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Magnetic Properties of Nickel Oxide Nanoparticles in Superparamagnetic State

Authors : Navneet Kaur, S. D. Tiwari

Abstract : Superparamagnetism is an interesting phenomenon and observed in small particles of magnetic materials. It arises due to a reduction in particle size. In the superparamagnetic state, as the thermal energy overcomes magnetic anisotropy energy, the magnetic moment vector of particles flip their magnetization direction between states of minimum energy. Superparamagnetic nanoparticles have been attracting the researchers due to many applications such as information storage, magnetic resonance imaging, biomedical applications, and sensors. For information storage, thermal fluctuations lead to loss of data. So that nanoparticles should have high blocking temperature. And to achieve this, nanoparticles should have a higher magnetic moment and magnetic anisotropy constant. In this work, the magnetic anisotropy constant of the antiferromagnetic nanoparticles system is determined. Magnetic studies on nanoparticles of NiO (nickel oxide) are reported well. This antiferromagnetic nanoparticle system has high blocking temperature and magnetic anisotropy constant of order 105 J/m3. The magnetic study of NiO nanoparticles in the superparamagnetic region is presented. NiO particles of two different sizes, i.e., 6 and 8 nm, are synthesized using the chemical route. These particles are characterized by an x-ray diffractometer, transmission electron microscope, and superconducting quantum interference device magnetometry. The magnetization vs. applied magnetic field and temperature data for both samples confirm their superparamagnetic nature. The blocking temperature for 6 and 8 nm particles is found to be 200 and 172 K, respectively. Magnetization vs. applied magnetic field data of NiO is fitted to an appropriate magnetic expression using a non-linear least square fit method. The role of particle size distribution and magnetic anisotropy is taken in to account in magnetization expression. The source code is written in Python programming language. This fitting provides us the magnetic anisotropy constant for NiO and other magnetic fit parameters. The particle size distribution estimated matches well with the transmission electron micrograph. The value of magnetic anisotropy constants for 6 and 8 nm particles is found to be 1.42 X 105 and 1.20 X 105 J/m3, respectively. The obtained magnetic fit parameters are verified using the Neel model. It is concluded that the effect of magnetic anisotropy should not be ignored while studying the magnetization process of nanoparticles.

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