Comment on: Weak Anisotropy and Disorder Dependence of the In-Plane Magnetoresistance in High-Mobility (100) Si Inversion Layers

In a recent paper Pudalov et al. [1] measured the in-plane magnetoresistance (MR) of high-mobility (100) Si inversion layers and demonstrated that the magnetic field for MR saturation depends strongly on sample quality. The saturation field found in experiment "varies for different samples by a factor of 2 at a given carrier density." They concluded that "the saturation of the MR cannot be identified with the complete spin polarization of free carriers". We, however, describe in this comment the saturation of the MR in the data of Pudalov et al. [1] by complete spin polarization of non-localized carriers and the existence of local moments.

For the interpretation of measurements of the MR for strong disorder one must take into account the existence of localized states in the metallic phase. In Ref. [1] it was argued that the carrier density \( n \) measured by Shubnikov-de Haas oscillations \( n_{SdH} \) and the one measured by the Hall voltage \( n_H \) are nearly identical. But this does not mean that localized states are not present in metallic samples. The conclusion one can draw from the relation \( n_{SdH} \approx n_H \) is that one cannot see localized states in the Hall resistivity: apparently the Hall resistivity is non-critical at the metal-insulator transition, which occurs at \( n \approx n_c \) or at the Fermi energy \( E_F = E_c \).

In the absence of a magnetic field extended states in a metal have a spin-degeneracy of two for spin-up and spin-down. Due to Coulomb interaction, localized states can be singly occupied or doubly occupied. At energies close to \( E_c \) the density of singly occupied localized states \( n_{so} \) will be small, far from \( E_c \) all localized states are singly occupied. In a two-fluid model for localized and extended electrons, as already used for the strongly disordered three-dimensional electron gas in Phosphorus-doped Silicon [3], we assume Curie paramagnetism for the localized singly occupied states of density \( n_{so} \) and Pauli paramagnetism for the extended states of density \( n - n_{so} \). The singly occupied localized states are treated as classical spins and are spin-polarized if the temperature \( T \) is sufficiently small: \( g^* \mu_B > k_B T \). The other electrons become completely spin-polarized for \( B > B_c \) with \( g^* \mu_B B \approx (n-n_{so})/\rho_F \), where \( \rho_F \) is the density of states of the spin-polarized free electron gas given in terms of the effective mass \( m^* \). We note that \( B_c \leq B_{so} = 2E_F/(g^* \mu) \) and due to the existence of localized states one finds \( B_c = 0 \) for \( n = n_{so} \). By taking into account the modification of screening effects and the density of states due to spin polarization the MR of the two-dimensional electron gas for weak disorder was calculated in Ref. [1]. The theory doesn’t contain localized states and the saturation field for the MR is \( B_{so} \). For strong disorder the saturation field is \( B_c \), as calculated above, and the resistance ratio \( R(B > B_c)/R(B = 0) \) is strongly increased compared to weak disorder.

In the experiments of Ref. [1] the values for \( B_c = 0 \) are extrapolated from finite \( B \) values. We find that the slope \( dB_c/dn = dB_{so}/dn \) does not depend on \( n_{so} \), in agreement with experimental results [1], where \( dB_c/dn = 5.7T/10^{11} \text{cm}^{-2} \) is found. According to Ref. [2] one expects that \( n_{so} \approx n_c \) for Silicon MOSFET’s with low peak mobility and \( n_{so} \ll n_c \) for more ideal samples, in agreement with experimental results [1]. For one sample with very high mobility Pudalov et al. [1] also found a larger saturation field than predicted for an ideal electron gas without localized states. We don’t believe that this is a real effect; the small shift might be related to the definition of the saturation field as used to analyze the experimental data or related to the relatively high temperature of the experiment.

In conclusion we argue that the MR-experiments of Pudalov et al. [1] give indications for local moment formation in the two-dimensional electron gas in the metallic phase.

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