Patented Aug. 14, 1945

2,382,652

UNITED STATES PATENT OFFICE

2,382,652

MAGNETIC MATERIALS

Ethan A. Nesbitt, Brooklyn, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

No Drawing. Application October 23, 1941, Serial No. 416,219

7 Claims. (Cl. 175—21)

This invention relates to permanent magnet alloys and to magnets produced therefrom which are cause to have more desirable properties as permanent magnets by a cold working treatment. The invention also relates to and includes methods of treating and producing such improved alloys and permanent magnets.

An object of the invention is the production of better and more efficient permanent magnet materials.

A feature of the present invention is the discovery that permanent magnet compositions, such as those described hereinafter, may be improved by reduction of the cross section thereof by a stage of cold working during their preparation and prior to the final heat treatment. Such working is preferably accomplished by methods which produce elongation and prevent lateral spreading. Methods that have been found beneficial include swaging, rolling with grooved rolls and wire drawing. It appears that the result of improved permanent magnet properties is manifested chiefly in the direction of elongation. Reduction of thickness by such rolling of a metal sheet as permits the material to spread laterally is only partially effective.

The evidence is that materials of or produced according to the present invention generally are anisotropic and their improved properties are manifested chiefly in the direction in which the elongation takes place.

In the Patent No. 2,298,225 it is pointed out that there are classes of materials which, if maintained at a certain high temperature but below the melting point, assume a form known as the "gamma" phase, and if the material is thereafter cooled to around room temperature, it tends to assume the "alpha" phase and thereafter if maintained at around 500° C. to 800° C., a finely dispersed small amount of the "gamma" phase forms in the "alpha" phase. This brief statement is to be read in the light of the information, diagrams, and discussion of said copending application.

As pointed out in Patent No. 2,298,225, dated October 6, 1942 a suitable procedure for preparing permanent magnet material is to melt the material and cool it to room temperature to produce formation of the "alpha" phase and thereafter elevate the material to a higher temperature between 500° C. to 800° C. for a length of time such as is necessary to allow a small amount of the "gamma" phase to precipitate in a highly dispersed form in the "alpha" phase. This produces dispersion hardening in the material and produces a very effective permanent magnet material. This method of forming permanent magnet materials is different and seemingly involves a different principle than that heretofore employed with respect to many others, such as alloys of iron, cobalt and molybdenum, in that in the present instance the material is converted into a low temperature "alpha" phase and thereafter has a small amount of the high temperature "gamma" phase precipitated therein in a fine and dispersed state. In the usual case of permanent magnets hardened by precipitation the high temperature phase is preserved and a small amount of the low temperature phase is precipitated.

In some alloys of the type under discussion the "gamma" to "alpha" transformation tends to occur at low temperatures at which the transformation becomes sluggish and non-equilibrium conditions exist.

Whether this is the case or not, cold rolling these alloys in grooved rolls or working them mechanically by any equivalent method causes or expedites the formation at room temperature of the "alpha" phase and brings them into equilibrium. Some alloys of this type may not change completely to the "alpha" phase at room temperature unless given the above treatment. Under the influence of the rolling treatment others change only partly to the "alpha" phase. Whether partial or complete this result is one beneficial aspect of the present invention. However, there is a second beneficial aspect which is due to crystal orientation. X-ray measurements confirm this and magnetic tests show the best permanent magnet properties in the direction of elongation. Either or both of these aspects may be present in some degree.

After the alloys are brought into the "alpha" phase by the combination of cooling and cold working they are raised to a temperature which brings them to the temperature which causes the precipitation in finely dispersed particles of some of the "gamma" phase. This results in the production of magnetic material having effective and desirable properties as permanent magnets in the direction of elongation. In every case care must be used not to raise the material to too high a temperature in order not to lose the effect of cold working.

A frequently used criterion of the desirability of permanent magnet materials is the product of "coercive force" and "residual induction." A more accurate figure of merit is that of "maxi-

mum energy product," which on the demagnetization portion of the hysteresis loop, is the product of induction B and magnetizing force H at a point where this produce is the greatest. See Wahl, "Applied Magnetism," pages 42 to 45, inclusive.

The above criterion is independent of the matter of cost, ease or difficulty of preparation rolling or drawing, brittleness, availability of raw materials and other factors which must receive consideration for many practical purposes and applications. Thus a permanent magnet composition which has an absolute maximum energy product less than some other which is less available or suitable from some one or more of the above aspects may be a valuable contribution to the art, if, for example, it may be made to possess a consistently greater "maximum energy product."

Among objects of the present invention are to provide better permanent magnets at little or no increase in cost; to produce useful permanent magnets from materials not hitherto known to possess permanent magnet properties to a useful extent; to improve the properties of compositions known to have useful permanent magnet properties; to produce useful permanent magnets from cheap or readily available raw materials, and to increase either the product of "coercive force" and "residual induction" or the "maximum energy product" of magnetic materials, to provide elongated magnetic materials such as tapes and strips having useful "maximum energy products"; and to provide useful magnets from materials which may be worked with facility.

The subject-matter of the invention or discovery comprises a range or group of magnetic alloys which by appropriate combined heat treatment and cold rolling or elongating treatment will have one or the other or both of the above-named magnetic products or the coercive force or the residual induction increased in the direction of elongation by from one hundred to several hundred per cent as compared to the material in the cast or unsuitably heat treated or unsuitably worked condition.

A feature of the invention or discovery is the lack of any necessity for quenching the material in order to improve its properties; however, quenching may be practiced without detriment and one of the beneficial aspects of the discovery is that the cooling rate may vary widely as convenience or necessity demands.

The alloys may be prepared in the form of rods, bars, wire or tapes. A suitable treatment for any specimen is first to give it the desired amount of cold working plus a low temperature bake. No other heat treatment is necessary. Satisfactory results have been obtained with reductions in area of 75 per cent, although this exact amount is by no means critical.

In greater detail, the material is cast, which gives it the necessary high temperature treatment; it may be given a further or special heat treatment at around 800° C. to 1300° C. The cooled material, which may be cooled to room temperature slowly or rapidly and must be cooled substantially below about 600° C., is forcibly elongated by rolling with grooved rolls, swaging, drawing through dies or by combinations of these methods or by any similar method or methods so as to reduce the cross section in one or several steps over a range from a small amount to a reduction to a small fraction of the original cross section. The material is then heated to a temperature generally in the region 500° C. to 800° C. and maintained for a long time in the extreme bottom of the range, one to several hours in the middle and much less if the temperature is at the top of the range. Too high a temperature destroys the effect of the cold rolling and too low a temperature or too short a time is only partially effective. A quenching treatment is unnecessary.

A typical composition according to the invention as outlined is:

Per cent iron	Per cent nickel	Per cent manganese	Per cent cobalt
72	18	5	5

The iron content may vary between 70 and 80 per cent, the nickel 15 and 25 per cent, the manganese 4 and 20 per cent, and the cobalt 4 and 20 per cent. Carbon over about 0.1 per cent is absent and the magnetic properties are not dependent thereon. Appreciable quantities of other common impurities may be present. These compositions exhibit substantial permanent magnet properties and are notably improved in properties by a treatment of the kind described. They may be prepared from raw materials which are ordinarily cheap and readily available. They exhibit magnetic properties increased around 100 per cent or more with the treatment described as compared with identical compositions as cast. The increase in energy product due to cold rolling alone may be considerably over 100 per cent as compared to the same material heat treated but not cold rolled.

The apparatus illustrated in the above-noted patent may be used to perform the cold rolling process.

The finished magnets are magnetized by the usual methods.

What is claimed is:

1. A magnetic composition comprising 72 per cent iron, 18 per cent nickel, 5 per cent manganese, and 5 per cent cobalt.

2. A magnetic composition composed of between 70 and 80 per cent iron, 15 and 25 per cent nickel, 4 and 20 per cent manganese, and 4 and 20 per cent cobalt.

3. A composition according to claim 2 which has been forcibly elongated while cold and thereafter heated above 500° C. but not above 800° C.

4. An article having properties adapted for permanent magnet use composed of an alloy comprising as essential constituents 72 per cent iron, 18 per cent nickel, 5 per cent manganese, and 5 per cent cobalt, produced by causing the alloy to pass through or into the temperature range of from 800° C. to 1300° C., cooling it substantially below 600° C., forcibly elongating the material in the cold condition, and thereafter maintaining it in the range 500° C. to 800° C. without exceeding about 800° C., whereby the material is caused to have increased ability to retain permanent magnetism in the direction of elongation.

5. An article having properties adapted for permanent magnet use composed of an alloy comprising as essential constituents between 70 and 80 per cent iron, 15 and 25 per cent nickel, 4 and 20 per cent manganese, and 4 and 20 per cent cobalt, produced by causing the alloy to pass through or into the temperature range of from 800° C. to 1300° C., cooling it substantially below 600° C., forcibly elongating the material in the cold condition, and thereafter maintaining it in the range 500° C. to 800° C. without exceed-

ing about 800° C., whereby the material is caused to have increased ability to retain permanent magnetism in the direction of elongation.

6. The method of producing a permanent magnet which comprises composing an alloy of 72 per cent iron, 18 per cent nickel, 5 per cent manganese, and 5 per cent cobalt, passing it into or through the temperature range 800° C. to 1300° C., cooling the material to the general region of room temperature, forcibly elongating the material while cold, and thereafter maintaining it at 500° C. to 800° C., cooling it, and magnetizing it along the general axis of the direction of elongation.

7. The method of producing a permanent magnet which comprises composing an alloy of between 70 and 80 per cent iron, 15 and 25 per cent nickel, 4 and 20 per cent manganese, and 4 and 20 per cent cobalt, passing it into or through the temperature range 800° C. to 1300° C., cooling the material to the general region of room temperature, forcibly elongating the material while cold, and thereafter maintaining it at 500° C. to 800° C., cooling it, and magnetizing it along the general axis of the direction of elongation.

ETHAN A. NESBITT.