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Properties of barium ferrite powder, prepared using a flux additive Na_2O

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Within ceramic technology using sodium as a flux component by precipitation from the melt obtained microfine powder of hexagonal barium ferrite. Defined functional magnetic parameters: the coercive force, and a constant effective magnetic anisotropy field and the maximum magnetic energy. The level of the received parameters corresponding to the requirements of the hard magnetic powder materials.

Keywords: magnetic properties, coercive force, residual magnetization, single-domain particles

В рамках керамічної технології з використанням Na_2O в якості одного з компонентів флюсу методом осадження з розплаву, отримано мікродісперсний порошок гексагонального фериту барію. Визначено функціональні магнітні параметри: коерцитивна сила, константа і поле ефективної магнітної анізотропії та максимальна магнітна енергія. Рівень отриманих параметрів відповідає вимогам, що пред'являються до магнітотвердих порошкових матеріалів.

Ключові слова: магнітні властивості, коерцитивна сила, залишкова намагніченість, однодоменні частинки.

В рамках керамической технологии с использованием Na_2O в качестве одного из компонентов флюса методом осаждения из расплава, получен микродисперсный порошок гексагонального феррита бария. Определены функциональные магнитные параметры: коэрцитивная сила, константа и поле эффективной магнитной анизотропии и максимальная магнитная энергия. Уровень полученных параметров соответствует требованиям, предъявляемым к магнитотвердым порошковым материалам.

Ключевые слова: магнитные свойства, коэрцитивная сила, остаточная намагниченность, однодоменные частицы

Introduction

One way to control the magnetic properties of the ferrite powders is to use of additives, containing as paramagnetic so diamagnetic ions. This supplements can play a role of "providers" of replacement of ions, that is, to change the original chemical composition of ferrite, and can regulate the morphological parameters of the particle, which is also affected, in one way or another, on the magnetic parameters of the powder as a whole.

This issue is devoted to a series of papers [1-5].

In [1], we measured the coercive force H_c of the hexagonal barium ferrite $BaFe_{12}O_{19}$, belonging to the class of hardmagnetic materials and finding a wide application in various spheres of human activity: technology, ecology, medicine. As a substitute Fe ions used ions Al, Cr, In and combinations of ions ZnGe, ZnV, ZnNb, ZnTa. The substitution for ions of Al, Cr, In leads to an increase in coercive force, which is interpreted as the result of increasing the critical single domain size and magnetic anisotropy field. In the case of other specified substitutions coercive force is decreased due to the decrease of the anisotropy field. In [2] studied the effect of the introduction of a number of additives in the form of oxides, in the initial and intermediate stages of sintering, on the coercive force and residual magnetization pre-prepared barium ferrite powder of stoichiometric composition. It is shown that the addition of SiO_2 and Al_2O_3 increased coercive force and maximum magnetic energy $(BH)_{max}$, unlike TiO_2, MgO, NiO and SnO_2, which have a negative impact. In [3] were used oxides of iron obtained from the iron pyrite and is initially containing impurities. The presence of impurities affect the rate of synthesis and magnetic properties of the final product: the additive CuO, ZnO and $CaCO_3$ increases the rate of synthesis, but has little effect on the value $(BH)_{max}$, while the impurities MnO, SiO_2, Al_2O_3 slowed synthesis and lowered $(BH)_{max}$.

Impact additive Na_2O presented in the literature insufficient [4, 5]. In [4] it shows that the addition of Na_2O after firing in amounts up to 0.15% resulted in a significant increase in the coercive force and maximum magnetic energy. In [5] during the growth of crystals $BaFe_{12}O_{19}$ from solution in the system Fe_2O_3-$BaCO_3$-Na_2CO_3 were received large crystals (up to 6 mm) of high quality.

The aim of this work was to obtain barium ferrite powder within the ceramic technology using Na_2O as one of the components of the flux and the investigation of final product properties.

Preparation of the barium ferrite powder

For barium ferrite powder preparation used method of precipitation from a melt in accordance with which to a mixture of ferrite-forming components a flux is added. As ferrite forming-components used $BaCO_3$ and γ-Fe_2O_3. The reaction was held at relatively high temperature (1100^{0}C) in accordance with the equation

$$BaCO_3 + 6Fe_2O_3 = BaFe_{12}O_{19} + CO_2\uparrow \qquad (1)$$

in the presence of a flux, the main component of which was water-soluble $BaCl_2 \cdot 2H_2O$. As a modifying addition unused carbide sodium

$$Na_2CO_3 \rightarrow Na_2O + CO_2\uparrow. \qquad (2)$$

Na_2O content in the flux is ~ 1%.

In studying the specific effects of small particles and thus superfine powders, of paramount importance is the size factor.

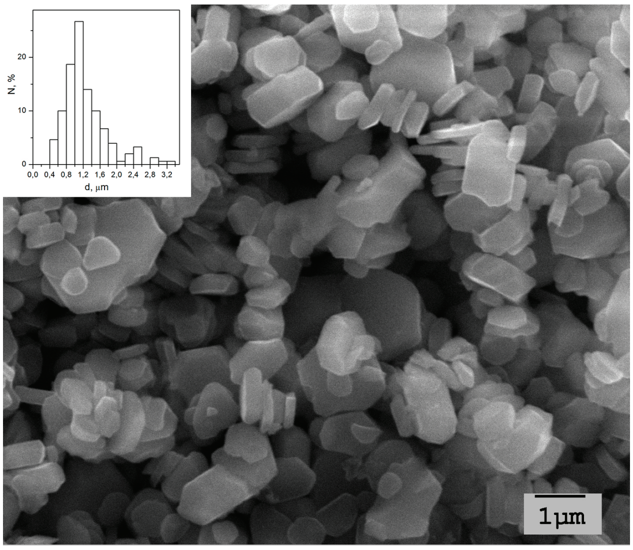

Fig.1. An electron micrograph of the powder particles and their size distribution.

Fig. 1 is an electron micrograph of the powder particles and their size distribution. The particles have a characteristic hexagonal shape. The average value of the diameter <d> = 1,2 µm, that is the condition for single-domain particles of barium ferrite d≤1,4 µm [6]. Thus 85% of the particles have a size in the range of (0.5-1.5) µm, which gives rise to an homogeneity of the resulting powder.

Magnetic properties

Magnetic measurements were performed at T = 300 K in the induction type magnetometer. Functional magnetic parameters of fine ferrite materials have been identified as a result of the research processes of magnetization and demagnetization. The studies were conducted on a pre-demagnetized non-oriented powder samples with packing factor of 0.4. Figure 2 shows the principal magnetization curve and the limit hysteresis loop of the sample. In the magnetization curve is observed characteristic of powder samples unsaturation of magnetization in fields exceeding the field of magnetocrystalline anisotropy of makroanalogue (17.8 kOe). The value of high-field magnetic susceptibility $\chi = 7 \cdot 10^{-4} \cdot G \cdot cm^3\, g^{-1} \cdot E^{-1}$ is in the range given in the literature for high-distersive ferrite systems ($1\text{-}10 \cdot G \cdot cm^3\, g^{-1} \cdot E^{-1}$) [7,8]. The value of the magnetization in the anisotropy field makroanalogue is 18% lower for makroanalogue that explains the "canted" magnetic structure of the structurally defective near-surface region of small particles [9]. Measurement of principal magnetization curve and limit hysteresis loop allowed to determine such fundamental parameters as coercive force H_c, constant K^{eff} and field H_a^{eff} of effective magnetic anisotropy, the maximum magnetic energy $(BH)_{max}$. Experimental value H_c = 4 kOe is approximately two times smaller for this of maroanalogue but is correlated with the data of reference [10] for magnetically powder materials.

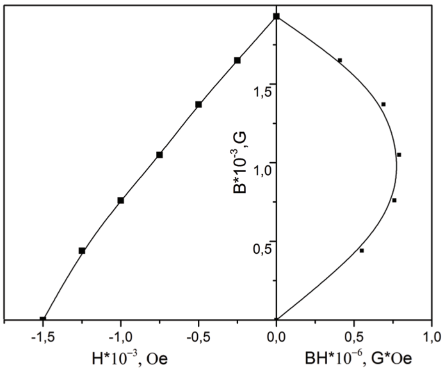

Fig.2. Principle magnetization curve and the limit hysteresis loop of the sample.

To determine the magnetic anisotropy constant and the field of used the "area method" [11], according to which the area bounded by the demagnetization curve in the first quadrant and straight, extrapolating high-field port of the magnetization curve of I(H) to the field H = 0 (Fig. 2, shaded area) equals $\frac{2}{3}K^{eff}$. The resulting value $K^{eff} = 1,4 \cdot 10^6 \cdot$ erg cm^{-3}. Effective magnetic anisotropy field of the test powder as a system of randomly oriented single-domain one-axis particles $H_a^{eff} = \frac{2K^{eff}}{I_S} = 8.8 \cdot 10^3$ Oe. If there is no interaction between the particles [12] the coercive force for such a system $H_c = 0.48 H_a^{eff} = 4.2$ kOe - a value close to the experimentally obtained.

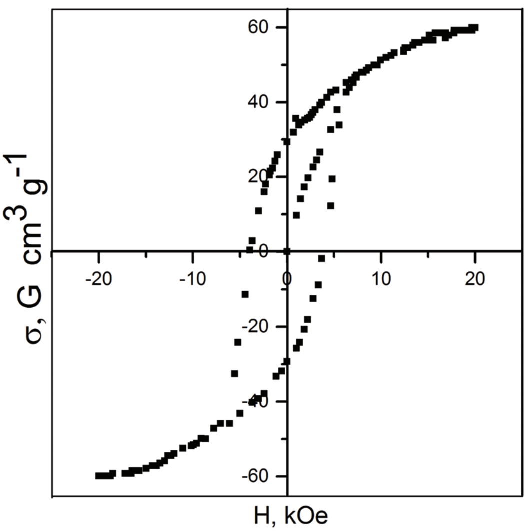

Fig.3. Demagnetization curve and magnetic energy is calculated according to her.

The maximum magnetic energy $(BH)_{max}$- parameter characterizing the density of magnetic energy stored in the magnetic material during magnetization is determined from the dependence of BH=f(B) in the second quadrant, Fig. 3. For the test powder $(BH)_{max}$=0,79·10^5 G · E 10^5, which corresponds to the upper limit of the range of values of this characteristic for the untextured powder of barium ferrite without additives [10].

Conclusions

1. The proposed technology has provided high quality of the resulting powder in terms of morphology and particle size distribution in the micrometer range.

2. This value is constant effective magnetic anisotropy K^{eff} in order of magnitude equal to the value for macroanalogue.

3. The value of the coercive force H_c, determined directly from the limit of the hysteresis loop, close to that calculated from the relation between H_c and the anisotropy field H^{eff} is valid for non-interacting particle systems.

4. The value of the maximum magnetic energy $(BH)_{max}$ to the powder under study corresponds to the top value of this characteristic for the barium ferrite powders modified without fluxing agents.

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