Tunnelling and noise in GaAs and graphene nanostructures

Submitted by Alexander S. Mayorov to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Physics
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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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September, 2008

Abstract

Experimental studies presented in this thesis have shown the first realisation of resonant tunnelling transport through two impurities in a vertical double-barrier tunnelling diode; have proved the chiral nature of charge carriers in graphene by studying ballistic transport through graphene p-n junctions; have demonstrated significant differences of $1/f$ noise in graphene compared with conventional two-dimensional systems.

Magnetic field parallel to the current has been used to investigate resonant tunnelling through a double impurity in a vertical double-barrier resonant tunnelling diode, by measuring the current-voltage and differential conductance-voltage characteristics of the structure. It is shown that such experiments allow one to obtain the energy levels, the effective electron mass and spatial positions of the impurities.

The chiral nature of the carriers in graphene has been demonstrated by comparing measurements of the conductance of a graphene p-n-p structure with the predictions of diffusive models. This allowed us to find, unambiguously, the contribution of ballistic resistance of graphene p-n junctions to the total resistance of the p-n-p structure. In order to do this, the band profile of the p-n-p structure has been calculated using the realistic density of states in graphene. It has been shown that the developed models of diffusive transport can be applied to explain the main features of the magnetoresistance of p-n-p structures.

It was shown that $1/f$ noise in graphene has much more complicated concentration and temperature dependences near the Dirac point than in usual metallic systems, possibly due to the existence of the electron-hole puddles in the electroneutrality region. In the regions of high carrier concentration where no inhomogeneity is expected, the noise has an inverse square root dependence on the concentration, which is also in contradiction with the Hooge relation.

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Conference presentations

- International Conference on Superlattices, Nanostructures and Nanodevices (ICSNN 2006) Oral contribution: Resonant tunnelling via two impurity levels in a vertical tunnelling nanostructure

- International Conference on Superlattices, Nanostructures and Nanodevices (ICSNN 2006) Poster contribution: Resistance fluctuations near the metal-to-insulator transition in the DEG in a Si-MOSFET