Conductivity of a 2DEG in Si/SiGe heterostructure near metal-insulator transition: the role of the short and long range scattering potential

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According to the well established one-parameter scaling theory of conductivity [1] any two dimensional electron system can exist only in insulating state and no metal-insulator transition (MIT) should be possible. Thus, it came quite as a surprise when an apparent metallic state and metal-insulator transition were observed first in Si MOSFETs [2] and, later, in several other 2D systems, such as p-SiGe, n- and p- AlGaAs and n-AlAs [3]. The fact that the MITs have always been seen in systems with a large r_s parameter (the ratio of the interaction energy to the kinetic energy) is an indication that electron-electron interaction plays an important role in the MIT. While it still remains unclear whether the observed MIT is a genuine transition or if a zero temperature metallic state can really exist at certain levels of interaction and disorder, its discovery has stimulated an extensive experimental and theoretical work in the area. In particular, a considerable progress has been made [4] in our understanding of the temperature dependent corrections to the conductivity due to electron-electron interaction not only in the diffusive regime $T\tau \le 1$, as previously, but also in the ballistic and the intermediate regimes $T\tau \ge 1$, typical in systems showing a MIT. Theoretical results [4] have been successfully used to describe the conductance temperature dependence and magneto-resistance in parallel magnetic field in several 2D systems on the metallic side of the apparent MIT. It should, however, be noted that this new theory relies on an approximation where the scattering potential is treated as point-like scatterers. This is definitely not true for high mobility heterostructures where the scattering potential is predominantly long range. The success of the theory [4] in describing the experimental data is therefore an indication that the short-range component of the disorder determines probably the interaction corrections to conductivity in zero field and $T\tau \ge 1$. The situation, however, changes if we consider the interaction contribution to the magnetoresistance in a transverse field, for which theory [4] makes no clear prediction. The point has been recently addressed in [5] where the interaction contribution to the magnetoresistance in a classically strong transverse field has been calculated for a smooth disorder and for arbitrary $T\tau$. The results have been promptly tested in an experiment on the magnetoresistance of a 2DEG in GaAs/AlGaAs heterostructure and a good agreement has been found [6]. We feel, however, that a proper test should include the analysis of both the magnetoresistance and the conductance temperature dependence in zero magnetic field.

In the present work we attempt to investigate these questions experimentally in a 2DEG SiGe heterostructure. Despite the abundance of information on the MIT in different types of heterostructures, so far there has been no observation on MIT in a 2DEG in SiGe heterostructure. This may in part be explained by the difficulty in fabricating a gated n-SiGe structure with a stable and controllable behavior. In the present work we report the first observation of the MIT in a SiGe

heterostructures (to our knowledge) with a 2D electron gas (see figure 1) and perform the analysis of the magnetoresistance data and the conductance temperature dependence on the metallic side of the MIT transition using the theories of Zala et al [4] and of Gornyi and Mirlin [5].

While the theory of Zala et al [4] gives a satisfactory description of our experimental results, we find only a poor agreement between our data and the magnetoresistance behavior predicted in the theory of Gornyi and Mirlin [5]. We attribute this fact to the possibility that in the intermediate and ballistic regimes and in the case of a mixed mechanism of scattering, where both the long-range potential and point-like centers contribute to electron scattering, the magnetoresistance cannot be properly described by a model that ignores one of the components of disorder.

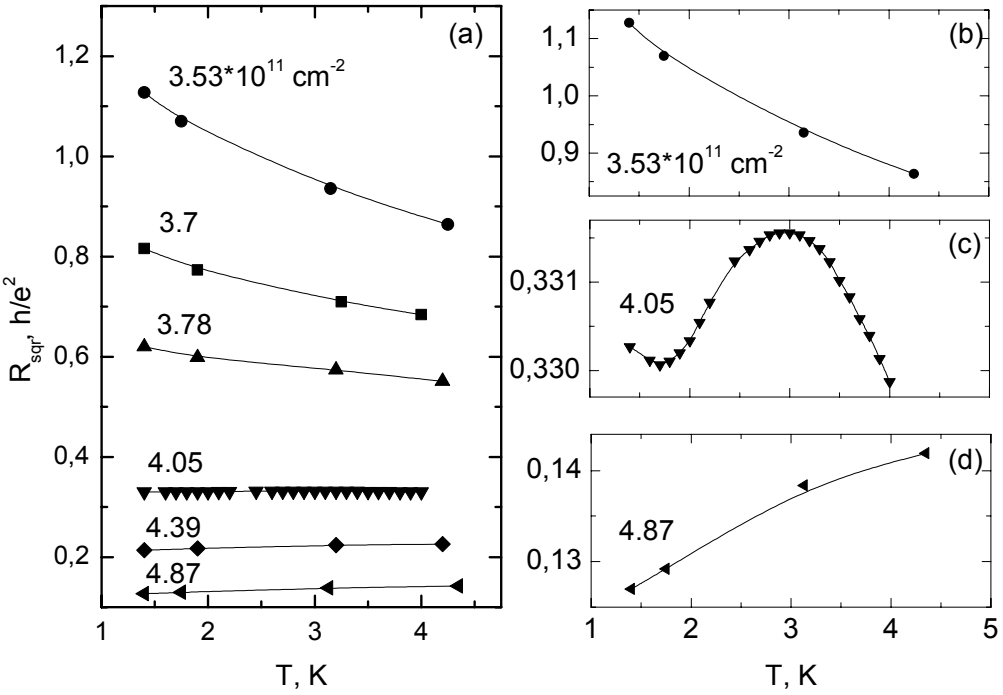

Figure 1: Temperature dependence of the resistivity of ours sample for different densities (a) varying the density in the sample drives it from an insulating state (b) to a metallic-like state (d) through a separatrix (c) (ie its resistivity is independent of T)

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