11th International Workshop on Computational Electronics
TU Wien, 25-27 May 2006

Quantum Transport Through Nano-Wires with One-Sided Surface Roughness

J. Feist,* A. Bäcker,† R. Ketzmerick,† S. Rotter,* B. Huckestein,‡ and J. Burgdörfer*
*Institute for Theoretical Physics, TU-Vienna, A-1040 Vienna, Austria
†Institute for Theoretical Physics, TU-Dresden, D-01062 Dresden, Germany
‡Institute for Theoretical Physics III, Ruhr-University Bochum, D-44780 Bochum, Germany
e-mail: feist@concord.itp.tuwien.ac.at

Disordered media and their transport properties are a central issue in solid state physics, as they are the root of numerous applications in electronics and optics [1], [2]. New experimental possibilities to investigate this field in the 'mesoscopic' regime have led to an increased interest in the classical-to-quantum crossover regime of transport where a whole new class of interesting phenomena has meanwhile been discussed [3].

In most investigations a static disorder is assumed to be present in the *bulk* of a material. The theoretical analysis of bulk disordered systems typically employs random matrix theory (RMT) [4], which has proven to be a very successful description. The formation of ballistic, diffusive, and localized transport regimes, as well as any dependence on the density of scatterers and the wire length can be studied. Reduction of system sizes leads, however, to an increased surface-to-volume ratio in nano-devices, such that *surface roughness* can be the dominant source of disorder scattering. The application of RMT to systems with surface disorder is, however, not straightforward, as different transport regimes can coexist with each other, depending on the angle (mode number) of the injected particle (wave) [5].

Using the modular recursive Green's function method [6], we numerically study electronic quantum transport through extremely long nano-wires in the presence of a one-sided surface roughness and a magnetic field. We demonstrate how these two effects conspire to keep the conductance at a high value throughout vast length scales of the wire. In the quantum-to-classical crossover of high Fermi energies ($E_F \to \infty$) this effect leads to exponentially diverging localization lengths.

Complementing previous investigations [7] we argue that the giant localization length found numerically falls clearly outside the scope of RMT predictions, but can be well understood in terms of the underlying mixed regular-chaotic classical motion which electrons are subject to in such a system. As we demonstrate by an analytical calculation, this effect can quantitatively be accounted for by dynamical tunneling between the transporting regular and chaotic parts of the underlying mixed classical phase space [9], [10]. We thereby establish a direct link between experimentally accessible transport quantities like the conductance and "dynamical tunneling".

Acknowledgments

Support by the Austrian Science Foundation (Grants No. FWF-SFB016 and No. FWF-P17359) is gratefully acknowledged.

References

[1] P. Sheng, *Introduction to Wave Scattering, Localization and Mesoscopic Phenomena* (Academic, New York, 1995).
[2] P. A. Lee and T. V. Ramakrishnan, Rev. Mod. Phys. **57**, 287 (1985).
[3] D. K. Ferry and S. M. Goodnick, *Transport in Nanostructures* (Cambridge University Press, Cambridge, 1997).
[4] C. Beenakker, Rev. Mod. Phys. **69**, 731 (1997).
[5] J. A. Sanchez-Gil, V. Freilikher, I. Yurkevich, and A. A. Maradudin, Phys. Rev. Lett. **80**, 948 (1998).
[6] S. Rotter, B. Weingartner, N. Rohringer, and J. Burgdörfer, Phys. Rev. B **68**, 165302 (2003).
[7] A. García-Martín, M. Governale, and P. Wölfle, Phys. Rev. B **66**, 233307 (2002).
[8] H. Schanz, M. F. Otto, R. Ketzmerick, and T. Dittrich, Phys. Rev. Lett. **87**, 070601 (2001).
[9] L. Hufnagel, R. Ketzmerick, M.-F. Otto, and H. Schanz, Phys. Rev. Lett. **89**, 154101 (2002).
[10] A. Bäcker, R. Ketzmerick, and A. G. Monastra, Phys. Rev. Lett. **94**, 054102 (2005).

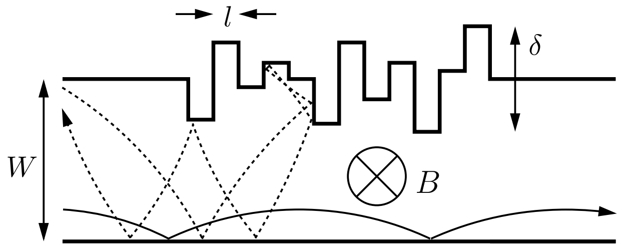

Fig. 1. Wire with one-sided surface disorder (top wall) in a magnetic field B. The strength of the disorder is governed by δ/W. Two typical (classical) electron trajectories are shown: A trajectory injected at a low angle (solid line) skips along the lower boundary and, avoiding contact with the disorder, gets transmitted. Injection at a steeper angle (dashed line) leads to disorder scattering and reflection.