composition of the rods was represented in FIG. 1. It was observed that FIG. 1 is typical with compositions of 4 to 15 atomic percent iron, 0.1 to 5 atomic percent nickel and the maximum, equimolecular platinum/cobalt. With a composition containing 8 atomic percent iron, 0.1 to 5 atomic percent nickel, balance equimolecular platinum/cobalt, the maximum energy product was at least 13.0M g.oe. With iron compositions below 4%, however, the maximum energy product was found to be generally below 9.5M g.oe. while, with iron content above 15%, e.g. about 20 atomic percent, the magnetic energy product falls as low as 30M g.oe. Similar tendencies were observed when copper was added. The copper was found to reduce the tendency of the alloy to react and was particularly desirable when nickel was present.

Example XI

The following table illustrates further comparison of the alloys of the present invention (marked with an asterisk *) with alloys outside its scope.

TABLE

Pt	Composition—atomic percent				Magnetic values		
	Co	Fe	Ni	Cu	K oe.	Kg.	M g.oe.
42	Balance	5			4.9	7.1	*11.8
42	do	8			4.7	7.2	*11.9
42	do	10			4.5	7.3	*12.0
42	do	0-3			4.5	5.8	*8.3
42	do	4			4.7	7.0	*11.0
42	do	15			4.0	7.5	*12.0
42	do	30			1.5	3.0	2.0
42	do	8	1		4.7	7.5	*13.0
42	do	8	2		4.6	7.6	*13.4
46	do	5			5.0	7.2	*11.7
46	do	8			4.9	7.3	*12.0
46	do	10			4.7	7.5	*12.3
46	do	0-3			4.7	6.0	9.0
46	do	4			4.9	7.1	*11.2
46	do	15			4.1	7.9	*12.3
46	do	30			1.8	3.3	2.9
46	do	8	1		4.9	7.7	*13.8
46	do	8	2		4.9	7.8	*14.0
50	45	5			4.9	7.3	*12.1
50	42	8			4.7	7.5	*12.3
50	40	10			4.2	7.6	*12.2
50	47-50	0-3			4.8	6.4	9.2
50	46	4			4.9	7.0	*11.0
50	35	15			4.2	7.6	*12.2
50	20	30			1.6	3.0	3.0
50	41	8	1		5.0	7.7	*13.9
50	40	8	2		5.0	7.9	*14.6
52	Balance	5			4.8	7.3	*12.0
52	do	8			4.7	7.5	*12.2
52	do	10			4.6	7.7	*12.3
52	do	0-3			4.3	6.0	8.8
52	do	4			4.8	7.2	*11.8
52	do	15			4.2	7.5	*12.2
52	do	30			1.5	3.0	2.8
52	do	8	1		4.9	7.8	*13.9
52	do	8	2		5.0	7.9	*14.3
56	do	5			4.6	7.2	*11.7
56	do	8			4.5	7.4	*11.9
56	do	10			4.3	7.6	*12.2
56	do	0-3			4.1	5.8	8.3
56	do	4			4.6	7.1	*11.6
56	do	15			4.2	7.7	*12.1
56	do	30			1.4	2.5	2.6
56	do	8	1		4.9	7.7	*13.8
56	do	8	2		5.1	7.6	*14.0

While the magnetic alloys in accordance with the present invention can be prepared in various known ways, the best practice is to follow the combined swaging and heat treatment originally described above which forms a part of the present invention.

We claim:

1. A magnetic material consisting essentially of an alloy of 40 to 60 atomic percent platinum, 4 to 15 atomic percent iron, 0 to 5 atomic percent nickel, 0 to 5 atomic percent copper, and the balance cobalt in an atomic proportion in excess of that of the iron.
2. The magnetic material defined in claim 1 wherein the platinum is present in an amount of 45 to 55 atomic percent.
3. The magnetic material defined in claim 1 wherein said alloy contains nickel and the atomic proportion of iron in said alloy is approximately ten times greater than the atomic proportion of nickel therein.
4. The magnetic material defined in claim 1 wherein said alloy contains copper and the atomic proportion of copper in said alloy is approximately one-hundredth the atomic proportion of iron therein.
5. The magnetic material defined in claim 1 which contains at least 0.1 atomic percent nickel and at least 0.01 atomic percent copper.
6. The magnetic material defined in claim 1 which consists essentially of 5 atomic percent iron and 0.5 atomic percent nickel with the balance a platinum/cobalt com-

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ponent containing 50 atomic percent platinum and 50 atomic percent cobalt (± 1 atomic percent).

7. The magnetic material defined in claim 1 which consists essentially of 5 atomic percent iron, 0.5 atomic percent nickel, 0.05 atomic percent copper and the balance a platinum/cobalt component containing 50 atomic percent platinum and 50 atomic percent cobalt (± 1 atomic percent).

8. The magnetic material defined in claim 1 consisting essentially of 50 atomic percent platinum, 4 to 15 atomic percent iron, 0 to 5 atomic percent nickel, and the balance cobalt.

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75-170; 148-31.57, 101

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,689,254
DATED : 5 September 1972
INVENTOR(S) : Kiyoshi INOUE and Hideo KANEKO

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, column 1, line 3, in the
assignors name for "kinzoki" read -- Kinzoku -- .

Signed and Sealed this
twenty-fourth Day of February 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks