MAGNETIZATION STEPS IN NANOWIRES

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Introduction

Magnetic semiconductors and semiconductor nanostructures are possible candidates for spin aligners and spin injectors in future spintronic devices [1]. The family of $A_{1-x}Mn_xB$, where A and B are group II and VI elements respectively, is a subgroup of the so-called diluted magnetic semiconductors (DMS). A reduction of the lateral dimensions of DMS should significantly affect their magnetic properties, which is essential for the miniaturization of electronic devices [2]. Recently, it has been shown that $Zn_{1-x}Mn_xS$ and $Cd_{1-x}Mn_xS$ can be successfully incorporated into the ordered arrays of mesoporous SiO_2 nanostructures of MCM-41 or SBA-15 type [3]. With typical pore diameters of a few nanometers the resulting DMS nanowires are ideal model systems for the study of magnetic properties in reduced dimensions. Here a central question concerns the nearest neighbor Mn-Mn exchange constant, whether it is affected by the miniaturization or not.

Experimental

Experimentally, the nearest neighbor Mn-Mn exchange constant can be determined from high-field magnetization steps, as has been done by Shapira and Oliveira [4] in bulk material of these DMS compounds. The magnetization steps result from the breaking of antiferromagnetically coupled Mn-Mn pairs by the external magnetic field. An exchange constant of -10 K has been found in the bulk material of $Cd_{1-x}Mn_xS$ [5]. The steps broaden with increasing temperature. Therefore, in order to observe magnetization steps in these nanostructures, measurements at sufficiently low temperatures and high fields are necessary. We attempted to perform M(B) hysteresis measurements in a 50 T short-pulse magnet (NHMFL-LANL) at 3He-temperature for $Cd_{1-x}Mn_xS$ nanowires with x = 0.05 and a diameters of 9 nm.

The magnetic moment in question is located at the Mn-ions in $Cd_{1-x}Mn_xS$ nanowires, which are incorporated in a SiO_2-matrix. The ratio between nanowire and SiO_2-matrix is approximately 50 %. The samples were available in powder form and had either to be filled into a small plastic capsule or mixed with epoxy to form a solid. In the first case the maximal volume was about 1mm^3, in the second case about 1.4 mm^3. Due to the small amount of magnetic ions it turned out that the magnetization was below the resolution achievable in the pulsed fields available and therefore no steps could be observed.

Conclusions

In order to observe steps in magnetization of these nanowires, which would provide information about the Mn-Mn exchange constant, it would be necessary to either increase the resolution of the experiment, e.g. by switching from a pulse magnet to a dc-field or measuring magnetic force instead of magnetization, or to increase the magnetic moment of the samples by increasing the ratio of the actual nanowire to the SiO_2-matrix.

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