

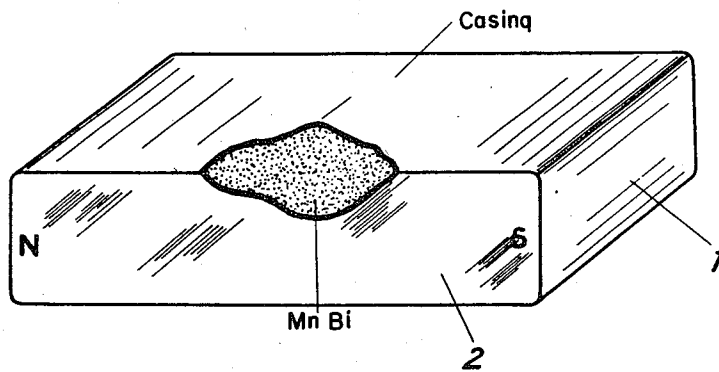
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PERMANENT MAGNET AND METHOD OF MANUFACTURE THEREOF

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## UNITED STATES PATENT OFFICE

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PERMANENT MAGNET AND METHOD OF  
MANUFACTURE THEREOF

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A number of metallic alloys or of defined compounds are known which possess special magnetic qualities called ferro-magnetic properties. Amongst these alloys or compounds only a small number possess the characteristics which are wanted for the manufacture of permanent-magnets, namely a coercive force and residual magnetisation intensity, which are large enough for the purposes contemplated.

Some alloys of iron and other metals, notably cobalt, nickel, aluminium, possess such special properties when they are in the shape of ingots, rods, forged or cast pieces, or when they are given such properties by a convenient heating treatment. For these reasons they are commonly used under these various shapes as permanent magnets.

It has also been proposed to manufacture magnets by starting from powders of such alloys which show, notably when they are in the state of rough castings, high coercive forces. Such a process permits using the waste or scraps of these substances, which otherwise could only be reused through a melting process, but the so obtained magnets have a coercive force the value of which is only at the most and as a rule, lower than the one which is obtained when a magnet of the same shape is manufactured by casting or by forging an ingot or a rod.

On another hand it has already generally been disclosed that manganese and bismuth alloys possess ferro-magnetic properties, and especially that they possess a Curie-point, but no data have been given as to their specific magnetisation, their coercive force or their residual magnetisation intensity and such alloys have never been used for making magnets.

The applicant has discovered the most surprising act that amongst all the alloys of manganese and bismuth, the well defined alloy corresponding to the chemical formula: Mn Bi, the existence of which has been disclosed, but which does not seem at present as having been isolated, possesses very particular ferro-magnetic properties. The applicant having succeeded in isolating the alloy Mn Bi, has discovered not only that it is "ferro-magnetic" but also that the said alloy which in massic state, i. e., in the state of ingot or cast piece, possesses as a rule but exceedingly small coercive forces and residual magnetisation-intensities, can be given, especially when the crystals of the same are separated from each other, e. g. by comminuting it into powder, extraordinarily high coercive force and residual magnetisation intensity.

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The above discovery has led the applicant according to the present invention, to use the alloy Mn Bi which he had been able to isolate and to study, for making permanent-magnets and he has invented a process which allows of taking advantage of the extraordinary properties of the said alloy for the manufacture of permanent-magnets which possess particularly valuable characteristics.

According to the invention an alloy of manganese and bismuth is manufactured which has a chemical composition which is as close as possible to the chemical formula Mn Bi. This alloy is preferably comminuted down to the state of a fine powder and the grains thereof are submitted to a selection in order to only keep the grains the chemical composition of which substantially corresponds to the formula Mn Bi; the so selected grains are then brought to the desired solid shape by any known agglomerating means, preferably by submitting them to an orientation field, and they are finally subjected to a very strong orientating magnetizing field which advantageously has the same direction as the orientating field.

The manufacture of the initial binary alloy of manganese and bismuth can be carried on, e. g. by melting together the two bodies of these elements. Such a melting can be carried on either at a high temperature, comprised for instance between 700 and 1,250° C. or on the contrary, at a relatively low temperature (from 260° C. and over) by dissolving solid manganese in molten bismuth. The melting process can e. g. be carried on by heating in a high frequency electric furnace, a powdered mixture of such weights of manganese and bismuth that they are respectively proportioned to the molecular weights of manganese and bismuth, the sizes of the grains of the elements being so chosen in relation with the frequency of the furnace, according to a practice known per se, that the fusion takes place. Whatever may be the manner in which the manganese-bismuth alloy is manufactured, it appears as preferable to aim at the formation of an alloy the composition of which is as close as possible to the chemical formula of the compound Mn Bi.

It may be advantageous to submit the ingots of Mn Bi alloy to an annealing treatment at a temperature comprised between 150 and 600° C. during a period of time of 2 to 100 hours, in order to obtain big crystals. The magnetic properties of the final magnets will be increased thereby.

The alloy is then crushed down to very fine

grains, for instance of the order of  $\frac{1}{100}$  of millimeter. As it has been disclosed hereabove these grains are eventually submitted to a selection in order to retain only the ones which correspond or substantially correspond to the chemical formula of the compound Mn Bi. This selection can be made by means of known processes based on the differences in the densities of the grains, or better by a magnetic action exerted on the latter. Such a selection is especially convenient when the chemical composition of the initial alloy substantially diverges from the one of the compound Mn Bi.

The grains which have been separated by this selection are then agglomerated by any known means used in the art. For instance they can be caused to float in the body of a more or less liquid binder such as the ones which are commonly used for the manufacture of agglomerated magnets when starting from known alloy powders for making magnets, or they are mixed therewith. Preferably, during the time the grains are still movable, the ensemble of the liquid binder and grains is submitted to a magnetic field capable of setting the grains in a predetermined direction, after which the binder is allowed to solidify. The magnetic field which is used for giving a predetermined direction to the grains (for orientating the grains) can be of the same order of intensity as the ones used for the same purpose for known other substances utilized in powdered state for making permanent-magnets. Whatever may be the process which is used for the agglomeration, the latter should preferably be carried on at relatively low temperatures—lower than the Curie-point of the compound Mn Bi—in order that it is possible to give to the grains a predetermined direction by means of a magnetic field. The said agglomeration can eventually be made in a magnetic-metal casing possessing the external shape which is required for the finished magnet, and in which the magnet can remain enclosed in view of being protected against external agents capable of modifying its composition.

In the accompanying drawing, the only figure is a perspective view of a magnet made of agglomerated powder according to the invention, enclosed in a casing.

In such drawing, 1 represents the casing in which the magnet has been agglomerated and 2 represents the pole faces of the magnet.

The magnetisation of the agglomerate is then performed by subjecting this agglomerate to a magnetizing field preferably having the same direction as the one which has been used for giving a predetermined direction to the grains (orientating the grains) but preferably possessing a much higher intensity as the one commonly used for the magnetisation of permanent-magnets. It has been acknowledged that when the agglomerate has been subjected under the hereabove disclosed conditions, to a magnetizing field of the order of 4,000 oersted—which field is already stronger than the ones commonly used—it possesses the following magnetic properties (which correspond to a filling coefficient of the agglomerate equal to one unit):

Magnetisation intensity=about 6,300 gauss  
Residual magnetisation intensity after the field has been suppressed=about 1,300 gauss  
Correspondent coercive force=500 oersted.

Such values correspond to very low characteristics of permanent magnets. As a set off if

under the same conditions, the agglomerate is subjected to a much stronger field, for example of the order of 20,000 oersted, the remarkable following results are obtained:

5 Magnetisation intensity=about 6,800 gauss  
Residual magnetisation intensity after the field has been suppressed=about 5,700 gauss  
Correspondent coercive force=4,000 oersted.

10 The magnetisation intensity is thus of the same order of magnitude as in the preceding case, but the residual magnetisation intensity is more than four times the previously reached figure, and the coercive force is eight times higher.

Such values of residual magnetisation and of coercive forces correspond to very remarkable characteristics for permanent magnets and they are considerably higher than the ones of known magnets. It is indeed known that the value of a magnet (setting aside the shape coefficient) is characterised by these two values taken together. Now as a matter of indication, the substances having a minimal hysteresis surface, which are used for making magnets, possess a residual magnetisation intensity of 12,000 gauss and a coercive force of 60 oersted; the substances having a maximal hysteresis surface possess a residual magnetisation intensity of 5,000 gauss and a coercive force of about 800 oersted. For instance the well known nickel-aluminium alloys used for making permanent alloys, possess a residual magnetisation intensity of the order of 6,000 gauss, i. e. close to the one stated hereabove for magnets made of the compound Mn Bi, but the value of their coercive force is, on the contrary, from six to ten times lower than that of 4,000 oersted obtained with the said Mn Bi alloy.

The figures quoted hereabove for the magnetic characteristics of the alloy Mn Bi do correspond to figures which have been measured on agglomerates, but as it has been said, they have reference to a filling coefficient of the agglomerate which is equal to one unit, in order to set alight the characteristics of the substance itself. The figures thus obtained on an agglomerate are obviously a function of the filling coefficient of the same. It can roughly be said that the residual magnetisation intensity of the agglomerate nearly proportionally varies with that coefficient; on the contrary, the coercive force varies but little and remains rather close to the value corresponding to a filling coefficient equal to 1.

On the other hand it is evident that the magnitude of 20,000 oersted which has been quoted as being the value of the magnetizing field with which the remarkable results stated hereabove have been obtained, is in no manner limitative and is only given by way of example. It can be departed from said value but one should always remain in a range of magnitudes, which are notably higher than those of the present common practice. As a mere indication a rule can be given that the magnetizing field which has to be used for manufacturing magnets according to the invention should preferably have a magnitude which is at least four to five times the one which corresponds to the saturation of the magnet. When needed, preliminary tests will allow to fix it in each particular case.

On the other hand, the above given figures have been taken from agglomerates the alloy grains of which had been given predetermined direction by means of a magnetic field during the step of agglomeration. Such an orientating

practice can be dispensed with but in such a case, the results show lower figures. The magnitudes obtained under the same magnetizing conditions as hereabove disclosed but without orientating the grains, only reach 30% as concerns the residual magnetisation intensity and 40% as concerns the coercive force, of the values which are obtained when the grains are submitted to an orientating operation.

I claim:

1. A permanent magnet possessing a high residual magnetization and a coercive force of at least 4,000 oersteds, said permanent magnet being made from a massive binary alloy of manganese and bismuth in which the proportions of manganese and bismuth substantially correspond to the molecular weights of said elements, which massive alloy has been crushed to a very fine powder from which the alloy crystals, the chemical composition of which is substantially Mn Bi, have been selected and agglomerated to the desired shape, the agglomerate having been then submitted to a strong magnetizing field.

2. A permanent magnet possessing a high residual magnetization and a coercive force of at least 4,000 oersteds, said permanent magnet being made from a massive binary alloy of manganese and bismuth in which the proportions of manganese and bismuth substantially correspond to the molecular weights of said elements, which massive alloy has been crushed to a very fine powder from which the alloy crystals, the chemical composition of which is substantially Mn Bi, have been selected and agglomerated to the desired shape, the agglomerate having been then submitted to a strong magnetizing field.

3. The process of making a permanent magnet, which comprises forming a massive binary alloy of manganese and bismuth in which the proportions of manganese and bismuth substantially correspond to the molecular weights of said elements, annealing said massive manganese bismuth alloy to increase the crystal size thereof, crushing said alloy in massive state to a very fine powder, selecting from said powder the alloy crystals, the chemical composition of which is substantially Mn Bi, mixing said crystals with a liquefied, setting binder, submitting the mixture to a magnetic field before the liquefied binder has set completely, thereby orienting the crystals,

causing the binder to set to form an agglomerate, and submitting the agglomerate to a strong magnetizing field.

4. The process of making a permanent magnet, which comprises forming a massive binary alloy of manganese and bismuth in which the proportions of manganese and bismuth substantially correspond to the molecular weights of said elements, annealing said massive manganese bismuth alloy to increase the crystal size thereof, crushing said alloy in massive state to a very fine powder, selecting from said powder the alloy crystals, the chemical composition of which is substantially Mn Bi, mixing said crystals with a liquefied, setting binder, submitting the mixture to a magnetic field before the liquefied binder has set completely, thereby orienting the crystals, causing the binder to set to form an agglomerate, and submitting the agglomerate to a magnetizing field of about 20,000 oersteds, the direction of which is the same as that applied for orienting the crystals.

CHARLES GUILLAUD.

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**Certificate of Correction**

Patent No. 2,576,679

November 27, 1951

**CHARLES GUILLAUD**

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 5, line 31, after "been" insert *annealed to increase the crystal size thereof and then;*

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of March, A. D. 1952.

[SEAL]

**THOMAS F. MURPHY,**  
*Assistant Commissioner of Patents.*