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(54) **High coercivity rare earth-  
transition metal magnets**

(57) Ferromagnetic compositions  
having intrinsic magnetic coercivities  
at room temperature of at least 1,000  
Oersteds are formed by the controlled  
quenching of molten rare earth-  
transition metal alloys. Hard magnets

may be inexpensively formed from the  
lower atomic weight lanthanide  
elements and iron. The preferable  
compositions lie within:—

At least one of Fe, 20—70 atomic  
Ni, Co percent

At least one of Ce, 80—30 atomic  
Pr, Na, Sm, Eu, Tb, percent  
Dy, Ho, Er, Tm, Y

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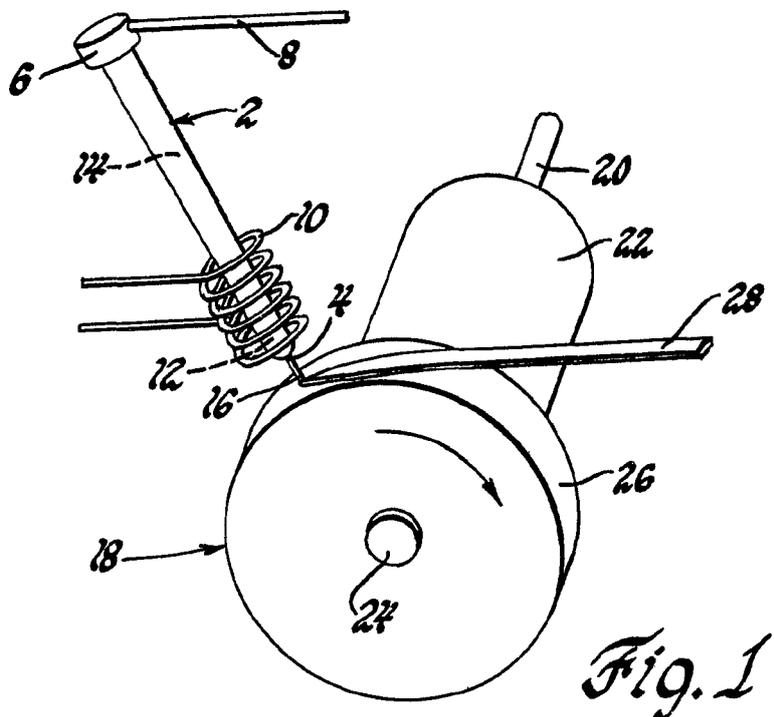


Fig. 1

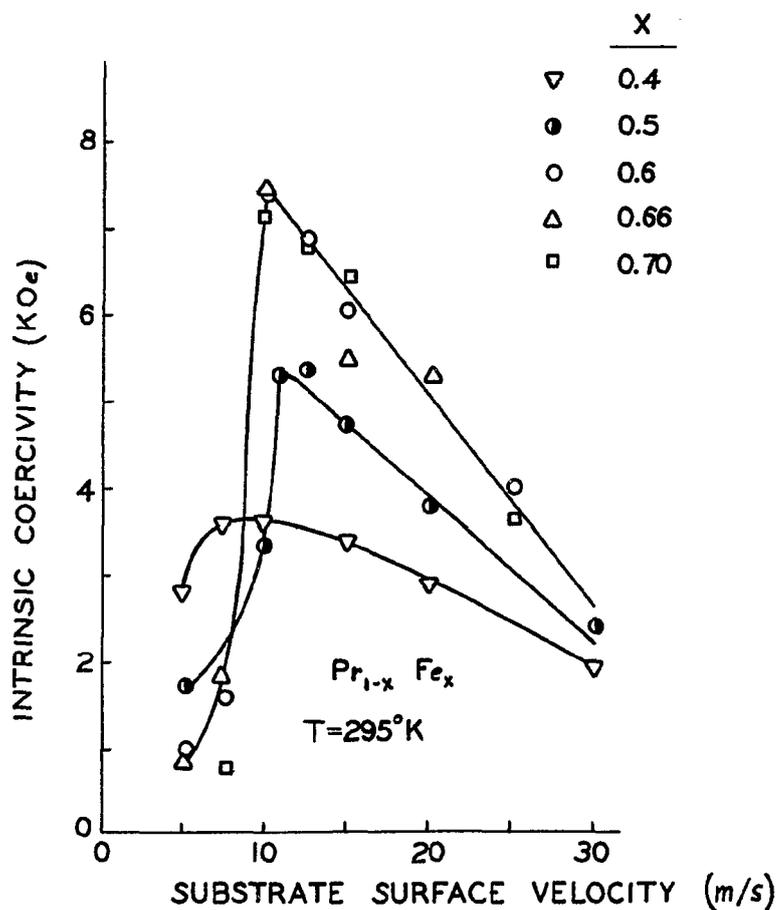


Fig. 6



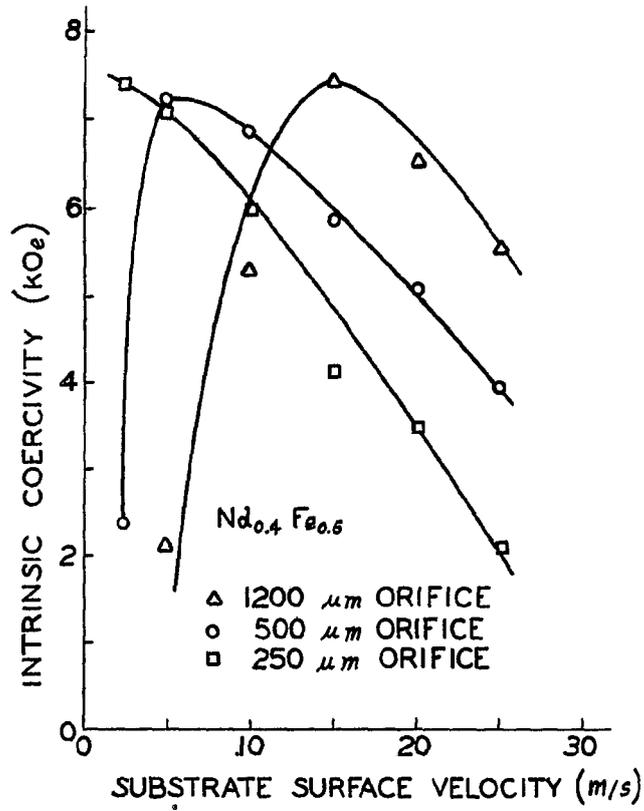
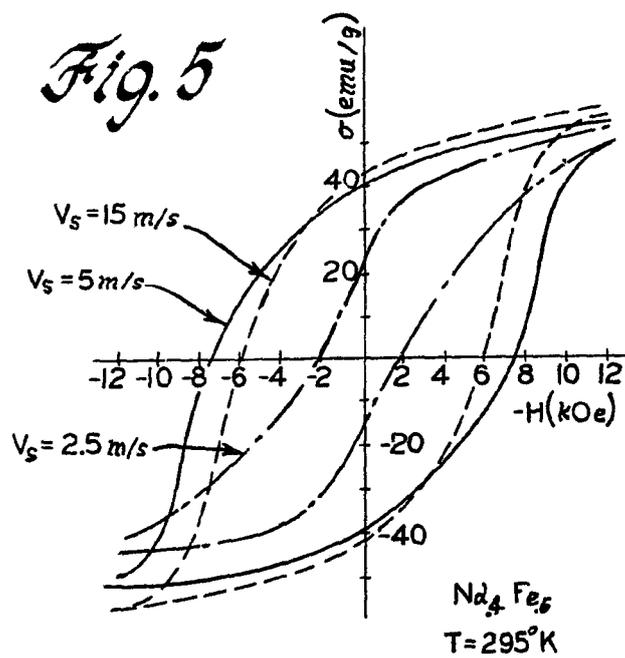


Fig. 4



## SPECIFICATION

**High coercivity rare earth-transition metal magnets**

This invention relates to rare earth-transition  
5 metal (RE—TM) alloys with room temperature  
magnetic coercivities and to a reliable method of  
forming such magnetic alloys.

Intermetallic compounds of certain rare earth  
and transition metals (RE—TM) can be made into  
10 magnetically aligned permanent magnets with  
coercivities of several thousand Oersteds. The  
compounds are ground into sub-crystal sized  
particles commensurate with single magnetic  
domain size, and are then aligned in a magnetic  
15 field. The particle alignment and consequently the  
magnetic alignment, is fixed by sintering or by  
dispersing the particles in a resinous binder or low  
melting metal such as lead. This is often referred  
to as the powder metallurgy process of making  
20 rare earth-transition metal magnets. When  
treated in this manner, these intermetallic  
compounds develop high intrinsic magnetic  
coercivities at room temperature.

The most common intermetallic compounds  
25 processable into magnets by the powder  
metallurgy method contain substantial amount of  
the elements samarium and cobalt, e.g.,  $\text{SmCo}_5$ ,  
 $\text{Sm}_2\text{Co}_{17}$ . Both of these metals are relatively  
expensive due to scarcity in the world market.  
30 They are, therefore, undesirable components for  
mass produced magnets. Lower atomic weight  
rare earth elements such as cerium,  
praseodymium and neodymium are more  
abundant and less expensive than samarium.  
35 Similarly, iron is preferred over cobalt. However, it  
is well known that the light rare earth elements  
and iron do not form intermetallic phases when  
homogeneously melted together and allowed to  
crystallize as they cool. Moreover, attempts to  
40 magnetically harden such rare earth-iron alloys by  
powder metallurgy processing have not been  
successful.

This invention comprises a novel, efficient and  
inexpensive method which can be used to  
45 produce magnetically coercive rare earth-iron  
alloys directly from homogeneous molten  
mixtures of the elements.

It is an object of the invention to provide  
magnetically hard RE—TM alloys, particularly  
50 RE—Fe alloys, and a reliable means of forming  
them directly from molten mixtures of the  
elements. A more particular object is to provide a  
method of making magnetically hard alloys from  
mixtures of rare earth elements and iron which do  
55 not otherwise form high coercivity inter-metallic  
phases when allowed to crystallize as they cool. A  
further object of the invention is to control the  
solidification of molten rare earth-iron mixtures to  
produce ferromagnetic alloys with substantially  
60 amorphous microstructures as determined by X-  
ray diffraction. A more specific object is to provide  
hard magnetic alloys with room temperature  
coercivities of at least several thousand Oersteds  
directly from molten mixtures of low atomic

65 weight rare earth elements such as Ce, Pr, Nd and  
Fe by a specially adapted quenching process.

In accordance with a preferred embodiment of  
the invention, a magnetically hard rare earth-iron  
metal alloy may be formed as follows. Mixtures of  
70 rare earth elements and iron are homogeneously  
alloyed in suitable proportions, preferably about  
0.2 to 0.66 atomic percent iron and the balance  
rare earth metal. The preferred rare earth metals  
are the relatively low atomic weight elements  
75 which occur early in the lanthanide series such as  
cerium, praseodymium, and neodymium. These  
alloys have some room temperature coercivity  
due to the presence of the rare earth elements,  
but it is generally less than 200 Oersteds. Herein,  
80 compositions with intrinsic coercivities less than  
about 200 Oersteds at room temperature (about  
25°C) will be referred to as soft magnets or as  
alloys having soft magnetic properties. The  
alloyed, magnetically soft RE—Fe mixture is  
85 placed in a cylindrical quartz crucible surrounded  
by an induction heating coil. The crucible has an  
orifice at the bottom for expressing a minute  
stream of molten alloy. The top of the crucible is  
sealed and provided with means for introducing a  
90 pressurized gas above the molten alloy to propel it  
through the orifice. Directly adjacent the orifice  
outlet is a rotating chill disk made of highly heat  
conductive copper electroplated with chromium.  
Metal ejected through the orifice impinges on the  
95 perimeter of the rotating disk so that it cools  
almost instantaneously and evenly. The orifice  
diameter is generally in the range of 250—1200  
microns. The preferred velocity of the perimeter of  
the rotating disk is about 2.5 to 25 meters per  
100 second. The disk itself can be considered an  
infinitely thick chill plate. The cooling of the ejected  
molten alloy is, therefore, a function of heat  
transfer within the alloy itself onto the chill  
surface. It has been found that, if the disk is  
105 maintained at room temperature, and the molten  
alloy is ejected through the orifice under a  
pressure of about 2.5 pounds per square inch  
(17.24 kPa), then the maximum thickness for  
cooled ribbon formed on the perimeter of the chill  
110 disk should be no more than about 200 microns.  
This provides a rate of cooling which produces the  
high coercivity magnetic alloys of this invention.  
Quench rate in spin melting can be controlled by  
adjusting such parameters as the diameter of the  
ejection orifice, the ejection pressure, the speed of  
115 the quench disk, the temperature of the disk and  
the temperature of the molten alloy.

Critical to the invention is controlling the  
quench rate of the molten RE—Fe alloys. Enough  
atomic ordering should occur upon solidification  
to achieve high magnetic coercivity. However, a  
nonmagnetic crystalline microstructure should be  
avoided. While spin melting is a suitable method  
of quenching molten RE—TM to achieve hard  
120 magnetic materials, any other equivalent  
quenching means such as, e.g., spraying the  
molten metal into a cryogenically cooled  
container would fall within the scope of the  
present invention.

For example, an alloy of  $\text{Nd}_{0.5}\text{Fe}_{0.5}$  has been spun melted from an orifice 500 microns in diameter at an ejection pressure of 2.5 psi (17.24 kPa) onto a room temperature chill surface

5 moving at a relative speed of 2.5 meters per second to directly yield an alloy with a measured coercivity of 8.65 kilo Oersteds. The spun melted magnetic alloy had a substantially flat X-ray diffraction pattern.

10 The invention and how it may be performed are hereinafter particularly described with reference to the accompanying drawings, in which:

15 Figure 1 is a schematic view of a spin melting apparatus suitable for use in the practice of the invention;

Figure 2 is a plot of substrate surface velocity versus intrinsic coercivity for  $\text{Nd}_{0.4}\text{Fe}_{0.6}$  at 295°K. The parenthetical numbers adjacent the data points are measure ribbon thicknesses;

20 Figure 3 is a plot of substrate surface velocity versus intrinsic coercivity for three different spun melted neodymium-iron alloys;

25 Figure 4 is a plot of chill substrate surface velocity versus intrinsic magnetic coercivity for spun melt  $\text{Nd}_{0.4}\text{Fe}_{0.6}$  at ejection orifice diameters of 1200, 500 and 250 microns;

Figure 5 is a hysteresis curve for  $\text{Nd}_{0.4}\text{Fe}_{0.6}$  taken at 295° K for four different chill substrate speeds;

30 Figure 6 is a plot of substrate surface velocity versus intrinsic coercivity for 5 different alloys of spun melted praseodymium-iron alloys.

35 Figure 1 shows a schematic representation of a spin melting apparatus that could be used to practice the method of this invention. A hollow, generally cylindrical, quartz tube 2 is provided for retaining alloys of rare earth and transition metal for melting. The tube has a small orifice 4 in its bottom through which molten alloy is expressed. Tube 2 is provided with cap 6 which sealably retains inlet tube 8 for a pressurized inert gas such as argon. An induction type heating coil 10 is disposed around the portion of quartz tube 2 containing the metals. When the coil is activated, it heats the material within the quartz tube causing it to melt and form a fluid mass 12 for ejection through orifice 4. Gas is introduced into space 14 above molten alloy 12 to maintain a constant positive pressure so that the molten alloy is expressed at a controlled rate through orifice 4. The expressed stream 16 immediately impinges on rotating disk 18 made of copper metal plates with chromium, to form a uniform ribbon 28 of alloy. Disk 18 is retained on shaft 20 and mounted against inner and outer retaining members 22 and 24, respectively. Disk 18 is rotated in a clockwise direction as depicted, by a motor (not shown). the relative velocity between expressed molten metal 16 and chill surface 26 is controlled by changing the frequency of rotation. The speed of disk 18 will be expressed herein as the number of meters per second which a point on the chill surface of the disk travels at a constant rotational frequency. Means may be provided within disk 18 to chill it. Disk 18 is much

more massive than ribbon 28 and acts as an infinitely thick heat sink. The limiting factor for the rate of chill of molten alloy of stream 4 is the thickness of ribbon 28. If ribbon 28 is too thick, the metal most remote from chill surface 26 will cool more slowly than that adjacent the chill surface. If the rare earth-iron alloy cools too slowly from the melt, it will solidify with a crystalline microstructure that is substantially nonmagnetic. If it cools too quickly, the ribbon will have relatively low coercivity (<1 koe). This invention relates to making hard RE—TM magnets by quenching molten mixtures of the elements at a rate between that which yields amorphous soft magnetic materials and non-magnetic crystalline materials. Herein, the term hard magnet or hard magnetic alloy will generally refer to an Re—Fe alloy with a room temperature coercivity greater than about 1,000 Oersteds that may be formed by quenching from the melt at a suitable rate. Generally, the intrinsic coercivity of these magnetic alloys will increase as the temperature approaches absolute zero.

90 The operational parameters of a spin melting apparatus may be adjusted to achieve optimum results by the practice of the method of the invention. For example, the rare earth and transition metals retained in the melting tube or vessel must be at a temperature above the melting point of the alloy to be in a sufficiently fluid state. The quench time for a spun melt alloy is a function of its temperature at expression from the tube orifice. The amount of pressure introduced into the melting vessel above a molten alloy will affect the rate at which metal is expressed through the orifice. The following description and examples will clearly set out for one skilled in the art methods of practicing, and the results obtainable, by the invention. In the above described spin melting apparatus, it is preferably to use a relatively low ejection pressure, (about 2—3 psig (13.79—20.68 kPa)). At such pressures the metal flows out of the orifice in a uniform stream so that when it impinges and is quenched on the cooling disk it forms a relatively uniform ribbon. Another parameter that can be adjusted is the orifice size at the outlet of the melting vessel. The larger the orifice, the faster the metal will flow from it, the slower it will cool on the chill surface and the larger will be the resultant ribbon. It is preferable to operate with a round orifice with a diameter from about 250—1200 microns. Other orifice sizes may be suitable, but all other parameters would have to be adjusted accordingly for much smaller or larger orifice sizes. Another critical factor is the rate at which the chill substrate moves relative to the impingement stream of rare earth-iron alloy. The faster the substrate moves the thinner the ribbon of rare earth transition metal is formed and the faster the quench. It is important that the ribbon be thin enough to cool substantially uniformly throughout. The temperature of the chill substrate may also be adjusted by the inclusion of heating or cooling

means beneath the chill surface. It may be desirable to conduct a spin melting operation in an inert atmosphere so that the Re—Fe alloys are not oxidized as they are expressed from the melting vessel and quenched.

The hard magnets of this invention are formed from molten homogeneous mixtures of rare earth elements and transition elements, particularly iron. The rare earth elements are the group falling in Group III of the periodic table and include the metals scandium, yttrium and the elements from atomic number 57 (lanthanum) to 71 (lutetium). The preferred rare earth elements are the lower molecular weight members of the lanthanide series. These are the most abundant and least expensive of the rare earths. In order to achieve the high magnetic coercivities desired, it is believed that the outer f-orbital of the rare earth constituents should not be empty, full, or half full. That is, there should not be zero, seven, or fourteen valence electrons in the outer f-orbital. This eliminates the elements lanthanum (5d 6s<sup>2</sup>), gadolinium (4f<sup>7</sup>5d 5s<sup>2</sup>), lutetium (5d 6s<sup>2</sup>) an actinium (6d 7s<sup>2</sup>) from the lanthanide series as well as scandium (3d 1 4s<sup>2</sup>) and yttrium (4d 1 5s<sup>2</sup>). Promethium is of little practical significance because it is a synthetically produced element. Thus, the rare earth elements useful for the invention include cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, holmium, erbium, thulium and ytterbium. Also suitable would be mischmetals consisting predominantly of these rare earth elements.

The transition metals which may be used in practice of the invention include the elements iron, nickel and cobalt. Iron is the preferred transition metal element because it is most abundant and relatively inexpensive.

Herein, the relative amounts of rare earth and transition metals will be expressed in atomic fractions. In an alloy of Nd<sub>0.6</sub>Fe<sub>0.4</sub>, e.g., the alloyed mixture would contain proportionately on a weight basis 0.6 moles times the atomic weight of neodymium (144.24 grams/moles) or 86.544 grams and 0.4 moles times the atomic weight of iron (55.85 grams per mole) or 22.34 g. On a weight percent basis Nd<sub>0.6</sub>Fe<sub>0.4</sub> would contain

$$\frac{\text{Wt Nd}}{\text{Wt Nd+Wt Fe}} \times 100 = 79.5\% \text{Nd}$$

and

$$\frac{\text{Wt Fe}}{\text{Wt Nd+Wt Fe}} \times 100 = 20.5\% \text{Fe.}$$

An atomic fraction of 0.4 would be equivalent to 40 atomic percent. The compositional range of the RE—TM alloys of this invention is about 20—70 atomic percent transition metal and the balance rare earth metal. Small amounts of other elements may be present so long as they do not materially affect the practice of the invention.

It is known that magnetically soft, amorphous,

glass-like forms of the subject rare earth-transition metal alloys can be achieved by spin melting followed by a rapid quench. Any atomic ordering that may exist in the alloys is extremely short range and cannot be detected by X-ray diffraction. They have high magnetic field saturations but low room temperature intrinsic coercivity, generally 100—200 Oe.

The key to practicing the present invention is to quench a molten rare earth-transition metal alloy, particularly rare earth-iron alloy, at a rate slower than the cooling rate needed to form amorphous, glasslike solids with soft magnetic properties but fast enough to avoid the formation of a crystalline, non-magnetic microstructure. High magnetic coercivity (generally greater than 1,000 Oe) characterizes quenched RE—TM compositions formed in accordance with the method of the invention. These hard magnetic properties distinguish the alloys made by the invention from any like composition previously formed by melt-spinning, simple alloying, or high rate sputtering followed by low temperature annealing. X-ray diffraction patterns of some of the Nd—Fe and Pr—Fe alloys do contain weak Bragg reflections corresponding to crystalline rare earths (Nd, Pr) and the RE<sub>2</sub>Fe<sub>17</sub> intermetallic phases. Owing to the low magnetic ordering temperatures of these phases (less than 330K), however, it is highly unlikely that they could be the magnetically hard component in these melt spun alloys. The coercive force is believed due to an underlying amorphous or very finely crystalline alloy. The Sm<sub>0.4</sub>Fe<sub>0.6</sub> and Tb<sub>0.4</sub>Fe<sub>0.6</sub> alloys also contain weak Bragg reflections which could be indexed to the REFe<sub>2</sub> intermetallic phases. These phases do have relatively high magnetic ordering temperatures (approximately 700K) and could account for the coercivity in these alloys. Magnets made by the present invention do not only have excellent magnetic characteristics, but are also easy and economical to produce. The following examples will better illustrate the practice of the present invention.

#### Example I

A mixture of 63.25 weight percent neodymium metal and 36.75 weight percent iron was melted to form a homogeneous Nd<sub>0.4</sub>Fe<sub>0.6</sub> alloy. A sample of the alloy was dispersed in the tube of a melt spinning apparatus like that shown in Figure 1. The alloy was melted and ejected through a circular orifice 500 microns in diameter with an argon pressure of 17.24 kPa (2.5 psi) onto a rotating chill disk initially at room temperature. The peripheral velocity of the chill disk was varied at 2.5, 5, 15, 20 and 25 meters per second. The intrinsic coercivities of the resulting alloys were measured at a temperature of 295°K. The alloy ribbons were pulverized to powder by a roller on a hard surface and retained in the sample tube of a magnetometer. Figure 2 plots the measured intrinsic coercivity in kiloOersteds as a function of the substrate surface velocity for the chill member. The parenthetical numbers adjacent the

data points correspond to measured ribbon thicknesses in microns. It is clear that a substrate velocity of 2.5 meters per second does not achieve the desired optimum coercivity. It is believed that the ribbon laid down at this substrate surface velocity was too thick (208 microns). It cooled slowly enough to allow the growth of nonmagnetic crystal structures. The optimum quench rate appeared to be achieved at a disk surface velocity of 5 meters per second. At higher disk speeds (faster quench and thinner ribbon) the room temperature intrinsic coercivity decreased gradually indicating the formation of amorphous soft magnetic structures in the alloy.

#### 15 Example II

Figure 3 shows a plot of measured intrinsic magnetic coercivity of  $295^\circ\text{K}$  as a function of chill disk surface velocity for three different neodymium iron alloys. The alloys were composed of  $\text{Nd}_{1-x}\text{Fe}_x$  where  $x$  is 0.5, 0.6 and 0.7. The maximum achievable coercivity seems to be a function of both the substrate surface velocity and the composition of the rare earth transition metal alloy. The greatest coercivity was achieved for  $\text{Nd}_{0.5}\text{Fe}_{0.5}$  and a chill disk surface speed of about 2.5 meters per second. The other two neodymium iron alloys containing a greater proportion of iron showed lower maximum coercivities achieved at relatively higher substrate surface velocities. However, all of the materials had extremely good maximum room temperature coercivities (greater than 6 kiloOersteds).

#### Example III

Figure 4 shows the effect of varying the size of the ejection orifice of an apparatus like that shown in Figure 1 for  $\text{Nd}_{0.4}\text{Fe}_{0.6}$ . The ejection gas pressure was maintained at about 2.5 psig (17.24 kPa) and the chill disk was initially at room temperature. The figure shows the substrate surface velocity must increase as the orifice size increases. For the 250 micron orifice, the maximum measured coercivity was achieved at a substrate speed of about 2.5 meters per second. For the 500 micron orifice, the optimum measured coercivity was at a chill surface speed of 5 meters per second. For the largest orifice, 1200 microns in diameter, the optimum substrate surface speed was higher, 15 meters per second. Again, the process is limited by the thickness of the ribbon formed on the chill surface. That is, that portion of the metal most remote from the chill surface itself must cool by heat transfer through the balance of the spun melt material at a rate fast enough to achieve the desired ordering of atoms in the alloy. Homogeneous cooling is desired so that the magnetic properties of the ribbon are uniform throughout. The faster the chill surface travels, the thinner the ribbon of RE—TM produced.

#### 60 Example IV

Figure 5 shows hysteresis curves for  $\text{Nd}_{0.4}\text{Fe}_{0.6}$  ejected from a 500 micron orifice at a gas

pressure of 2.5 psi (17.24 kPa) onto a chill member moving at rates of 2.5, 5, and 15 meters per second, respectively. Those alloys ejected onto the substrate moving at a speed of 2.5 meters per second had relatively low room temperature coercivity. The narrow hysteresis curve suggests that this alloy is a relatively soft magnetic material. Alternatively, the relatively wide hysteresis curves for chill substrate velocities of 5 and 15 meters per second are indicative of materials with high intrinsic magnetic coercivities at room temperatures. They are good hard magnetic materials.

#### Example V

Figure 6 is a plot of chill disk velocity versus measured intrinsic coercivity in kiloOersteds for alloys of  $\text{Pr}_{1-x}\text{Fe}_x$  where  $x$  is 0.4, 0.5, 0.6, 0.66 and 0.7. The alloys were ejected at a pressure of about 2.5 psig (17.24 kPa) through a 500 micron orifice. The  $\text{Pr}_{0.34}\text{Fe}_{0.66}$  and  $\text{Pr}_{0.3}\text{Fe}_{0.7}$  alloys quenched on a disk moving at about ten meters per second had measured intrinsic coercivities at  $22^\circ\text{C}$  of greater than 7 kiloOersteds. The  $\text{Pr}_{0.6}\text{Fe}_{0.4}$  alloy had a maximum measured coercivity of about 3.8 kiloOersteds at a quench disk surface velocity of about five meters per second.

Samples of  $\text{Tb}_{0.4}\text{Fe}_{0.6}$  and  $\text{Sm}_{0.4}\text{Fe}_{0.6}$  alloys have also been spun melted. The maximum coercivity measured for the terbium alloy was about three kiloOersteds. The samarium alloy developed a room temperature coercivity of at least 15 kiloOersteds, the highest coercivity measurable by the available magnetometer. Spun melted samples of  $\text{Y}_{0.6}\text{Fe}_{0.4}$  did not develop high intrinsic coercivities. The measured coercivities of the yttrium samples were in the 100—200 Oersted range.

Thus the present invention comprises a reliable and inexpensive method of making alloys of rare earth elements and iron into hard magnetic materials. Heretofore, no one has been able to make such high coercivity magnets from low molecular weight rare earth elements, mischmetals, or even samarium and iron.

#### Claims

1. A method of making an alloy with permanent magnetic properties at room temperature comprising the steps of:
  - forming a mixture consisting essentially of 20 to 70 atomic percent of one or more transition metals taken from the group consisting of iron, nickel and cobalt and the balance of one or more rare earth elements taken from the group consisting of cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, holmium, erbium, thulium, and ytterbium;
  - heating said mixture to form a homogeneous molten alloy;
  - and quenching said molten alloy at such a rate that it solidifies substantially uniformly and instantaneously to form a substantially noncrystalline alloy, as determined by X-ray

diffraction, having a room temperature coercivity of at least 1,000 Oersteds.

2. A method of making an alloy with permanent magnetic properties at room temperature according to claim 1, in which the mixture consists essentially of 20 to 70 atomic percent iron and the balance one or more rare earth elements taken from the group consisting of praseodymium, neodymium, and samarium.

3. A method of making an alloy with permanent magnetic properties at room temperature according to claim 1 or 2, in which the homogeneous molten alloy is expressed from an orifice having a diameter of less than 1,200 microns; and said expressed alloy is immediately impinged onto a chill surface moving at such a rate with respect to the expressed alloy such that the alloy solidifies substantially instantaneously to form a substantially amorphous alloy ribbon with a thickness of less than 200 microns.

4. A method of making an alloy with permanent magnetic properties at room temperature according to claim 1 or 2, in which said mixture is melted in a crucible having an outlet orifice with a diameter of less than 1,200 microns; and said alloy is melt spun from said orifice and impinged onto a chill surface traveling at such a velocity relative thereto that a homogeneous amorphous alloy ribbon having a thickness of less than 200 microns and a substantially noncrystalline or very finely crystalline microstructure as determinable by X-ray diffraction is formed.

5. A magnetically hard, substantially amorphous alloy consisting essentially of 20 to 70 atomic percent of one or more transition metal elements taken from the group consisting of iron, nickel and cobalt and the balance of one or more rare earth elements taken from the group consisting of cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, holmium, erbium, thulium and ytterbium, said alloy being formed by a method according to claim 1, and having a magnetic coercivity of at least 1,000 Oersteds at room temperature.

6. A magnetically hard, substantially amorphous alloy according to claim 5, consisting essentially of 20 to 70 atomic percent iron and the balance of one or more rare earth elements taken from the group consisting of cerium, praseodymium, neodymium, and samarium or mischmetals thereof.

7. A friable ribbon of rare earth-transition metal alloy that can be reduced to particles which are alignable in a magnetic field and suitable for making permanent magnets, said ribbon being formed by a method according to claim 3 or 4, said alloy ribbon having a substantially amorphous or very finely crystalline microstructure as determinable by X-ray diffraction and an intrinsic magnetic coercivity at room temperature of at least 1,000 Oersteds.

8. A method of making a rare earth-iron alloy with permanent magnetic properties at room temperature substantially as hereinbefore

particularly described with reference to the examples and to the accompanying drawings.

New Claims or Amendments to Claims Filed on 31st August 1982

70 **New or Amended Claims:—**

9. A method of making an alloy with permanent magnetic properties at room temperature comprising the steps of:

forming a mixture consisting essentially of one or more transition metals taken from the group consisting of iron, nickel and cobalt and the balance of one or more rare earth elements taken from the group consisting of cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, holmium, erbium, thulium, and ytterbium;

heating said mixture to form a homogeneous molten alloy;

quenching said molten alloy at a rate such that it solidifies substantially uniformly and instantaneously to form an alloy having intrinsic magnetic coercivity at room temperature of at least about 1,000 Oersteds.

10. A method of making an alloy with permanent magnetic properties at room temperature comprising the steps of:

forming a mixture of iron and one or more rare earth elements taken from the group consisting of praseodymium, neodymium, samarium and misch-metals thereof;

heating said mixture to form a homogeneous molten alloy;

quenching said molten alloy at a rate such that it solidifies substantially uniformly and instantaneously to form a substantially noncrystalline or finely crystalline alloy as measured by X-ray diffraction that has a room temperature coercivity of at least about 1,000 Oersteds.

11. A method of making a hard magnetic alloy directly from a molten mixture of iron and rare earth elements comprising:

melting a mixture consisting essentially of iron and one or more rare earth elements taken from the group consisting of neodymium, praseodymium, cerium, samarium and misch-metals thereof;

expressing said molten mixture from an orifice sized to produce a ribbon of chilled alloy less than about 200 microns thick;

immediately impinging said expressed mixture onto a chill surface moving at a rate with respect to the expressed metal such that it solidifies substantially instantaneously to form a brittle alloy ribbon with a thickness less than about 200 microns which when magnetized in a suitable magnetic field has a measurable magnetic coercivity at room temperature of at least about 1,000 Oersteds.

12. A method of making an iron-rare earth elements alloy having a magnetic coercivity of at least 1,000 Oersteds at room temperature comprising alloying a mixture consisting

essentially of one or more transition metals taken from the group consisting of iron, nickel, and cobalt and the balance of one or more rare earth elements taken from the group consisting of

5 cerium, praseodymium, neodymium, samarium, europium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and misch-metals thereof;

10 melting said iron-rare earth alloy in a crucible having an outlet orifice sizes to produce a ribbon of chilled alloy less than about 200 microns thick;

15 melt spinning said alloy from said orifice and impinging the spun metal on a chill surface travelling at a velocity relative thereto such that a homogeneous amorphous alloy ribbon having a thickness less than about 200 microns and a substantially noncrystalline or very finely

crystalline mixture as determinable by X-ray diffraction is formed.

20 13. A magnetically hard alloy consisting essentially of one or more transition metal elements taken from the group consisting of iron, nickel and cobalt and the balance of one or more rare earth elements taken from the group consisting of cerium, praseodymium, neodymium,

25 samarium, europium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and misch-metals thereof, said alloy being formed by instantaneously and uniformly quenching a homogeneous molten mixture of the rare earth

30 and transition metal elements producing an alloy with a magnetic coercivity of at least 1,000 Oersteds at room temperature.