NANOSCALE CLUSTERIZATION AT THE METAL-INSULATOR BOUNDARY IN DILUTED MAGNETIC 2D QUANTUM WELLS

J. Jaroszyński, D. Popović (NHMFL); T. Andrearczyk, G. Karczewski, J. Wróbel, T. Wojtowicz, T. Dietl (Institute of Physics, Polish Academy of Sciences)

Introduction

Magnetotransport study in diluted magnetic semiconductor (DMS) modulation doped (Cd,Mn)Te quantum wells (QW) reveals features commonly observed in colossal magnetoresistive (CMR) [1] materials, such as a strong negative magnetoresistance (MR) as well as dramatic and nonmonotonic changes in the zero- field resistance ρ, which occur at the metal-insulator boundary.

Experimental

Modulation-doped n-(Cd,Mn)Te:I QW were grown by molecular beam epitaxy and contain a 2D electron system confined to a $Cd_{0.985}Mn_{0.015}Te/Cd_{0.8}Mg_{0.2}Te$ heterostructures. The peak 4.2 K mobility is 6×10^4 cm^2 /Vs, the 2D electron density n_s is controlled by a metal front gate in the range of $1.4 < n_s < 6.2 \times10^{11}$ cm^{-2}.

Results and Discussion

Fig. 1 shows ρ(T,B=0) at different n_s. At elevated T and high n_s, ρ (T) is weakly metallic with. an apparent 2D metal-to-insulator (MIT) transition at $n_s \approx 2.2\times10^{11}$ cm^{-2}. However, at some $T^*(n_s)$ a dramatic increase of ρ by orders of magnitude is observed for moderate n_s in the vicinity of the MIT. As shown in Fig. 2, at high T, and at low T and either high or low n_s, a weak positive MR dominates, which as in other DMSs originates from an s-d exchange-induced giant spin-splitting of band states. However, exclusively in the range of T and n_s, where at B=0 the upturn of ρ(T) is observed, a weak B rapidly drives the system back towards metallic behavior. As a result, a colossal negative MR is observed. Similar behavior was observed in other DMSs [2]. It was usually attributed to spin-disorder scattering associated with the formation of bound magnetic polarons (BMP). However, formation of BMP is rather unlikely in 2D, since donors in our system are set back far from the conducting channel, while Mn ions are electrically neutral in the II-VI DMS. Since the phenomena observed here resemble magnetotransport in CMR materials, it is possible that they also share a similar origin. Most likely, they reflect nanoscale phase separation of the electron fluid and the emergence of ferromagnetic clusters in an intermediate density regime.

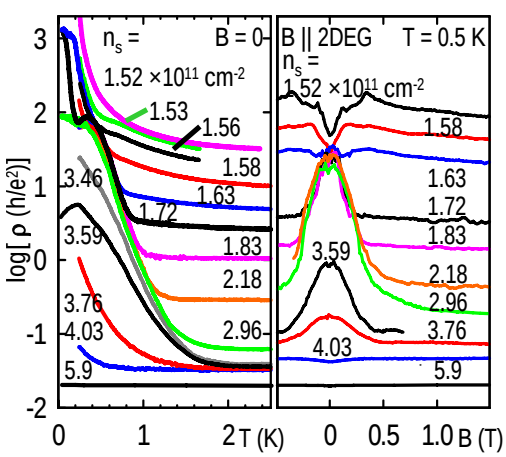

Fig. 1: Resistivity vs. *T* for different electron densities at *B* = 0.

Fig. 2: Resistivity vs. *B* for different electron densities at *T*= 0.5 K.

Conclusions

Our results [3] suggest that the magnetic and electric clusterization around the MIT is ubiquitous not only in CMR manganites and other transitional oxides but also in disordered magnetic semiconductors.

Acknowledgements

This work was supported by NSF Grants No. DMR-0071668 and DMR-0403491, by the NHMFL through NSF Cooperative Agreement No. DMR-0084173, and by INTAS Grant No. 03-51-5266.

References

[1] Dagotto, E., *et al*., Phys. Rep., **344**, 1 (2001).
[2] von Molnar, S., *et al*., J. Appl. Phys., **38**, 959 (1967).
[3] Jaroszyński, J., *et al*., cond-mat/0509189 (2005).