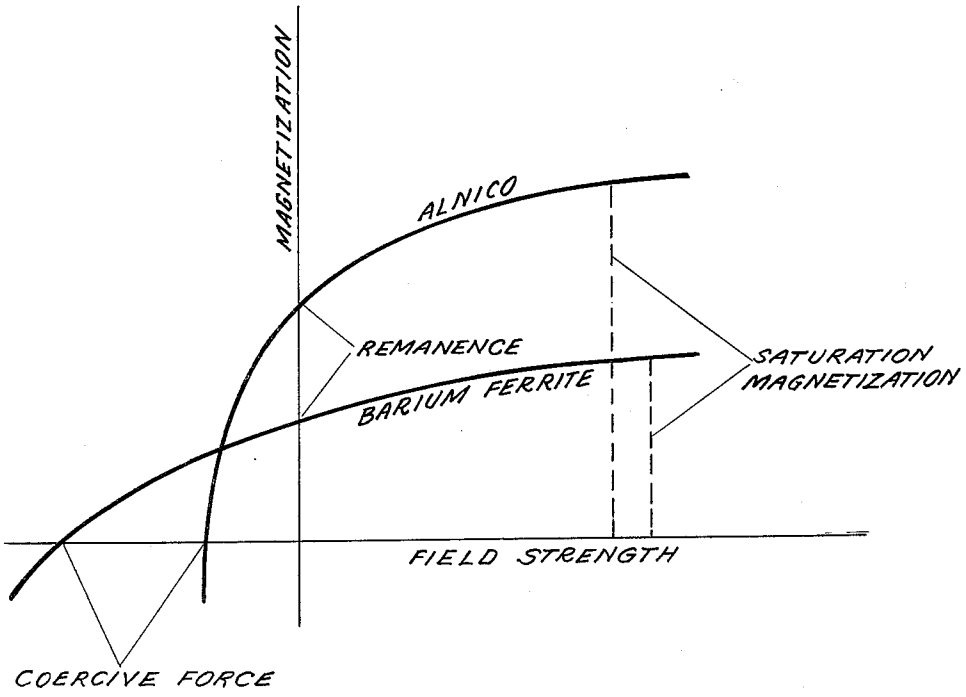
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FERRITE MATERIAL CONTAINING FLUORINE

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FERRITE MATERIAL CONTAINING FLUORINE

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Our invention relates to novel ferrites and more particularly to novel magneto-plumbite ferrites such as barium ferrite in which part of the oxygen of the barium ferrite is replaced by fluorine, and therefore the trivalent iron is reduced to di-valent iron or can be replaced by another di-valent metal.

The commonly known ferrite used as a magnet is barium ferrite—$BaO6(Fe_2O_3)$. This ferrite has the advantage of being inexpensive. It has a high coercive force, and therefore is increasingly used in place of steel a Alnico magnets.

However, it has the disadvantage of having low remanence magnetization due to the fact that the molecules of barium ferrite contain only 20 non-compensating electron spins which are the basis for the saturation magnetization of the material.

In accordance with our novel composition of matter, we raise the remanence magnetization of prior ferrites.

Accordingly, an object of our invention is to provide a novel composition of matter for increasing remanence magnetization.

A further object of our invention is to provide a novel ferrite for increasing remanence magnetization.

These and other objects will be clear from the drawing in which the FIGURE is the usual hysteresis loop of magnetizable material.

This figure shows the hysteresis curves of a representative Alnico, that means metal magnet, and of barium ferrite. It can be seen that the Alnico magnet has several times higher remanence than the ferrite, but on the other hand the coercive force of the Alnico magnet is much lower than the coercive force of the barium ferrite.

As the desirable property of a permanent magnetic material is a high energy product i.e. the product of magnetization times field strength which will result from a high coercive force and remanence respectively, these latter two parameters should be increased as much as possible.

In its turn, remanence depends very much on the saturation magnetization, it is between the value of saturation magnetization and 50% of it. It can be seen from the curve that barium ferrite and similarly all known ferrite magnets have the drawback of a relatively low saturation magnetization and accordingly therefore of a low remanence.

We have discovered that by replacing one or a small number of oxygen ions of a ferrite by fluorine ions that the saturation magnetization could be increased because of the fact that the di-valent oxygen is now replaced by only mono-valent fluorine, and therefore that tri-valent iron is now either partly being reduced to di-valent metal or the iron can be replaced now by another di-valent metal of similar ion size. But if the ferrites already contain divalent metal ions, they can be replaced by monovalent metal ions when the oxygen ion is replaced by fluorine. For instance, we have made $LiFFe_2O_3$ which is derived from the known $FeOFe_2O_3$.

The ferrites are really non-compensated antiferromagnetic or ferrimagnetic materials. This means the magnetization is only the difference between a stronger magnetization in one direction and a weaker magnetization in the opposite direction.

Clearly, if we can reduce the weaker magnetization in the opposite direction, then the remaining difference will become larger and therefore the magnetization, both saturation magnetization and remanence magnetization, will now be larger.

This reduction of magnetization in the opposite direction will be achieved if we have replaced tri-valent iron by di-valent iron which has less Bohr-magnetons or with another material having less or no Bohr-magnetons under the condition that this tri-valent iron was sitting at a site in the crystal where it contributes to the magnetization into the opposite direction.

As an example of our invention, the Bohr-magnetons of the previously mentioned barium ferrite add up to 20 non-compensated Bohr-magnetons per molecule, whereas if two oxygen ions are replaced by fluorine according to the formula $BaF_25(Fe_2^{III}O_3)2(Fe^{II}O)$, they add up to 22 Bohr-magnetons. This material having higher saturation magnetization does have higher remanence magnetization and therefore can give a stronger magnet.

The available work a magnet can produce depends on the product of remanence magnetization with coercive force (BH). It can be proved theoretically that the maximum BH which can be reached in any material is $(2\pi I_s)^2$. It is therefore very important to increase the saturation magnetization (I_s) as much as possible. In our case by increasing the saturation magnetization from 20 to 22 Bohr-magnetons, a 20% increase of the energy products might be attainable. Up to now an increase of remanence magnetization of 8% has been attained.

A class of ferrites of hexagonal crystals structure has been described by G. H. Jonker in the Proceedings of the XVIth International Congress on Pure and Applied Chemistry, section on mineral chemistry, 1958, 117–123. We have replaced in a number of the compounds described by Jonkers, one or a small number of the oxygen ions by the same number of fluorine ions, and at the same time changed tri-valent ions to di-valent ions or replaced them by di-valent cobalt ions. In the latter case we have obtained compounds which show a preferred direction of magnetization in a plane perpendicular to the hexagonal *c* axis which Jonkers also describes for some compounds in the above-mentioned paper.

Especially we have replaced two oxygen ions in the barium ferrite, which is one of the compounds described by Jonkers, but which was well-known previously.

The samples are prepared in the following way. Barium fluoride (BaF_2) 100 grams is thoroughly mixed with iron oxide (Fe_2O_3) 425 grams in a ball mill for 24 hours together with a wetting agent such as alcohol. Then the material is dried and pre-fired to a temperature of 1100° C. for 12 hours. Following this the material is ground again in a ball mill for 24 hours together with a wetting agent such as alcohol and then pressed into the desired shape under the influence of a magnetic field, about 7000 oersteds, under a pressure of about ½ ton per quare centimeter (6000 to 17,000 pounds per square inch). The material is then dried carefully in a drying oven for two hours at a temperature of 120° C. and then sintered in a furnace at a temperature of 1280° C. under an atmosphere of thoroughly dry oxygen. The product is then carefully cooled and magnetized. The composition at that stage is $BaF_25(Fe_2O_3)2(FeO)$.

We have also made a similar compound by replacing the di-valent iron in this compound by di-valent cobalt and have obtained a composition which is close to $BaF_25(Fe_2O_3)2(CoO)$.

The barium can be replaced totally or partially by other ions, especially by strontium, lead, calcium or by a combination of these.

An additional advantage of the fluoride besides the

higher magnetization of the barium fluoride described in detail is the following: Much higher resistance against corrosion. There is also the assumed advantage of higher electric resistance of these fluorides where the di-valent iron ion is replaced by di-valent metals like magnesium and zinc.

We claim:

1. A barium ferrite, having the formula $BaO.6Fe_2O_3$, and having a hexagonal magneto plumbite crystal structure in which two out of nineteen oxygen atoms are replaced by fluorine.

2. A barium ferrite having a hexagonal magneto plumbite crystal structure having the formula

$$BaF_2.5(Fe_2O_3).2(FeO)$$

3. A barium ferrite having a hexagonal magneto plumbite crystal structure having the formula

$$BaF_2.5(Fe_2O_3).2(CoO)$$

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