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Origin of ferromagnetism in nanocomposite iron oxide films

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Hematite, α-Fe_2O_3, is the most stable iron oxide under ambient conditions and is commonly found in nature. Its magnetic properties have been studied extensively both in bulk form and in the form of ultrafine particles. Below the Néel temperature, T_N ~950 K, bulk hematite is a weak ferromagnet, which undergoes a reorientation magnetic phase transition at the Morin temperature, T_M ~265 K, to a purely antiferromagnetic phase. Magnetic properties of hematite depend strongly on the grain size and display most interesting effects when the single crystal particles approach the size range of nanometers. As the particle size decreases, the Morin temperature is reduced and tends to vanish for particles smaller than ~20 nm.[1] If the particles become small enough, the direction of the magnetic moment in a single domain fluctuates due to thermal agitation, leading to superparamagnetic behavior and to spatial freezing of the effective magnetic moment of particles below the - blocking temperature T_B, [2] which is strongly dependent on particle size and shape.

We have studied thin films (10-20 nm thick) of hematite deposited on cold Si substrate by means of reactive magnetron sputtering using different sputtering conditions (controlled sample bias, partial pressure of nitrogen in deposition atmosphere and sample rotation). Microscopic images obtained with SEM and TEM revealed chemical inhomogeneity and presence of elongated precipitates. Their morphology is dependent on deposition conditions. VSM measurements have shown that magnetic properties of the films are significantly influenced by that morphology (Fig.1). The most intriguing is observation of opening of hysteresis loop for selected samples and directions, which indicates significant magnetic anisotropy.

We suspect that ferromagnetism can be attributed to different structure and chemical state of precipitates, e.g. maghemite or magnetite, with respect to hematite matrix. This hypothesis has been tested using XAFS experiment performed at SuperXAS beamline of SLS at PSI. (Fig. 2). Indeed, the iron K absorption spectra do shift edge towards lower incident photon energy for the samples revealing strongest magnetic effect.

The relation between morphology, magnetic and chemical properties of the samples of the nanocomposite iron oxides will be discussed in details.

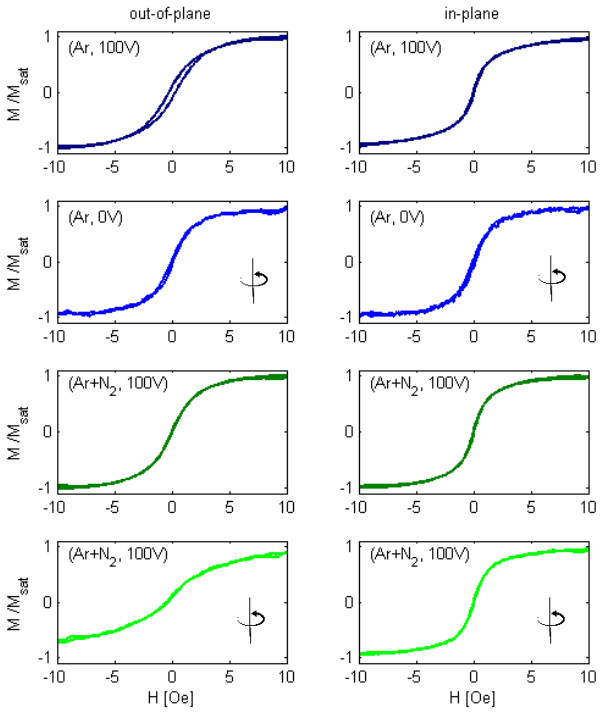

Figure 1. Hysteresis loops obtained via VSM. Deposition conditions (atmosphere, sample bias) indicated in brackets. Arrow determine presence of rotation during the process.

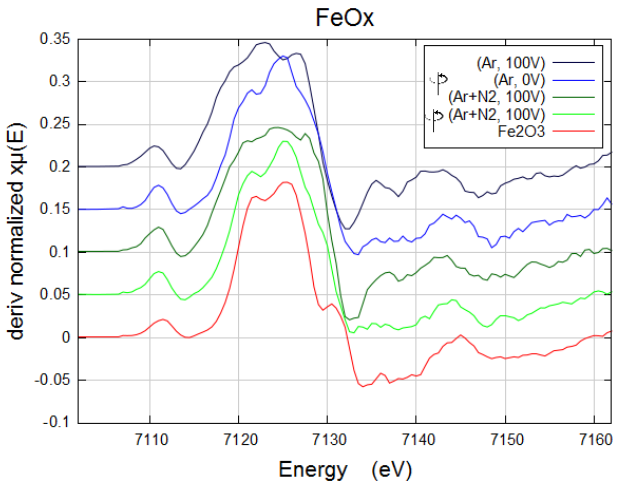

Figure 2. First derivative of Fe K-edge XAFS spectra of films studied and reference hematite powder (SA corrected).

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