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Numerical study of the effect of disorder and magnetic field on the quantum transport of two-dimensional nanostructures modeled by tight-binding approximation

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Abstract
In recent years, semiconductor nanostructures have become the model systems of choice for investigation of electrical conduction on short length scales. Quantum transport is studied in a two dimensional electron gas because of the combination of a large Fermi wavelength and large mean free path. In the present work, a numerical method is implemented in order to contribute to the understanding of quantum transport in narrow channels in different conditions of disorder and magnetic fields. We have used an approach that has proved to be very useful in describing mesoscopic transport. We have assumed zero temperature and phase coherent transport. By using the trick that a conductor connected to infinite leads can be replaced by a finite conductor with the effect of the leads incorporated through a 'self-energy' function, a convenient method was provided for evaluating the Green's function of the whole device numerically. Then, Fisher-Lee relations was used for calculating the transmission coefficients through coherent mesoscopic conductors. Our calculations were done in a model system with Hard-wall boundary conditions in the transverse direction, and the Anderson model of disorder was used in disordered samples. We have presented the results of quantum transport for different strengths of disorder and introduced magnetic fields. Our results confirmed the Landauer formalism for calculation of electronic transport. We observed that weak localization effect can be removed by application of a weak perpendicular magnetic field. Finally, we numerically showed the transition to the integral quantum Hall effect regime through the suppression of backscattering on a disordered model system by calculating the two- terminal conductance of a quasi-one-dimensional quantum conductor as a strong magnetic field is applied. Our results showed that this regime is entered when there is a negligible overlap between electron edge states localized at opposite sides of the sample.

Keywords: quantum transport, Green’s function, tight-binding model, disorder, magnetotransport

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