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Unusual ferromagnetism at nanoscale due to surface-spin-reorientation

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Mn-based silicides are attractive from the viewpoints of fundamental science and potential applications in spintronics, owing to their exotic spin textures and unique crystal structures. However, bulk alloys show only weak low-temperature magnetic ordering and this inhibits their practical room-temperature applications. Our recent report shows that magnetic nanoclusters exhibit entirely different magnetic properties from the corresponding bulk alloys due to nanoscale effects. In this study, we report the synthesis of novel Mn5Si3 nanoclusters using a gas-aggregation type cluster-deposition method and show unusual ferromagnetism experimentally and by first-principle DFT calculations, in a sharp contrast to antiferromagnetic behavior shown by bulk alloys below 100 K. TEM studies show that Mn5Si3 nanoclusters are monodispersed with an average size d » 8.7 nm and an rms standard deviation σ/d»0.1. The nanoclusters are also single crystalline and form the $D8_8$-type hexagonal structure as shown by HRTEM (Figure-1a) and FFT (Figure-1b) images, respectively. The nanoclusters show appreciable coercivities (Hc=900 Oe at 3 K and 450 Oe at 300 K) and high saturation magnetic polarization (Js=12.5 kG at 3 K and 10.5 kG at 300 K) [Figure-1(c)] with a high Curie temperature (Tc≈590 K) [Figure-1(d)]. The fitting of magnetization curve at high-field region (35-70 kOe) using the law-of-approach to saturation method yields an appreciable magneto crystalline anisotropy constant $K1$≈12 Mergs/cm^3. Thus, easy-axes of the nanoclusters were successfully aligned using an external magnetic field prior to deposition, which results in improved Hc (1700 Oe at 3 K and 600 Oe at 300 K). The nanocluster magnetic properties are mainly due to the large surface spin-polarization (m=3.3 μ_B/Mn) that subsequently spin-polarizes the nanocluster-core (m=0.9 μ_B/Mn), as revealed by the DFT simulations.

Recent Publications

1. Bhaskar Das, Balamurugan Balasubramanian, Priyanka Manchanda, Pinaki Mukherjee, Ralph Skomski, George C Hadjipanayis and David J Sellmyer (2016) Mn_5Si_3 Nanoparticles: Synthesis and Size-Induced Ferromagnetism. *Nano Letters*; 16: 1132.
2. Balamurugan Balasubramanian, Priyanka Manchanda, Ralph Skomski, Pinaki Mukherjee, Shah R Valloppilly, Bhaskar Das, George C Hadjipanayis, and David J Sellmyer (2016) High-coercivity magnetism in nanostructures with strong easy-plane anisotropy. *Applied Physics Letters*; 108: 152406.

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S Mühlbauer, et al. (2009) Skyrmion Lattice in a Chiral Magnet. *Science*; 323(5916): 915-919.

Biography

Bhaskar Das is a post-doctoral scientist at the Ames Laboratory of United States Department of Energy (US-DOE). He did his Ph.D. at the Nebraska Center for Materials and Nanoscience of University of Nebraska-Lincoln, Department of Physics and Astronomy. His area of research involves physics of magnetism, nanoscience, materials physics and spintronics. Currently he is working at the US-DOE lab in the project related to magnetism for renewable energy and device technologies.

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