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Magnetic and transport properties in Mn doped III-V semiconductor: The cases of GaAs and InP

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The nature of carrier-induced ferromagnetism in both Mn doped III-V compounds GaAs and InP is investigated. Although, direct band gap and effective masses are very close in both InP and GaAs, we demonstrate that the magnetic properties change drastically. The influence of the acceptor level position on magnetic properties will prove to be crucial. Because of both dilution effects (percolation) and short-range nature of the carrier induced Mn-Mn magnetic couplings (calculated), thermal/transverse spin fluctuations and disorder effects (localization) have to be properly treated (beyond effective medium or perturbation approach). To tackle efficiently this issue, different large-scale theoretical approaches are combined: Kernel Polynomial Method (KPM) for the accurate calculation of Mn-Mn couplings, Monte Carlo (MC) and Local Random Phase approximation (L-RPA) for the magnetic properties (T_C, T- dependent magnetization, and magnetic excitation spectrum and spin stiffness). T_C in (In, Mn)P is found much smaller than that of Mn doped GaAs and scales linearly with Mn concentration in contrast to the square root behavior found in (Ga, Mn)As. Moreover, we find that the magnetization behave almost linearly with the temperature in contrast to the standard mean field Brillouin shape. These findings are in quantitative agreement with the experimental data and reveal that magnetic and transport properties are extremely sensitive to the position of the Mn acceptor level. We finally discuss the transport properties in both compounds and demonstrate that our non-perturbative theory is able to capture not only qualitatively but quantitatively as well the transport properties in these materials such as the Infrared optical conductivity, the carrier and Mn concentration dependent Drude weight, the effects of sample annealing, and also the Metal-Insulator-Transition as observed experimentally in Mn doped GaAs, whilst (In,Mn)P remains an insulating compound.

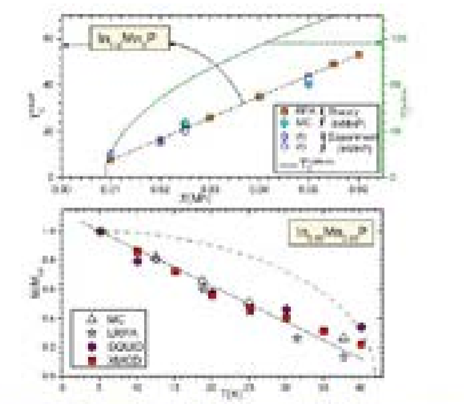

Fig. 1. (top) Curie temperature in (In,Mn)P as a function of Mn concentration (theory vs experiment), for comparison Tc in (Ga,Mn)As is also shown (green continuous line). (bottom) magnetization in 3% doped InP as a function of temperature (theory and experiment), filled symbols correspond to experimental data whilst open symbols to theoretical calculations (Monte Carlo and Local Random Phase Approximation) the dashed line represent a standard Brillouin magnetization curve for S=5/2. Figures extracted from Ref. [1].

Biography

Georges Bouzerar is a Research Director at Centre National de la Recherche Scientifique (CNRS). He is an expert in quantum and classical magnetism (itinerant and localized) and in quantum transport. He has completed his PhD in mesoscopic physics (interplay between electron-electron interaction and disorder) in 1996 from Paris XI (Orsay) University. He has spent several years as a Postdoc in Germany (Koeln University, Berlin University, Max Planck Institute) and in France (Laue Langevin Institute in Grenoble). He got a Senior Scientist permanent position at CNRS in 2004 and became research director in 2011. Over the past 10 years he has focused attention on spintronics, in particular on magnetism and transport in diluted magnetic semiconductors and non-magnetic impurity induced ferromagnetism. He has contributed by about 25-30 papers to this research area and received a prize in 2014 from the French Academy of Science for his achievements in this field.

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