3 - 4 Modification of Microwave Permeability of Fe_3O_4 Magnetic Films with Swift Heavy Ion Irradiation

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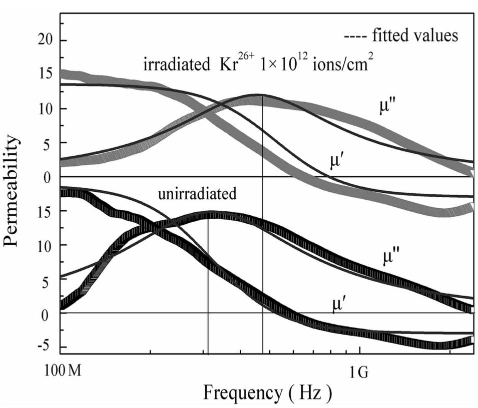

Fig. 1 Magnetic spectra (microwave permeability) of the pristine and irradiated Fe_3O_4 films.

Magnetite (Fe_3O_4) is not only a kind of typical soft magnetic ferrite material but also a new kind of important spintronics material because of its high spin polarization (ca. 100%) at the Fermi level and high Curie temperature (~858 K). However, the expected significant magnetoresistance (MR) effect of Fe_3O_4 was not observed, especially at room temperature[1]. So, how can we modify the physical properties of Fe_3O_4 films? It is well known that the properties of materials determined by its own structures, and swift heavy ion (SHI) irradiation is a unique and effectual tool, which is recognized to produce controlled defects (point/cluster and columnar), structural disorder, stress and phase transformations and to modify the physical properties of materials. Here, modification of the magnetic anisotropy and microwave permeability properties of SHI irradiated Fe_3O_4 films are presented.

The polycrystalline Fe_3O_4 thin films used in this study with thickness of 1 μm were synthesized on glass substrates by electroless plating. Then, the irradiation experiment was performed by using 2.03 GeV Kr^{26+} ions with different fluences on the HIRFL-SSC (IMP, Lanzhou). The complex relative permeability was measured on a network analyzer (Agilent 8720 ET) within a frequency range of 0.1~3 GHz.

The static and dynamic magnetic properties of the polycrystalline Fe_3O_4 films, are sensitive to 2.03 GeV Kr ions irradiation and exhibit diverse behaviors with different fluence. According to the static magnetic measurement results and related theory, for the pristine and irradiated films, effective magnetic anisotropy (E_{eff}) is about 5.1×10^5 erg/cm^3 and 2.7×10^6 erg/cm^3, E_d value is about 5.5×10^5 erg/cm^3 and 9.3×10^5 erg/cm^3, respectively. ($E_k = 1.3\times10^5$ erg/cm^3)

Fig. 1 shows the microwave permeability (magnetic spectra) of pristine and irradiated Fe_3O_4 films. Obviously, the irradiated films exhibit significant enhancement in microwave permeability. After SHI irradiation, microwave permeability increase, especially at lower end of frequency range. For instance, the real part (μ' values) of permeability of the irradiated films is about equal that of the pristine films, but for the imaginary parts of permeability (μ''), the resonant frequency of the irradiated films have larger value ($f_0 = 470$ MHz) than that of the pristine films ($f_0 = 310$ MHz). There are some reasons for the increased permeability (resonant frequency). According to the shape-dependent Snoek's law with cubic magnetocrystalline anisotropy field given below, we can obtain the related values of anisotropy[2]. For the pristine and irradiated films, E_{eff} is about 9.9×10^5 erg/cm^3 and 3.1×10^6 erg/cm^3, E_d value is about 5.5×10^5 erg/cm^3 and 1.8×10^6 erg/cm^3, respectively.

$$(\mu_i - 1)f_0 = \frac{1}{3\pi}\gamma M_s \quad (1), \qquad f_0 = \frac{\omega_0}{2\pi} \quad (2), \qquad \omega_0 = \gamma H_{eff} \quad (3)$$

where ω_0 is the circle frequency, γ is the gyromagnetic ration.

It is clear, the experimental results show that both methods can obtain the same change tendency: after SHI irradiation, the values of E_{eff} and E_d increase significantly. In another word, the magnetic anisotropy can be modified by SHI irradiation and the increases of anisotropy (E_{eff} and E_d) have the very important application in both static and dynamic magnetic fields.

References

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[2] A. N. Lagarkov, K. N. Rozanov, N. A. Simonov, et al., Handbook of Advanced Magnetic Materials, 5(2005), Tsinghua University Press, Beijing, China.