Magnetic Phase Transitions in Nanoclusters and Nanostructures

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Nanoclusters and nanostructures possess new magnetic properties when compared to the bulk materials. For example, the critical cluster size exists ensuring the first order magnetic phase transitions (FOMPT) [1, 2] when cluster magnetization disappears by jump. This critical cluster size is analog the critical magnetic points (the Curie or Neel points) for the FOMPT in the bulk magnetic materials that dramatically differ from superparamagnetic behavior. In this work we deal with 3 nanosystems showing FOMPT: 1) 1-3 nm isolated iron oxide clusters localized in (A) copolymer styrene and divinylbenzen and (B) polyacryl acid and polyethylenimide matrixes, 2) 30-50 nm disordered iron oxide nanoclusters obtained at the outset of sintering, 3) 10-15 nm iron oxide nanoclusters prepared from reversed micelle and template-sending showed cluster ordered structure. We discuss thermodynamic models of magnetic phase transitions in nanoclusters taking into consideration the cluster-matrix, cluster-cluster interactions, surface tension, influence of defects and stresses and intercluster ordering.

In the system 1) the FOMPT was observed by Mössbauer spectroscopy and magnetization measurements. For the matrix (A) a week cluster-matrix interaction was observed and the FOMPT was interpreted in terms of action of surface pressure up to 1GPa and compressibility of iron oxide clusters at the temperature range 4.2-6K. In the matrix (B) the origin of the FOMPT we discuss in terms of strong influence of cluster-matrix interaction and the influence of surface tension and magnetic anisotropy in the vicinity 3K-6K.

Iron oxide nanosystems 2) obtained by thermal decomposition of ferric oxalate showed structure disorder. The FOMPT in these nanosystems was observed at 20 - 300K and was found to be dependent on structure defect density. Shear stress under high pressure action was the reason why a great number of iron oxide clusters have been involved in magnetic phase transition whereby the transition temperature decreased because of severe plastic deformation and structure defect generation. For nanosystem consisting of iron oxide and nanostructured metal europium the effect of plastic deformations of Eu caused first-to-second order change of magnetic phase transition accompanied by an increase in the Neel point.

In the cluster ordered system 3) we observe fivefold increase of magnetization and increase of Curie or Neel temperature than compare with disorder iron oxide nanocluster 2) and with disordered iron oxide nanoclusters obtained by aerosol technique ($NaCl$-$Fe(NO_3)_3$ thermal decomposition). The ordered nanosystem 3) again demonstrates the FOMPT. In contrary, the disordered nanoclusters obtained by aerosol technique showed only superparamagnetc behavior. As compared to NaCl-doped iron oxide nanoclusters showing superparamagnetic behavior the cluster organized iron oxide nanosystems showed considerable magnetization and coercitive force. These effects can be interpreted in terms of the FOMPT like in the system 1) and 2). The possible reason in this case is the peculiar nanocluster ordered structure with its specific Curie or Neel temperatures generated by intercluster exchange interaction.

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