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Abstract

Full Text

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FERRITES OF THE $MgO{-}MnO_t{-}Fe_2O_3$ SYSTEM WITH AN ADDITION OF Sc_2O_3

(Presented by Academician V. I. Spitsyn on July 7, 1962)

Ferrites used in matrix-memory systems do not fully satisfy the requirements imposed on them. They possess a long remagnetization time, high induction, low linearity of the hysteresis sections of spontaneous and forced demagnetization, and considerable power consumption for transmitting an information sign. In this connection, extensive investigations are being carried out on the effect of various additions on the magnetodynamic properties of ferrites. Thus, for example, it was established that in yttrium ferrites of garnet structure the introduction of the Sc^{3+} ion substantially increased the magnetic moment ([1]).

Meanwhile, the influence of additions of scandium oxide on the magnetic and electrical characteristics of ferrites of spinel structure in the $MgO{-}MnO_t{-}Fe_2O_3$ system has not been covered in the literature.

Some parameters of the scandium atom, such as the unfilled electron shell $3d$ ([2]), the low screening coefficient of the $3d$ shell ([3]), the small ionic radius of Sc^{3+} and the high ionization potential ([4]), and X-ray structural data ([5]), make it possible to assume that introducing Sc_2O_3 into the $MgO{-}MnO_t{-}Fe_2O_3$ system should give positive results.

Fig. 1. Comparative oscillograms of the output-signal amplitude of HS and VT-1 ferrites. 1 –ferrite of the VT-1 grade; 2–8 –ferrites of the HS grade containing from 0.05 to 0.18 mole % Sc_2O_3

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Static magnetic characteristics of ferrites

Figure 2: Static magnetic characteristics of ferrites

The present investigation is devoted to studying the influence of the Sc_2O_3 content on the useful magnetic and electrical characteristics of scandium-containing ferrites.

In studying batch compositions, we proceeded from the premise that the ratio of components in the ferrite should satisfy a formula of the form: $(MgO—MnO)_{1+a}Fe_{2-(a+b)}Sc_bO_4$, where a, b are molar fractions.

According to this formula, the batch composition, calculated as oxides, varied as follows: MgO from 0 to 50 mole %, MnO_t from 0 to 62.5 mole %, Fe_2O_3 from 33 to 50 mole %, Sc_2O_3 from 0.25 to 25 mole %.

For preparing the batch, scandium oxide was used; the impurity content in it was (%): Th–0.1; Zr $<$ 0.1; Fe, Ca, Si, Y, Yb, Ti $<$ 0.05; Al and Mg $<$ 0.01. The purity of the other oxides corresponded to the usual requirements for obtaining matrix ferrites in serial production. The technology for manufacturing scandium-containing ferrites does not differ in any way from the generally accepted technology. The ferrites containing scandium were designated by us with the grade HS.

Fig. 2. Static magnetic characteristics of ferrites: *a*–HS-2; *b*–S-1; *v*–VT-1 (ITM VT, Academy of Sciences of the USSR); *g*–D-2, *d*–IS80T-B (U.S. firm)

As a result of the investigation it was established that the introduction of scandium oxide makes it possible to obtain a family of ferrites with a wide range of pulse parameters satisfying the requirements of high-speed memory systems. Figure 1 shows a family of amplitude characteristics of HS ferrites with different contents of Sc_2O_3 (from 0.05 to 0.18 mol.%). The characteristics were recorded on an IKh-1 pulse characterograph. Core size: $1.2 \times 0.8 \times 0.4$ mm; readout current 1.8a; $\tau_\phi = 0.1$ μsec. For comparison, an oscillogram of a domestic ferrite of grade VT-1 of the same–

of the $MgO–MnO_t–Fe_2O_3$ system, but containing no scandium ([6]). From these characteristics it follows that, for ferrites of the HS grade, the magnitude of the coercive force can be varied by the addition of Sc_2O_3 over a wide range.

The results of measuring the static magnetic characteristics of ferrite cores of the HS-2 grade are presented in Fig. 2a. Here, for comparison, the magnetic characteristics are given of ferrites used in matrix memories of computing devices (b, c, d, e). From the data presented it follows that the addition of scandium oxide sharply lowers the magnetic induction in HS ferrite, and greatly improves the linearity and slope of the hysteresis-loop sections $B_s—B_r—B_1$. The latter circumstance makes it possible to reduce the amplitude of noise, which is an important factor for high-speed memory systems.

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Fig. 3

Figure 3: Fig. 3

Fig. 4

Figure 4: Fig. 4

Fig. 3. Comparative time characteristics of ferrites HS-1, HS-2 (upper curves) and of two specimens of BT-1 ferrite as a function of the intensity of the switching field (core size $1.2 \times 0.8 \times 0.4$ mm)

In Fig. 3 are shown the pulse characteristics $1/\tau$ as a function of the intensity of the switching fields for ferrites HS-1 and HS-2, in which the scandium content was 0.05–0.06 and 0.10–0.12 mol.% respectively. As can be seen, with an increase in the scandium oxide content the switching time decreases sharply in comparison with ordinary BT-1 ferrites, with lower power expenditures for switching. Therefore the $1/\tau$ curves shift into the region of smaller switching fields.

The introduction of scandium oxide also affects the magnitude of the output-signal amplitude during switching. In Fig. 4 are shown comparative amplitude oscillograms of ferrite cores HS-2 and BT-1. Switching conditions: read current 1.5 A, $\tau_\phi = 0.1$ μsec. Core size $1.2 \times 0.8 \times 0.4$ mm.

Fig. 4. Comparative amplitude characteristics of ferrites HS-2 (1) and BT-1 (2)

It follows from Fig. 4 that, at identical coercive currents, the amplitude of the output signal of HS-2 ferrite is half the amplitude of the output signal of BT-1 ferrite. The small magnitude of the output signal causes less self-heating of the core during high-frequency switching. The magnetoelectric properties of ferrites of the HS grade are characterized by the following data: saturation induction $B_m = 500 \div 1500$ G;

coercive force $H_c = 0.5 \div 2$ Oe; squareness ratio $B_r/B_m = 0.95 \div 0.97$; switching coefficient $S_\omega = 0.2 \div 0.5$ Oe • µs; threshold field $H_0 = 0.5 \div 2.5$ Oe; specific electrical resistivity $\rho = 10^8 \div 10^{10}$ ohm • cm.

From the data presented it follows that HS-grade ferrites can be used as elements of matrix and register memories of high-speed computers. As an example, we note that HS-1 ferrite has a coercive force $H_c = 1.5 \div 1.8$ Oe and is intended for matrix memory systems in half-current coincidence modes; HS-2 ferrite has a coercive force $H_c = 1 \div 1.2$ Oe and is used in operative memory. In the Z mode the remagnetization time is 0.12—0.15 µs; HS-8 ferrite is recommended for high-speed register memory.

It should be noted that, for the further development of the theory of ferrimagnetism, it is of interest to study the influence of Sc_2O_3 on the transformation of the magnetic properties of the spinel structure up to complete compensation

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of the magnetic moments of the octahedral and tetrahedral sublattices.

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