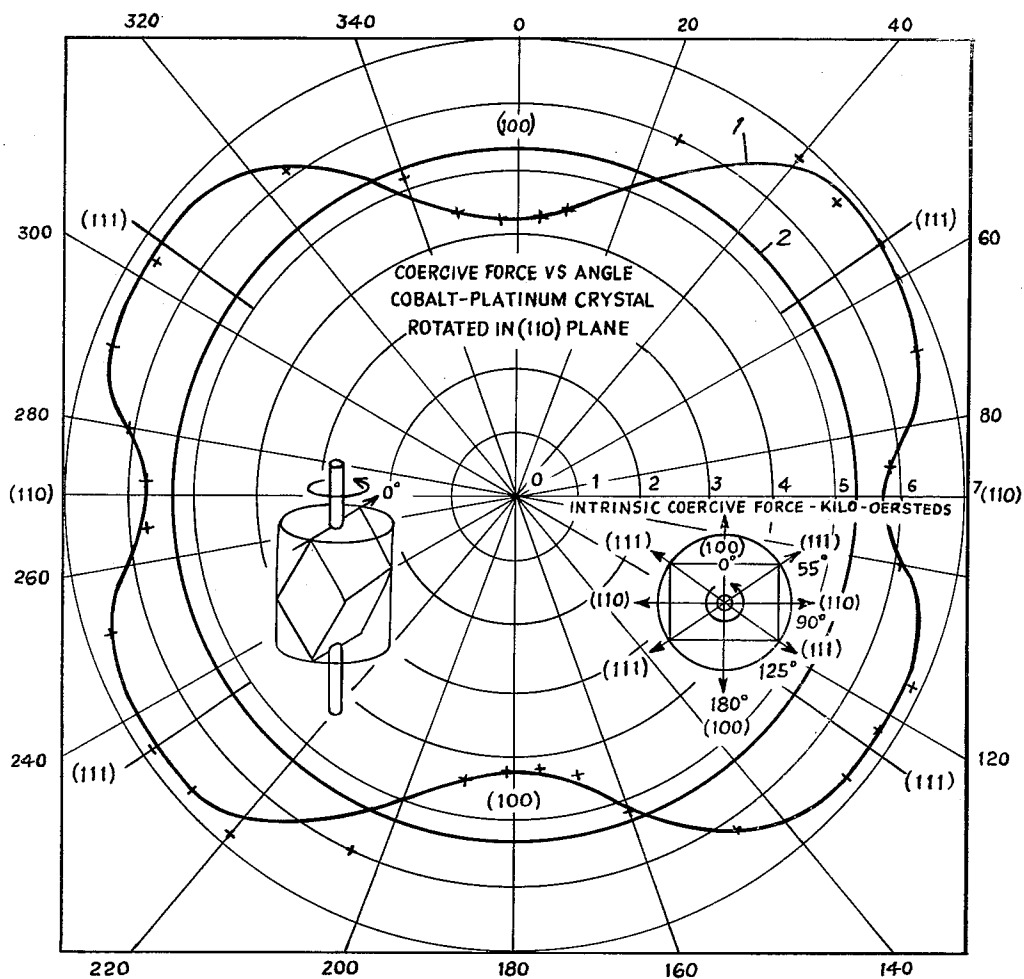


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## COBALT-PLATINUM ALLOY AND MAGNETS MADE THEREFROM

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This invention relates to a permanent magnet and more particularly to a cobalt-platinum magnet which is magnetically anisotropic.

The need for an extremely powerful but small permanent magnet has existed for some time. Such magnets would find extensive use in instruments and motors where, due to space requirements, small but very powerful magnets are required. One example of such a use is in electric watches. The driving force in these watches is attained by the interaction of an electro-magnetic field of an electrically energized coil with that of the magnetic field produced by a permanent magnet. Since the space available for the magnet is extremely limited, and since the energy requirements of the electric watch must necessarily be minimized, it has been necessary to obtain a magnetic material with a high flux density.

Another use to which powerful magnets are applied are those medical applications in which a magnet is employed to remove ferromagnetic objects from the human body. Obviously, these magnets should be as small as possible in order to be applicable to various removal operations.

Various attempts have been made to adapt the well known Alnico magnets for use in miniature instruments and meters but with limited success. The Alnico magnets do not exhibit as high a resistance to self-demagnetization as is sometimes desired. Alnico has also been found to be rather hard to machine which is a decisive disadvantage where it is to be used in miniature devices.

The discovery and development of cobalt-platinum magnets opened a new avenue to the construction of small, powerful magnets. The CoPt magnet is normally several times as strong as the best known Alnico magnets when compared at equal shapes having low  $L/D$  ratios, i.e., 3 or less. The CoPt alloys are more readily fabricated than Alnico in that the former are ductile and lend themselves to being fabricated by conventional metal manufacturing methods. The CoPt magnet with its high coercive force also has five to eight times more resistance to demagnetization than the Alnico magnets.

Even though the present CoPt magnets are far superior to prior known magnets, there are still many instruments and devices which require a greater magnetic force per unit area of magnet than present CoPt magnets, which are multicrystalline and magnetically isotropic, can produce. This is especially true in micro-miniature devices where space is at a premium. Another example is in microwave tubes. In this devices which incorporate a permanent magnet, it has often been necessary to increase the size of the finished package because the magnets used would have insufficient power if made any smaller. Thus, it can be seen that there exists a great need for a smaller yet stronger magnet than can be produced by the present known methods.

The present invention satisfies such need. According to this invention, it has been discovered that if cobalt-platinum single crystals are used as the raw material for the CoPt magnet, a magnet having a significantly higher intrinsic coercive force than that of magnets made from the standard equiaxed multicrystalline CoPt alloy may be obtained.

An essential aspect of this invention resides in the discovery that CoPt single crystals are magnetically anisotropic. It has been further discovered that single crystal

magnets of CoPt exhibit orientation preference, viz., if they are crystallographically oriented in certain directions, they will possess an enhanced intrinsic coercive force. Discovery of these phenomena thus makes possible the fabrication of smaller yet stronger magnets than were heretofore obtainable using the equiaxed multicrystalline CoPt alloys of the prior art.

It is accordingly a primary object of the present invention to provide an improved CoPt alloy possessing significantly improved magnetic properties.

It is another object of the present invention to provide an improved CoPt alloy magnet comprised of a CoPt alloy in the form of a single crystal which is so crystallographically oriented as to have a significantly increased intrinsic coercive force.

It is a further object of the present invention to provide an improved CoPt alloy comprised of CoPt single crystals oriented in approximately the [110] or [111] directions.

Another object of the present invention is to provide an improved CoPt alloy magnet comprised of CoPt single crystals oriented in approximately the [110] or [111] directions.

A still further object of the present invention is to provide a magnet composed of a magnetically anisotropic and properly oriented CoPt single crystal.

It is another object of the present invention to provide a novel method of fabricating magnets composed of a magnetically anisotropic CoPt single crystal.

These and further objects and advantages of the invention will become more apparent upon reference to the following description and claims and the appended drawing wherein:

The single figure is a circular graph showing the intrinsic coercive force of a CoPt single crystal magnet plotted against crystallographic orientation in comparison with the intrinsic coercive force of a CoPt magnet composed of randomly oriented crystals.

According to the present invention, it has been found that magnets having a higher maximum flux density than obtained by previous processes may be produced by using single CoPt crystals, which are magnetically anisotropic. Permanent magnets which are formed of these magnetically anisotropic CoPt crystals are found to exhibit a considerable increase in intrinsic coercive force if the crystallographic orientation is substantially along the [110] or [111] axes. The process for producing a CoPt magnet having such a crystallographic orientation may be carried out in substantially the following manner.

First it is necessary that a CoPt crystal be obtained which has the desired crystallographic characteristics. This may be done in one of several ways. One of these methods for obtaining a CoPt crystal having proper crystallographic orientation is to allow a given quantity of liquid CoPt to freeze very slowly, resulting in the solidification of material consisting of large crystals. Metallographic preparation can then be used to determine the size and location of crystal boundaries. Once the size and location of the crystal boundaries are known, a single crystal oriented substantially in the [110] or [111] directions as shown by X-ray diffraction can be machined out of the metal. By using this method, crystals having a minimum dimension of approximately .150 inch have been obtained.

An alternate process which is finding increased commercial application is known as "crystal growing" or "crystal pulling." This process requires the use of a seed crystal which is slowly withdrawn from the CoPt liquid metal which is held just above the freezing point. By this method, large single crystals of CoPt may be produced.

The crystallographic orientation of the grown CoPt crystal is determined and controlled by the orientation of the seed crystal and it can be any direction preferred.

If one wished to make magnets of highest intrinsic coercive force, he would grow a crystal of CoPt in the [111] direction. Predetermination of orientation of the seed or confirming determination of the grown crystal is done by means of X-ray diffraction.

Yet a third means of producing large crystals is by "zone refining" or "zone growing." In this method a "melt zone" is slowly traversed along a CoPt rod, thereby producing a large grained or crystalline structure.

A fourth method of producing a CoPt single crystal having the desired orientation involves the fabrication of multicrystalline rods or strips by rolling or drawing so as to obtain preferred orientation within the alloy and thereby obtaining a magnet with preferred orientation. Heat treatment of this magnet must, of course, be selected so as not to destroy the preferred orientation imparted by the process. Such heat treatment should consist of only an ordering heat treat process (see below).

The above stated methods are given by way of example only and are not intended to in any way cover all the methods by which CoPt crystals having preselected crystallographic orientation may be produced. Various other methods will also be readily apparent to those skilled in the crystal art.

Once the desired properly oriented CoPt crystal is obtained, it is necessary to heat-treat the crystal before the desired magnetic properties are obtained. The heat treating steps employed may effectively be those described in a paper by Gebhardt and Koster ["Das System Platin-Kobalt Mit Desonderer Berucksichtigung Der Phase CoPt" in *Zeitschrift fur Metalkunde*, pp. 253-261 (1940)] though this is only one of a number of heat treating processes which may be employed. This process consists essentially of three steps:

(1) A disordering heat treatment, in which the single crystal is heated sufficiently to give the crystal a homogeneous condition with the atoms in a random or disordered orientation. This disordering treatment may be carried out by heating to about 1800-2000° F. for about one hour.

(2) A water quench to room temperature to retain the disordered structure in a stable but non-equilibrium condition.

(3) An aging or ordering treatment, in which the quenched crystal is heated to about 1200° F. for about one-half hour. This ordering treatment imparts enough thermal energy to the atoms to allow them to move from their random location in the face-centered cubic lattice to defined positions of a face-centered tetragonal lattice.

The heat-treated alloy is then magnetized in a field of 25,000 to 50,000 oersteds.

The optimum composition of the CoPt having desirable permanent magnetic properties contains cobalt and platinum atoms in a ratio of approximately 1:1 and forms the intermetallic compound CoPt, viz., approximately 23.2% weight cobalt and 76.8% by weight platinum. It is possible, however, to use an alloy having cobalt in a weight percentage of approximately 18.5-28.5, balance platinum.

As a specific example of the present invention, a single crystal of CoPt may be prepared by the "crystal growing" process previously described. In this process, CoPt having a 1:1 atomic ratio is held at a temperature approximately 1-2° above its freezing point (approximately 1525° C.). A small portion of the melt is removed and permitted to solidify and a seed crystal is prepared by mechanically orienting the solidified portion so that its axis is in the [111] direction. The oriented seed crystal is then placed in a water-cooled copper stud and lowered towards the melt until contact with the melt surface is made by the seed. The seed crystal is brought in contact with the melt surface so that its [111] axis is normal to the melt surface. The seed crystal is then slowly

withdrawn from the melt surface, causing a cylindrical-shaped CoPt growth to form on the seed crystal.

The resulting solid is then heat treated, including a disordering heat treatment at 2000° F. for 1 hour, a water quench to room temperature, and a final ordering heat treatment at 1200° F. for one-half hour.

The heat treated alloy is then magnetized in a field of 25,000 oersteds.

In the single figure accompanying the instant specification, intrinsic coercive force has been plotted both for a multicrystalline CoPt rod and for a CoPt single crystal, both subjected to the same heat treatment and magnetization. To obtain the measurements in question, the single crystal CoPt specimen was rotated in the [110] plane and representative intrinsic coercive force data obtained throughout 360° of rotation. The rod specimen was given the standard D.C. magnetic hysteresis loop test. The intrinsic coercive force of the single crystal is shown at 1 and that for the multicrystalline CoPt at 2. As will be seen, the intrinsic coercive force of the latter is constant and has a value of approximately 5,300 oersteds. The intrinsic coercive force of the single crystal, however, exhibits orientation preference with the optimum direction being the [111] direction. As shown in the drawing, the intrinsic coercive force in the [111] direction is approximately 6,800 oersteds, an increase in 28% above that of the multicrystalline rod.

This increase in intrinsic coercive force is not limited, however, to the [111] direction. As the drawing illustrates, the intrinsic coercive force of the single crystal in the [110] direction is approximately 300 oersteds greater than that of the multicrystalline rod and angular deviations of as much as 30° from the [111] and 5° from the [110] directions also exhibit an increased intrinsic coercive force varying in intensity.

From the above, it is readily seen that a CoPt magnet constructed in accordance with the present invention will have a quality far superior to heretofore known magnets. The use of a CoPt magnet of the magnetically anisotropic single crystal oriented in the [111] direction will provide up to 28% more coercive force than other known CoPt magnets. Under certain circumstances this allows at least some reduction in the size of a magnet required to furnish a given external field strength. Similar though lesser reductions in magnet size will result through use of such crystal oriented in the [110] direction. This increased power and reduction in the size of the magnet required may be of tremendous importance where a small, powerful magnet is required. The improved magnets of the present invention are also extremely useful in environments requiring an extremely high coercive force, such as in microwave tubes.

When used in the claims, the terms "substantially the [111] direction" and "substantially the [110] direction" shall be construed to embrace deviations from the [110] and [111] directions which still permit the crystal to exhibit an intrinsic coercive force greater than that of a magnetically isotropic CoPt crystal of the same composition and which has been subjected to the same heat and magnetizing treatment.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A permanent magnet consisting of a CoPt a single crystal alloy consisting essentially of about 18.5% to 28.5% by weight of cobalt and about 71.5% to 81.5%

5

by weight of platinum, said magnet being magnetically anisotropic and having maximum intrinsic coercive force which is about 25% higher than the intrinsic coercive force of a substantially magnetically isotropic multicrystalline permanent magnet of the same alloy.

2. The magnet as defined in claim 1 wherein the CoPt crystal alloy consists essentially of about 23.2% by weight of cobalt and 76.8% by weight of platinum.

3. A permanent magnet consisting of a CoPt a single crystal alloy consisting essentially of about 18.5% to 28.5% by weight of cobalt and 71.5% to 81.5% by weight of platinum, said magnet being magnetically anisotropic and having an intrinsic coercive force which is at least about 5600 oersteds and is at least 9% higher than the intrinsic coercive force of a substantially magnetically isotropic multicrystalline permanent magnet of the same alloy.

4. A magnetically anisotropic magnet composed of a CoPt single crystal consisting essentially of 18.5% to 28.5% by weight of cobalt and the balance consisting essentially of platinum.

5. The magnet as defined in claim 4 wherein the CoPt single crystal consists essentially of about 23.2% of cobalt and 76.8% by weight of platinum.

6. The magnet of claim 4 wherein the magnetic axis of said crystal is crystallographically oriented in substantially the [110] direction.

7. The magnet of claim 4 wherein the magnetic axis of said crystal is crystallographically oriented in substantially the [111] direction.

8. A magnetically anisotropic CoPt single crystal consisting essentially of 18.5% to 28.5% by weight of cobalt and the balance consisting essentially of platinum.

9. The single crystal of claim 8 wherein the magnetic axis of said single crystal is oriented in substantially the [111] crystallographic direction.

6

10. The single crystal of claim 8 wherein the magnetic axis of said single crystal is oriented in substantially the [110] crystallographic direction.

11. A magnetically anisotropic CoPt single crystal consisting essentially of 18.5% to 28.5% by weight of cobalt and the balance consisting essentially of platinum, said crystal having an intrinsic coercive force in the [111] direction of approximately 6800 oersteds and, in the [110] direction, of approximately 5600 oersteds.

12. A magnetically anisotropic CoPt single crystal crystallographically oriented in a locus of planes from the [111] plane  $\pm$  approximately 30° of rotation from said [111] plane and the [110] plane  $\pm$  approximately 5° of rotation from said [110] plane said crystal consisting essentially of 18.5% to 28.5% by weight of cobalt and the balance consisting essentially of platinum.

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