CONDUCTANCE OF A ONE-DIMENSIONAL WIRE WITH STRONG RANDOM IMPURITIES

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The problem of electron transport in one-dimensional (1D) conductors, such as nanotubes, nanowires, and nanofibers, continues to draw much attention. It has become a source of interesting and challenging questions for basic research and, at the same time, a vital area of emerging nanotechnology. From both standpoints, it is very important to understand how conducting properties of 1D systems are affected by unavoidable impurities and defects. Here we address this question for the case of 1D metals - systems whose electron energy spectrum is gapless in the absence of disorder. The disorder is expected to diminish their conductance. Interestingly, for many of such 1D "metals" the suppression is very strong and a markedly insulating behaviour is observed: the conductance drops by orders of magnitude as either temperature T or the bias voltage V is reduced. It has been a question of both fundamental and practical interest to determine what barriers to transport are responsible for such phenomena, what conduction mechanisms enable electrons to overcome those barriers at finite V and T, and whether one can develop a quantitative theory to describe them.

In order to shed light on these issues we analyze a model in which a 1D wire contains a finite concentration of randomly positioned strong impurities. The impurities effectively divide the wire into a chain of weakly-coupled quantum dots. We show that the conductance of such a system is dominated by the Coulomb blockade and exhibits a rich dependence on voltage V and temperature T due to the interplay of sequential and co-tunnelling. The conductance of a long wire is always limited by the "breaks": randomly occurring clusters of quantum dots with a special length distribution pattern that inhibits the transport no matter how the activation and tunnelling are combined. We find a broad range of parameters where the conductance exhibits an approximately algebraic dependence on T and V with *unequal* exponents, which resembles the behaviour experimentally observed in long nanowires. At lower temperatures the conductance crosses over to stretched exponential laws typical of the variable-range hopping.

References:

[1] M. M. Fogler, S. V. Malinin, T. Nattermann, cond-mat/0602008.
[2] M. M. Fogler and R. S. Kelley, Phys. Rev. Lett. **95** (2005) 166604.

Figure 1: Illustration of the theoretical model. Dots symbolize strong random impurities.