Influence of free charge carrier density on the magnetic behavior of (Zn,Co)O thin film studied by Field Effect modulation of magnetotransport

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The origin of (ferro)magnetic ordering in transition metal doped ZnO is a still open question. For applications it is fundamental to establish if it arises from magnetically ordered impurity clusters, embedded into the semiconducting matrix, or if it originates from ordering of magnetic ions, dilute into the host lattice. In this latter case, a reciprocal effect of the magnetic exchange on the charge carriers is expected, offering many possibilities for spintronics applications. In this paper we report on the relationship between magnetic properties and free charge density investigated by using Zinc oxide based field effect transistors, in which the charge carrier density is modulated by more than 4 orders of magnitude, from 10^{16} to 10^{20} e−/cm^3. The magnetotransport properties are employed to probe the magnetic status of the channel, both in pure and cobalt doped zinc oxide transistors. We find that it is widely possible to control the magnetic scattering rates by field effect. We believe that this finding is a consequence of the modulation of magnetization and carrier spin polarization by the electric field. The observed effects can be explained by the change in size of bound magnetic polarons that induces a percolation magnetic ordering in the sample.

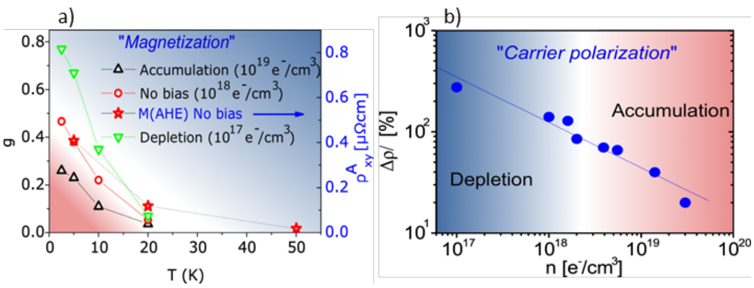

Fig. 1 a) Estimation of the (Zn,Co)O sample magnetization from the magnetoresistance fit and the anomalous Hall effect. The left and right vertical scale are chosen in such a way that the point at 5K and zero bias coincide.

b) Maximum positive value of the low temperature magnetoresistance in (Zn,Co)O as a function of the carrier concentration inferred from Hall Effect. According many authors it is directly related to the spin carrier polarization.

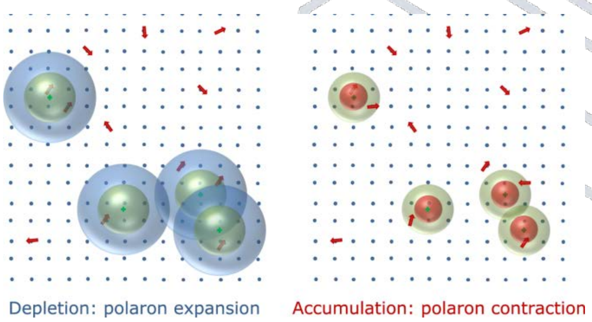

Fig. 2: Schematic drawings for the size evolution of bounded magnetic polaron with carrier concentration. Red arrows and cyan dots represent magnetic impurities and donor defects, respectively; blue, red and green spheres represent the expanded, contracted and natural polaron sizes, respectively. The increase in carrier density reduces the polaron radius and consequently increases the bound magnetic polaron separation; thus, the magnetic coupling decreases (right). The opposite situation happens when the carrier density decreases (left).