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Origin and control of ferromagnetism in magnetically doped semiconductors. The case of (Ga,Fe)N

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The comprehensive search for materials exhibiting spintronic functionalities has resulted in the discovery of a number of magnetically doped or nominally undoped wide-band gap semiconductors and oxides showing ferromagnetic features persisting up to high temperatures. In order to shed light on the origin of the high-TC ferromagnetism in these materials systems, we have undertaken studies of MOVPE-grown (Ga,Fe)N, either undoped or co-doped with Si or Mg, combining the magnetic (SQUID and EPR), magnetooptical, and XANES investigation with a thorough structural and chemical characterization (SIMS, TEM, EDS, synchrotron XRD), that provides information on the Fe distribution at the nanoscale. In this talk, we first discuss our quantitative study of the exchange coupling between the spins S = 5/2 localized on the Fe ions and of the effective mass electrons. Our results point to an anomalous p-d exchange splitting of the valence band [1], that we explain in terms of a renormalization of extended states occurring if the impurities perturb strongly the crystal potential. We then show that the Fe ions are incorporated in the nitride matrix in a way giving rise either to a diluted random alloy or to ferromagnetic nanocrystals that aggregate by precipitation or by spinodal decomposition into regions more or less rich in the magnetic component, and that can be controlled by the growth parameters and co-doping with shallow donors and acceptors [2].

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[2] A. Bonanni, A. Navarro-Quezada, Tian Li, M. Wegscheider, R.T. Lechner, G. Bauer, Z. Matej, V. Holy, M. Rovezzi, F. D'Acapito, M. Kiecana, M. Sawicki, and T. Dietl, Phys. Rev. Lett. 101, 135502 (2008).