EFFECTS OF Mg DOPING AND SINTERING TEMPERATURE ON THE MAGNETORESISTANCE OF SINTERED Fe_3O_4 FERRITES

C. T. Lie[1], P. C. Kuo[1], C. Y. Chou[1], I. J. Chang[1], and J. W. Chen[2]
[1] Institute of Materials Science and Engineering, National Taiwan University, Taipei, Taiwan
[2] *Department of Physics, National Taiwan University, Taipei, Taiwan*

Introduction

Currently, the magnetoresistance (MR) of pure Fe_3O_4 has been investigated by few groups [1-2]. The MR value of Fe_3O_4 in these studies was found very small at room temperature (MR = 0~1.7 %). For the sintered Fe_3O_4 ferrite, its MR value was dependent on the microstructure and sintering conditions. In this work, we improve MR value of the sintered Fe_3O_4 ferrite *at room temperature to about 7.3 % with small amount of Mg addition.* The effects of Mg content, sintering temperature (Ts), and microstructure on its magnetoresistance at room temperature were investigated.

Experimental procedure

The high-purity Fe_3O_4 powder was mixed with various amount of MgO powder (0~25 mol.%). After fully mixed, the mixed powder was compressed into a pellet (10 mm diameter, 1 mm thick) under a pressure of 53393 lb/in^2 then sintering in argon atmosphere at temperatures between *1050 °C and 1200 °C for 3 hours. Composition of the sintered samples* was analyzed by energy disperse spectrometer (EDS). Crystalline structure of the sintered sample was determined by using X-ray diffractometer (XRD) with CuKα radiation. Microstructure was observed with a scanning electron microscope (SEM). The Fe^{2+} and Fe^{3+} ion contents of the sintered sample were examined by chemical titration method. The magnetoresistance of the sintered sample was measured at room temperature with the four-probe method and the maximum applied field was 9 kOe.

Results and discussion

It is found that the Fe_3O_4 and $MgFe_2O_4$ phases are co-existed in all samples which sintered at temperatures between 1050 °C and 1200 °C from their X-ray diffraction patterns. This indicates that the MgO oxide reacts with some Fe_3O_4 to form $MgFe_2O_4$ ferrite during sintering. From the analysis of SEM element mapping, we find that the Mg ions are dispersed uniformly in all sintered samples. Figure 1 shows the relationship between MR value and T_s of various sintered samples with different Mg contents at room temperature. The optimum T_s, which means that maximum MR value can be obtained is about 1100 □ for all samples, as shown in Fig. 1. Figure 2 shows the relationship between Mg content and MR value at room temperature of the sintered sample which was sintered at 1100 □. The maximum MR value is about 7.3 % which occurs at Mg content of 0.93 at.%. The grain size of this sample is about 2.5 μm and its density is 4.95 g/cm^3 which is about 94 % theoretical density of the pure Fe_3O_4 (That is 5.24 g/cm^3).

Chemical titration analysis of Fe^{2+} and Fe^{3+} ions contents indicates that the nonstoichiometric phases of Fe_3O_{4+X} and $Mg_2Fe_2O_{4-X}$ are also existed in the sintered sample. The electric resistivity ρ of the sintered sample was measure by the four-probe method at temperatures between 80 K and room temperature. The relationship between log ρ and $T^{-1/2}$ of sintered samples with different Mg contents was shown in Fig.3. $T^{-1/2}$ and log ρ are linearly related for all samples, implying that the magnetoresistance effect of these sintered samples is spin-dependent tunneling [3]. This means that the insulators Fe_2O_3, $Mg_2Fe_2O_4$, and $Mg_2Fe_2O_{4-X}$ provide the tunneling barriers for enhancing the MR value. The length of spin-dependent tunneling barrier becomes too large and the MR value decreases with increasing Mg content as the Mg doping amount is higher than 0.93 at.%, as shown in Fig.2.

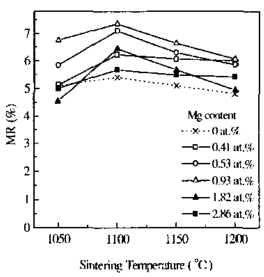

Fig. 1. Relationship between MR value and T_s of various sintered samples which have different Mg contents.

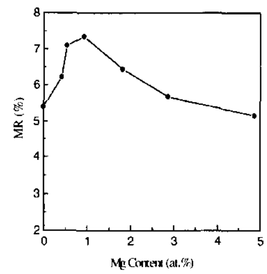

Fig. 2. Relationship between MR value and Mg content of the sintered sample.

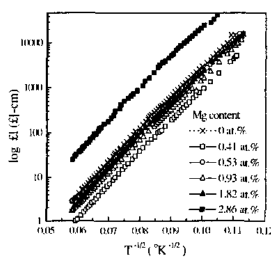

Fig. 3. log ρ vs. $T^{-1/2}$ of various samples which were sintered at 1100 °C.

References

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