Anti-ferromagnetism in paramagnetic ion doped semiconductor nanocrystals

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Magnetism of a diluted magnetic semiconductor is known established mainly by those of individual paramagnetic ion dopants, which themselves are paramagnetic but interacting with each other anti- ferromagnetically. The anti-ferromagnetic (AFM) interactions are usually merged in the pronounced paramagnetism of magnetic ion doped nanocrystals and hardly exposed since the underlying AFM interactions are significant only between nearest neighbor magnetic ions, a portion of magnetic ion dopants, and do not essentially change the overall paramagnetic features. Nevertheless, the AFM interactions between magnetic ions in magnetic semiconductors have been extensively thought to significantly affect the magnetic features, including the reduced effective Mn concentration, fast spin relaxation, and low Curie temperature in the ferromagnetic phase. In this work, I will review our recent theoretical and experimental investigations of the magnetism of CdSe:Mn nanocrystals (NCs), where an efficient approach to the exposure and analysis of the hidden AFM in the paramagnetism of CdSe:Mn nanocrystals was proposed. Theoretically, the widely used exact diagonalization (ED) technique and mean field theory (MFT) are no longer applicable for the measured nanocrystals with the moderate number of Mn ions, typically 10~80 per NC. A key advance made in this work is the development of an analysis method that allows us to distinguish the anti-ferromagnetic interactions between aggregative Mn2+ ions from the overall pronounced paramagnetism of magnetic-ion-doped semiconductor nanocrystals. We build up a solvable model that still individually preserves each Mn spins and the exploitation of group theory technique to count the tremendously high degeneracies of the energy spectrum with no need of any heavy numerical computation. With the aid of the theory, we clearly reveal the signatures of AFM from the measured temperature dependent magnetic susceptibilities, and by fitting them with the theoretical calculations, we can estimate the number of Mn ions and even infer most probable spatial distributions of Mn ions.

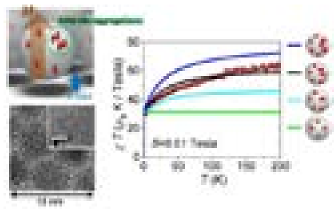

Figure 1: Left panel: Schematic and transmission electron microscope (TEM) images of the measured CdSe:Mn nanocrystals (NC's) doped with Mn2+ ions, some of which are aggregated. Right panel: Product of measured and simulated magnetic susceptibility and temperature versus the temperature (□*T vs. T*).

Biography

Shun-Jen Cheng received *Doctor rerum naturalium* (Dr. rer. nat.), (Doctor of natural sciences) in physics from University of Würzburg, Germany in 2001, with the accomplishment of the thesis entitled "Collective excitations and Coulomb drag in two-dimensional systems" under the instruction of his supervisor Prof. Rolf. R. Gerhardts. In 2002, Dr. Cheng joined the "Quantum Theory group" led by Prof. Pawel Hawrylak at National Research Council of Canada in Ottawa, Canada, as Research Associate. In 2003, Dr. Cheng returned his home country and began his Professorship at Department of Electrophysics at National Chiao Tung University (NCTU), Hsinchu, Taiwan. He is currently Professor in physics at Department of Electrophysics at NCTU, Hsinchu, Taiwan. His research interests are in the theories of multi-exciton physics, magnetic-ion doped semiconductor nanostructures, and two- dimensional transition-metal dichalcogenides.

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