MAR05-2004-003393

Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Interfacial Control of Ferromagnetism in (Ga,Mn)As-based Hetero- and Nano-structures

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We discuss recent experiments that demonstrate how heterointerfaces impact the magnetic properties of hetero- and nanostructures derived from the "canonical" ferromagnetic semiconductor (Ga,Mn)As. In this material, holes created by the Mn acceptors mediate a ferromagnetic interaction between the Mn ions, and the Curie temperature (T_C) is determined by a complex interplay between substitutional magnetic ions, interstitial defects and holes. Although as-grown epilayers of (Ga,Mn)As typically have $T_C \leq 110$K, post-growth annealing at low temperatures (180°C - 250°C) significantly enhances the ferromagnetic properties, leading to $T_C \sim 150$K. We first describe experiments that examine the effects of capping ferromagnetic (Ga,Mn)As epilayers with a thin layer of undoped GaAs [Stone *et al*, Appl. Phys. Lett. **83**, 4568 (2003)]. We find that the overgrowth of even a few monolayers of GaAs significantly suppresses the enhancement of the ferromagnetism associated with low temperature annealing, suggesting that heterointerfaces have a direct impact on the migration of interstitial defects during post-growth annealing. We next demonstrate how nanopatterning allows us to provide alternate defect diffusion pathways, hence remove the constraints on T_C imposed by the presence of heterointerfaces [Eid *et al*, submitted]. Finally, we examine the influence of an overgrown antiferromagnet (MnO) on the magnetic properties of (Ga,Mn)As, demonstrating the first example of exchange biasing of this ferromagnetic semiconductor [Eid *et al*,Appl. Phys. Lett. **85**, 1556 (2004)]. Detailed studies show that systematic control over the highly reactive MnO/(Ga,Mn)As interface is essential for the routine achievement of exchange bias in this important spintronic material. This work was carried out in collaboration with K. F. Eid, M. B. Stone, O. Maksimov, K. C. Ku, B. L. Sheu, W. Fadgen, P. Schiffer, T. Shih, and C. Palmstrom. Supported by ONR and DARPA.