MAR06-2005-003205

Abstract for an Invited Paper
for the MAR06 Meeting of
the American Physical Society

Quantum Transport of Semiconductor Nanowires Coupled to Superconductors[1]

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We report the electronic transport properties of the first superconducting transistors based on semiconductor nanowires (ref. Y.-J. Doh et al., Science 309, 272 (2005)). These nanoscale superconductor-semiconductor devices enable the fabrication of new nanoscale superconducting electronic circuits and at the same time provide new opportunities for the study of fundamental quantum transport phenomena. Indium arsenide (InAs) semiconductor nanowires individually contacted by two aluminum-based superconductor electrodes yield surprisingly low contact resistances. Below 1 kelvin, the high transparency of the contact gives rise to proximity-induced supercondcutivity and a resistance-free current (supercurrent) can flow through the nanowire from one superconducting contact to another. The supercurrent can be switched on and off by a gate voltage acting on the electron density in the nanowire. A variation in gate voltage induces universal fluctuations in the normal-state conductance, which are clearly correlated to critical current fluctuations. The alternating-current Josephson effect gives rise to Shapiro steps in the voltage- current characteristic under microwave irradiation. For indium phosphide (InP) nanowire devices, however, Coulomb blockade effect dominates the electrical transport, which can be modeled as a quantum dot weakly coupled to superconductors. As a result of BCS (Bardeen-Cooper-Schriffer) singularity of density of states, a negative differential conductance is observed in the superconducting state. By applying high magnetic field, Zeeman splitting is observed and g-factor of InP nanowire is estimated to be 1.5.

[1]This work is a result of collaboration between Kavli Institute of Nanoscience Delft and Philips Research Laboratories in the Netherlands and Laboratorio Nazionale TASC-INFM in Italy.