11th International Conference on Advanced Materials
ICAM 2009
Rio de Janeiro Brazil
September 20 - 25

Magnetic and Electric Properties of Non-Magnetic Metallic Films Containing Nanometer Size Clusters of Iron

W.T. Herrera[(1,2)], Y. Xing[(2)], S.M. Ramos[(2)], P. Munayco[(2)], M. Fontes[(2)], E.M. Baggio-Saitovitch[(2)], and F.J. Litterst[(2,3)*]

(1) Instituto de Física, Universidade do Estado de Rio de Janeiro, Rua São Francisco Xavier 524, 20559-900, Rio de Janeiro, Brazil
(2) Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, 22290-180, Rio de Janeiro, Brazil, william@cbpf.br
(3) Institute for Physics of Condensed Matter, Technische Universität Braunschweig, Mendelssohnstrasse 3, 38106 Braunschweig, Germany, j.litterst@tu-bs.de
* Corresponding author.

Abstract – Thin films of cadmium and silver containing 0.1-several at % Fe have been prepared by vapor co-deposition. Depending on substrate temperature and iron concentration we could systematically follow the formation of nanometer size clusters of iron from initially dilute iron monomers. Samples were characterized via X-ray diffraction, resistivity, magnetization, susceptibility and Mössbauer spectroscopic measurements. The magnetic freezing observed at low temperatures, is controlled via the inter-particle interactions via conduction electron polarization. Magnetic hyperfine data and resistivity indicate a competition between magnetic coupling and Kondo effect.

Dilute magnetic impurities in non-magnetic metallic matrices have been intensively studied in the past for investigating single ion Kondo effect and the development of spin glassy behavior upon increasing magnetic interactions with dopant concentration. There is newly arising interest in dilute magnetic nano-clusters in non-magnetic surroundings which is mainly related to the electronic properties of quantum dots. The quantum fluctuations associated with quantum dots are supposed to strongly affect electronic and magnetic correlations in their surrounding leading to unusual and little understood phenomena.

We therefore have started an investigation of magnetic iron nano-clusters formed in non magnetic hosts with low solubility for iron. Here we will concentrate on films of cadmium in comparison with our earlier studies on silver films. Nanometer size clusters of iron can be formed in films containing iron in the range from 0.1 to several at% via vapor co-deposition. Characterization of samples was performed via X-ray diffraction, resistivity, magnetization, susceptibility, and Mössbauer spectroscopic measurements at various temperatures and applied magnetic fields. Up to concentrations of about 2 at% Fe the iron clusters are well defined as distinguished from their hyperfine parameters. Possible structural configurations will be discussed.

Magnetization reveals Curie-Weiss behavior with Curie-Weiss temperatures around 1-5 K. Spin-freezing is traced from Mössbauer and magnetization data with freezing temperatures ranging from below 4 K up to about 15 K depending on cluster concentration. Models for describing the dynamic hyperfine spectra in this temperature range will be presented taking into account different mechanisms for cluster-cluster interactions.

Above the freezing temperature we can derive average cluster magnetic moments from magnetization data and also from the field dependence of the magnetic hyperfine fields at Fe obtained in applied external fields. Both macroscopic and local magnetic data are in good agreement yielding moments on the order of 15-20 μ_B for iron clusters in Cd films, compared with 35-40 μ_B found for Ag films. I.e., in both cases the clusters comprise only few atoms. The hyperfine spectra taken in applied field indicate a reduction of the iron moments at low temperatures which can be interpreted with moment compensation via conduction electron scattering. A competition between Kondo effect and the magnetic coupling of clusters via conduction electron polarization interaction could be clearly traced from the resistivity data of the silver films.

Whereas in films with iron concentrations up to about 2 at% we have controlled formation and growth of small clusters, this is no more the case for higher concentrations. Strong irreversibility in magnetization is found extending up to 100 K. The hyperfine data prove the presence of the same kinds of clusters as found for lower concentration yet with much bigger sizes.