Magnetic properties of hematite nanoparticles

The magnetic properties of hematite (α-Fe2O3) particles with sizes of about 16 nm have been studied by use of Mossbauer spectroscopy, magnetization measurements, and neutron diffraction. The nanoparticles are weakly ferromagnetic at temperatures at least down to 5 K with a spontaneous magnetization that is only slightly higher than that of weakly ferromagnetic bulk hematite. At T greater than or similar to 100 K the Mossbauer spectra contain a doublet, which is asymmetric due to magnetic relaxation in the presence of an electric field gradient in accordance with the Blume-Tjon model. Simultaneous fitting of series of Mossbauer spectra obtained at temperatures from 5 K to well above the superparamagnetic blocking temperature allowed the estimation of the pre-exponential factor in Neel's expression for the superparamagnetic relaxation time, \(\tau(0) = (6 +/ - 4) \times 10^{-11} \) s and the magnetic anisotropy energy barrier, \(E_{\text{bm}}/k = 590 +/ - (150)(120) \) K. A lower value of the pre-exponential factor, \(\tau(0) = 1.8 +/ - 3.2(1.3) \times 10^{-11} \) s, and a significantly lower anisotropy energy barrier \(E_{\text{bm(magn)}}/k = 305 +/ - 20 \) K was derived from simultaneous fitting to ac and dc magnetization curves. The difference in the observed energy barriers can be explained by the presence of two different modes of superparamagnetic relaxation which are characteristic of the weakly ferromagnetic phase. One mode involves a rotation of the sublattice magnetization directions in the basal (111) plane, which gives rise to superparamagnetic behavior in both Mossbauer spectroscopy and magnetization measurements. The other mode involves a fluctuation of the net magnetization direction out of the basal plane, which mainly affects the magnetization measurements.

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