Thermodynamic spin magnetization in silicon inversion layers

Authors:O.Prus, Y.Yaish, M.Reznikov, U.Sivan and V.M.Pudalov

Recommended and a Commentary By: Teun Klapwijk, University of Delft

The two-dimensional electron gas (2DEG), realized in semiconductor heterostructures, exhibits an extremely rich phenomenology at low densities where electron correlations play a very important role. Theoretically, this regime is outside perturbative approaches and many crucial aspects of this interesting physics still lack a satisfactory explanation. Apart from correlations disorder plays a prominent role as well. Initially, it was thought that the subject was adequately dealt with in the scaling theory of localization by Abrahams *et al.* As is always tempting, this theory was quickly confirmed by experiments, also in Si-MOSFETs, but at the expense of ignoring some deviations. Experiments carried out by Kravchenko *et al* highlighted these deviations and argued convincingly, at least for some researchers, that it indicated the experimental observation of a metal-insulator transition in 2 dimensions, in clear contrast with the predictions of Abrahams *et al*, which claim that in 2 dimensions no true metallic state can exist. Since the orginal observations of Kravchenko *et al* the experimental body of knowledge has expanded considerably. Most of it is based on Si-MOSFETs, in which the electron correlations are, at reasonable densities, particularly strong (due to the effective mass and the dielectric constant). Some more recent work uses GaAs/AlGaAs heterostructures (Tsui et al, Störmer et al, and others) in which disorder is less and sufficiently low carrier densities can be reached. In developing theoretical explanations it is evident that the spins of the electrons play a prominent role. For high densities the usual paramagnetic limit of the non-interacting 2D gas is expected. Upon decreasing the density one expects an increase in spin susceptibility. It has been predicted that one subsequently will observe a quantum-phase transition to a ferromagnetic liquid phase followed by an antiferromagnetic Wigner crystal. For even lower densities one might get a ferromagnetic Wigner crystal. (Cf. for example Attacalite et al, PRL 88, 256601 (2002) for the case without disorder). All experiments to date are based on transport measurement (including magneto-transport). A recent summary of the experiments is given by Kravchenko and Sarachik cond-mat/0309140.

Given the crucial importance of the spin correlations the recently published paper by Prus *et al*, which introduces a new method to measure the thermodynamic spin magnetization is a very interesting step forward. The method consists of applying a small modulation on a constant parallel magnetic field and detecting the small current (10-15 A) that flows in response to the change in chemical potential. The observed signal consists of a diamagnetic contribution and the aimed for spin contribution. They outline a route to isolate the spin-magnetization, which then would allow firm experimental statements. Further evaluation is clearly needed. The most important result is however the demonstration of a method to measure these small values of the magnetization in a very dilute 2 DEG. The method is very likely to stimulate a badly needed new experimental approach to the problem.