

Controlled aggregation of magnetic cations in (Ga,Fe)N

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The 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 exhibiting ferromagnetic features persisting up to high temperatures. The nature of this puzzling robust ferromagnetism has become one of the most controversial topics in nowadays materials science and condensed matter physics [1].

In order to shed new light on the origin of high- T_C ferromagnetism, we have undertaken studies of MOVPE-grown (Ga,Fe)N [2-5], either undoped or co-doped with Si or Mg, combining magnetic (SQUID and EPR), magneto-optical, and XANES investigation with a comprehensive structural and chemical characterization (SIMS, TEM, EDS, synchrotron XRD), that provides information on the Fe distribution at the nanoscale.

Our results show that the Fe ions are distributed in the nitride matrix in a way giving rise either to a diluted random alloy [2-5] or to ferromagnetic FeN_x nanocrystals that aggregate by precipitation [2,3,5] or by spinodal decomposition into (Ga,Fe)N regions more or less rich in the magnetic component [3,5]. This aggregation of Fe cations shows a strong dependence on the Ga flow rate, allowing – when appropriately mastered – a control of the solubility limit of the transition metal ions in GaN. In the perspective of testing the possibility to affect the incorporation of the magnetic ions in a semiconducting host through the tuning of the Fermi level we describe the effects of co-doping with donors (Si) and acceptors (Mg) on the magnetic behavior of the (Ga,Fe)N system. Our findings guide us to conclude that the Coulomb interaction between magnetic ions can indeed be adjusted via co-doping, with dramatic and controllable effects on the aggregation of the Fe-rich nanocrystals [5]. The novel mechanism of nano-self-organisation that we present, promises to result in new multi-component semiconductor/magnetic systems, whose characteristics and functionalities can be tuned over a wide range by fabrication parameters, co-doping, and substrate engineering.

[1] see, e.g., A. Bonanni, Topical Review, *Semicond. Sci. and Technol.* 22, 41 (2007).

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