Influence of disorder on carrier-induced ferromagnetism in surface doped (Cd,Mn)Te quantum wells.

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It has been proposed theoretically [1] and shown experimentally [2] that in (Cd,Mn)Te quantum wells the presence of a 2D carrier gas induces a ferromagnetic interaction between localized Mn spins due to the strong exchange coupling between Mn spins and charge carriers. The most interesting configuration is that of p-type modulation doped structures. The first results have been obtained in (Cd,Mn)Te quantum wells, using nitrogen acceptors for doping the $Cd_{1-x-y}Zn_xMg_yTe$ barrier material [2,3]. Those results were correctly decribed in terms of the mean field model. The critical temperature was found to be proportional to the density of free spins x_{eff}, which increases with the Mn concentration x for small values of x. Increasing the value of x above 5% slightly increases x_{eff}, but also strongly increases the number of nearest neighbour pairs (with a strong antiferromagnetic coupling) and increases disorder.

In this work we used acceptor surface states to create a hole gas in (Cd,Mn)Te quantum wells [4]. A hole density above $2*10^{11}$ cm^{-2} was obtained. We were able to increase the maximal Mn content in the well up to 11%. This allows us to test theoretical models used for the description of the magnetic ordering induced by the 2D carrier gas at high Mn contents.

As previously reported [2,3], we observed that below a certain temperature the PL line features a splitting attributed to the effective field resulting from local ferromagnetic order, and a shift to low energy. The position of the maximum of PL plotted versus temperature shows thus a distinct kink convenient for the determination of the transition temperature~[3]. We performed magnetooptical susceptibility measurements and found that the results obey a Curie-Weiss law. At low Mn content (up to 5%) the Curie-Weiss temperatures agree with the transition temperatures determined from PL. Both values agree with the mean field model prediction. At higher Mn concentrations the Curie-Weiss temperatures become smaller than the transition temperatures, and the difference increases with the Mn content in the quantum well, while the mean field model produces an intermediate value.

This difference can be attributed to the increased carrier localization induced by the disorder in the system [5]. It can be introduced by the Mn ions along with possible formation of complexes of antiferromagnetically coupled spins in Mn rich quantum wells.

We also performed photoluminescence mapping with a resolution below 1 μm and found that the main type of disorder present in quantum wells with moderate Mn concentration is due to carrier density fluctuations. We discuss the characteristic temperatures of the magnetic phase in terms of various types of disorder.

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