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MAGNETIC ALLOYS

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

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This invention relates to permanent magnet alloys and to magnets made therefrom. In particular the present invention relates to alloys comprising cobalt, molybdenum, chromium, and iron, and to permanent magnets made therefrom.

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

The permanent magnet alloys of the present invention are capable of being mechanically shaped, as by hot swaging, and possess maximum energy products and electrical resistivities which are high as compared to permanent magnet materials in common use. They are, moreover, formed of relatively cheap and available materials.

The alloys of the present invention are formed of cobalt, molybdenum, chromium and iron together with incidental impurities, in the proportions of from 2 per cent to 10 per cent cobalt, from 14 per cent to 21 per cent molybdenum, from 3 per cent to 6 per cent chromium and the remainder iron except for incidental impurities.

The desirable properties of the alloys are developed by an initial high temperature heat treatment followed by quenching and a second heat treatment at a lower temperature. The initial heat treatment may be effected by maintaining the alloy at a temperature of from about 1150° C. to about 1350° C., and preferably at a temperature between 1200° C. and 1300° C., for a suitable period of time, ordinarily from about twenty minutes to about one hour or more. This initial heat treatment is carried out in an atmosphere which will not cause undesirable oxidation of the body of alloy, such as an atmosphere of hydrogen, methane or city gas. The small amounts of oxygen which are present in city gas have the effect of decarburizing the alloy but are not sufficient to cause any significant oxidation of the metal itself.

The quenching which follows the initial heat treatment may be carried out in any suitable manner, as by immersing the alloy, at substantially the temperature of heat treatment, in a body of oil maintained at substantially room temperature.

The final heat treatment following quenching may vary from a treatment in which the alloy is maintained for several hours at 550° C. to a treatment in which the alloy is maintained at 800° C. for a few minutes. Ordinarily it is not practical to heat treat at below 550° C. since an unduly long heating time is required. It is not desirable to use a temperature above 800° C. be-

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cause of the difficulty of control. Ordinarily it is more desirable to use temperatures not exceeding 750° C. Best control, with a practical heating time, is achieved with temperatures of from 625° C. to 685° C. Within this temperature range, a satisfactory heating time is about one hour, although the heating may be continued for longer, if desired.

A preferred alloy of the present invention comprises from 72 to 74 per cent iron, from 4.5 to 5.5 per cent cobalt, from 16 to 18 per cent molybdenum, and from 4.5 to 5.5 per cent chromium.

The amount of carbon present is preferably less than 0.05 per cent, and should not be more than 0.1 per cent. A higher percentage of carbon would tend to lower the coercive force and the residual induction of the alloy. Other impurities commonly found in magnetic alloys may be present in small amounts, although it is preferable to keep these to a minimum, such as less than 1 per cent. Manganese may be present in amounts of 0.3 to 0.5 per cent to remove the free sulfur.

The following data are given to illustrate the improvement obtained in the alloys of the present invention over the commonly used magnetic alloys of iron, molybdenum, and cobalt. A composition containing 79 parts iron, 16 parts molybdenum, and 5 parts cobalt, when heat treated in the manner described above, had a residual induction after saturation of 9800 gauss, a coercive force of 170 oersteds, and a BrHc product of 1,570,000. When 5 per cent of the iron in this alloy was replaced by 5 per cent of chromium, the BrHc product was 2,450,000. Thus by replacing 5 per cent of the iron with chromium, the BrHc figure of merit was increased 56 per cent.

In another specific case, it was found that a composition containing 71 parts of iron, 17 parts of molybdenum, and 12 parts of cobalt, had a resistivity of 45 microhm-centimeters. Six per cent of the cobalt of this composition was replaced with 1 per cent of iron and 5 per cent of chromium, to produce a composition containing 73 parts of iron, 16 parts of molybdenum, 6 parts of cobalt, and 5 parts of chromium, which was heat treated in the same manner as the first-mentioned composition. The latter composition had a resistivity of 62 microhm-centimeters. Thus by replacing some of the cobalt of the first-mentioned composition with chromium and iron, a 38 per cent increase in the resistivity was obtained.

The following table gives further data on the results obtained with various alloys of the present invention. The (BH)_m is the maximum energy

product, which on the demagnetization side of the hysteresis loop, is the product of induction B and magnetizing force H where this product is the greatest.

and from 72 to 74 per cent of iron, except for incidental impurities.

4. An article having properties adapted for permanent magnet use composed of an alloy con-

Per Cent Iron	Per Cent Cobalt	Per Cent Molybdenum	Per cent Chromium	Heat Treatment	(BH) _m × 10 ⁻⁶
74	4	17	5	1300° C., quench 650° C. 1 hour.	0.98
73	6	16	5	1300° C., quench 650° C. 1 hour.	1.08
72	7	16	5	1300° C., quench 650° C. 1 hour.	1.09
71	8	16	5	1300° C., quench 650° C. 1 hour.	1.11
73	5	17	5	1250° C., quench 650° C. 1 hour.	1.16
73	5	17	5	1300° C., quench 650° C. ½ hour.	1.23

The alloys of the present invention may be hot swaged and hot formed and may be prepared in various forms such as rods and bars. The finished magnets may be magnetized by any of the usually employed methods.

Various changes and modifications may be made in the disclosed embodiments without departing from the spirit and scope of the invention.

What is claimed is:

1. A permanent magnet alloy consisting of from 2 per cent to 10 per cent cobalt, from 14 per cent to 21 per cent molybdenum, and from 3 per cent to 6 per cent chromium, the remainder being iron except for incidental impurities.

2. A composition according to claim 1 which is quenched from a temperature of from 1200° C. to 1300° C., and then heated at about 625° C. to about 685° C.

3. A permanent magnet alloy composed of from 4.5 to 5.5 per cent cobalt, 4.5 to 5.5 per cent chromium, from 16 to 18 per cent molybdenum,

20 taining from 4.5 to 5.5 per cent cobalt, from 4.5 to 5.5 per cent chromium, from 16 to 18 per cent molybdenum, and from 72 to 74 per cent of iron, said alloy treated by a method comprising heating to from about 1200° C. to about 1300° C., followed by quenching, reheating to from about 625° C. to about 685° C. and magnetizing.

ETHAN A. NESBITT.

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