ELECTRON TRANSPORT IN SEMICONDUCTOR NANOWIRES

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The recent development of catalytic methods for the synthesis of wire-shaped semiconductor nanostructures has generated widespread interest in these novel nanomaterials, especially in view of the large variety of their potential applications. Semiconductor nanowires have indeed many attractive properties. An obvious advantage lies in their inherently small diameter (down to a few nm) leading to transversal quantum confinement. In spite of their small diameter, however, semiconductor nanowires can be tens of microns long. Such a conveniently large aspect ratio yields ample freedom for the integration of multiple structures and functionalities in one single nanowire. Other unique features are the versatility in the choice of constituent materials (Si, Ge, and basically any semiconductor compound) and the possibility to form various types of one-dimensional heterostructures via the consecutive growth of different semiconductors, even in the presence of a large mismatch in the respective lattice parameters. Throughout the recent years, a substantial amount of work has been carried out to improve control over the growth of semiconductor nanowires, to understand their structural and electronic properties, and to develop processes for device fabrication. In spite of this large effort and following advances the important amount of knowledge gained, many even rather basic questions are still waiting for a conclusive answer.

In this talk I will present an up-to-date view on electron transport in semiconductor nanowires with an emphasis on the low-temperature regime. Most of the discussion will focus on the following key aspects: 1) Basic electrical properties; 2) Electrical contacting and gating; 3) Low-temperature electron transport: Coulomb blockade effect, size quantization, phase-coherent transport, and superconducting proximity effect. Among the most remarkable results, I shall mention the experimental realization of Josephson junctions formed by individual semiconductor nanowires bridging two superconducting electrodes. Two distinct cases will be discussed: i) The supercurrent is carried by coherent transport of correlated pairs of electrons across the nanowire. In this case the critical current can be tuned by a gate voltage acting on the carrier density in the nanowire; ii) An interacting quantum is defined in the nanowire by means of local gate electrodes. In this case, we have demonstrated that the direction of the supercurrent can be inverted simply by adding (or removing) a single electron to the quantum dot.

References:

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Figures:

Fig. 1. Scanning electron micrograph of a SQUID device fabricated from two Josephson junctions based on InAs semiconducting nanowires. The bottom-right nanowire has two gates ~100nm apart from each other. These two gates are used to define a single quantum dot in the central portion of the nanowire. The corresponding gate voltages control both the electronic state of the dot as well as the tunnel couplings with the remaining portions of the nanowire.