Intrinsic phase separation in magnetically doped 2DES

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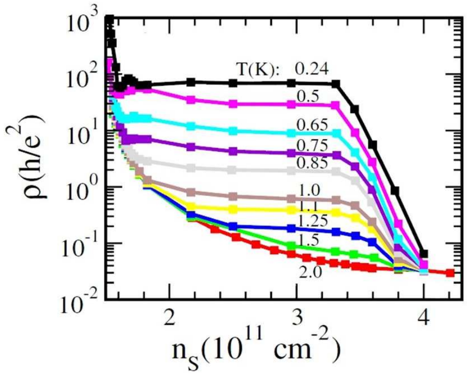
There is growing evidence that phase separation is responsible for several striking effects, such as colossal magnetoresistance (CMR) around metal-insulator transition (MIT) in bulk manganites and similar complex magnetic materials. At the same time, the apparent metal-insulator transition (MIT) in two-dimensional electron systems (2DES) remains one of the most challenging problems of condensed matter physics. Several recent theoretical studies suggest the existence of an intermediate region near the 2D MIT, where the competition between distinct ground states results in their phase separation. Thus particularly intriguing are properties of magnetically doped 2DES in semiconductor heterostructures with their relatively simple electronic and crystal structure. They make it possible to study both magnetism and reduced dimensionality effects near the MIT in one sample with electron density tuned externally.

We report [1] on magnetotransport in 2D modulation doped (Cd,Mn)Te:I diluted magnetic quantum well (QW). This MBE grown sample contains a 10 nm wide $Cd_{0.985}Mn_{0.015}Te$ in which the 2DES is confined by $Cd_{0.8}Mg_{0.2}Te$ barriers. A 10 nm thick layer of the front barrier residing 20 nm away from the QW is doped with iodine donors up to $n_I \approx 10^{18}$ cm^{-3}. A front metal gate controls electron density from 1.4 to 4.2 $\times 10^{11}$ cm^{-2}.

We observe anomalous transport around metal-insulator boundary. Resistivity shows very strong temperature and magnetic field dependence, as in other CMR materials. However, resistivity depends unusually weak on electron density, as figure on the right shows.



Resistivity of (Cd,Mn)Te heterostructure as a function of electron density at different temperatures shows strikingly weak density dependence.

We suggest, that observed phenomena reflect nanoscale phase separation of the electron fluid and the emergence of ferromagnetic clusters in an intermediate density regime. Our results suggest that the clustering around the MIT is ubiquitous not only in CMR manganites and underdoped cuprates but also in disordered semiconductors. This picture is in striking agreement with recent dynamical mean-field theory calculations. [2]

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References

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