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Magnetoresistance of sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrites

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Abstract

Magnetoresistance (MR) of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite with $x = 15$–97 at% were investigated. The MR value was increased from 2.5% for $x = 15$ to 4.8% for $x = 97$ at room temperature with maximum applied field of 8.8 kOe. The plot of $\log \rho$ versus $T^{-1/2}$ of all sintered samples exhibited a linear relationship, indicating that the dominant MR effect was spin-dependent tunneling between the Fe_3O_4 phase through α-Fe_2O_3 barrier. The percolation threshold for the conduction paths in this system is in the vicinity of $x = 40$ at%.

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Keywords: Magnetoresistance; Sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite; Fe_3O_4; α-Fe_2O_3

Recently, magnetite (Fe_3O_4) attracted much attention due to its high magnetoresistance (MR) value [1–3]. Coey et al. [4] had reported that the MR values of Fe_3O_4 in polycrystalline thin lm and compacted powder were 1.7% and 1.2% at room temperature, respectively. In this study, the effects of Fe_3O_4 content on the MR value and resistivity of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite were investigated. $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ is one kind of metal–insulator granular system. Although Fe_3O_4 is a half metallic oxide but it could be a conductor to compare with the insulator α-Fe_2O_3. In metal-insulator granular system, the magnetoresistance (MR) value is dependent on the concentration of metal. Tang et al. [1] had shown that resistivity of the γ-Fe_2O_3/Ag system changed dramatically at percolating limit, which is a critical concentration of metal in metal-insulator granular system.

The $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ powder with different x were prepared by reducing the α-Fe_2O_3 (99.98%) powder in the mixture of Ar (95%) + H_2 (5%) atmosphere at 350°C for 0.5–6 h. These powder were compressed into pellets (10 mm diameter, 1 mm thick) with a pressure of 6500 lb/cm^2 then sintered in flowing He gas at 1100°C for 3 h. The content of Fe_3O_4 in the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite was between 15 and 97 at%. The Fe_3O_4 content was determined from chemical titration analysis of Fe^{2+} and Fe^{3+} ions contents in the sample. The electric resistivity (ρ) was measured by the four-probe method. The magnetoresistance ratio, defined as $MR = [\rho(H) - \rho(H=0)]/\rho(H=0)$, were obtained at room temperature with a maximum applied field of 8.8 kOe and the applied field H was parallel to the direction of current.

Fig. 1(a) shows the relationship between MR value and x value of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite. The MR value increases rapidly from 2.5% to 3.8% as x is increased from 15 to 40. When $x > 40$, the MR value increases slowly from 3.8% to about 4.8% as x is increased from 40 to 97. This correlates to the rapid drop of ρ value from $7.09 \times 10^4\,\Omega$cm to $19\,\Omega$cm as x increases from 15 to 40, as shown in Fig. 1(b). Fig. 1(b) shows the relationship between ρ value and x value and x value of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite. When $x > 40$, the ρ value decreases slowly from 19 to $1\,\Omega$cm. This indicates that the percolation threshold of the conduction paths in this system is in the vicinity of

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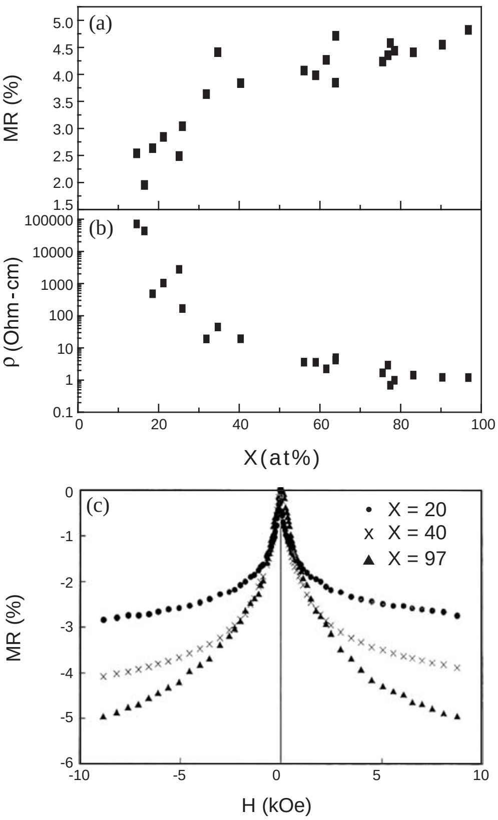

Fig. 1. Variations of (a) the MR value and (b) the resistivity (ρ) with x value of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite. (c) Relations between the MR values and the applied field for $x = 20$, 40, and 97.

$x = 40$. Fig. 1(c) shows the MR value as a function of the applied field for the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite at room temperature for $x = 20$, 40, and 97.

In order to understand the electron transport behavior, the $\log \rho$ versus $T^{-1/2}$ curves of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite with $x = 18$, 40, and 97 were plotted in Fig. 2. A linear relation between $\log \rho$ and $T^{-1/2}$ was observed for all the samples. This indicated that

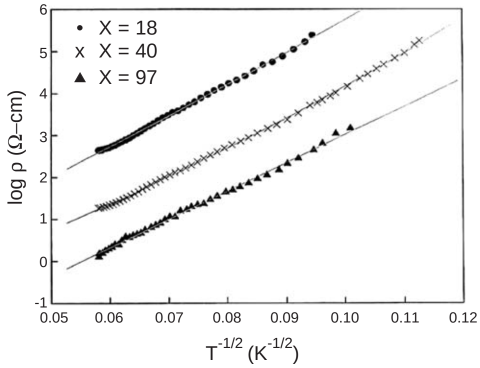

Fig. 2. Log ρ versus $T^{-1/2}$ curves for various sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrites.

the dominant magnetoresistance effect is spin-dependent tunneling [5,6]. α-Fe_2O_3 is a tunneling barrier, because it is a insulator.

In conclusion, the MR effect of the sintered $(Fe_2O_3)_{100-x}(Fe_3O_4)_x$ ferrite have been investigated. The MR value is about 4.8% at room temperature when $x = 97$. The electron transport in this system is tunneling mode, in which the electrons flow through α-Fe_2O_3 barrier between the magnetic Fe_3O_4 phases.

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