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Effects of co-doping on ferromagnetism in (Zn,Cr)Te.

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Room-temperature ferromagnetism in semiconductors has emerged as one of the most challenging topics in today's materials science and technology. Indeed, enormous research activities have so far been directed towards developing ferromagnetic semiconductors with high transition temperatures. Despite many reports claiming high-temperature ferromagnetism for a broad class of diluted magnetic semiconductors, their intrinsic nature has sometimes been controversial[1], with a lack of elaborated analysis of structural and electronic properties. Among them, Cr-doped ZnTe has been regarded as one of the promising materials of room-temperature ferromagnetism because its intrinsic nature was confirmed through magnetic circular dichroism (MCD) measurement[2]. In this presentation, we report the effect of co-doping of charge impurities on ferromagnetic properties in this material. It was found that ferromagnetism was suppressed in (Zn,Cr)Te co-doped with nitrogen (N) as an acceptor impurity[3] and was enhanced in a crystal co-doped with iodine (I) as a donor impurity[4]. In particular, the apparent Curie temperature T_C of $Zn_{1-x}Cr_xTe$ with a Cr composition of $x = 0.05$ increased up to 300K at maximum due to I-doping, compared to T_C ∼30K in the undoped crystal. In the structural and compositional analysis using TEM/EDS, it was revealed that the origin of this remarkable effect of the co-doping was the variation of Cr distribution in the crystals; the Cr distribution was strongly inhomogeneous in I-doped crystals with higher T_C, in contrast to an almost uniform distribution in undoped or N-doped crystals with lower T_C or being paramagnetic. In the crystals of inhomogeneous distribution, Cr-rich regions with a typical size of several ten nanometers formed in the Cr-poor matrix act as ferromagnetic nanoclusters, resulting in an apparent ferromagnetic behavior of the whole crystal. These variation of the Cr uniformity can be linked to a change in the Cr charge state due to the co-doping, which is considered to affect the aggregation energy of Cr ions in the host compound ZnTe[5]. These findings will open a new way to control the formation of magnetic nanoclusters in the semiconductor matrix and ferromagnetic properties by manipulating the charge state of magnetic impurities.

[1] see, *e.g.* C. Liu *et al.*, J. Mater. Sci.: Mater. Electron. **16**, 555 (2005), S. A. Chambers *et al.*, Mater. Today **9**, 28 (2006).
[2] H. Saito *et al.*, Phys. Rev. Lett. **90**, 207202 (2003).
[3] N. Ozaki *et al.*, Appl. Phys. Lett. **87**, 192116 (2005).
[4] N. Ozaki *et al.*, Phys. Rev. Lett. **97**, 037201 (2006).
[5] T. Dietl, Nature Mater. **5**, 673 (2006).