Electron transport experiments in semiconductor quantum dots

Wilfred van der Wiel

PRESTO-JST; Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; Department of NanoScience, Delft University of Technology, PO Box 5046, 2600 GA Delft, The Netherlands.

wilfred@tomoko.phys.s.u-tokyo.ac.jp

Quantum dots are man-made sub-micron structures in a solid, in which the number of free electrons can be varied from several thousands down to zero. An extra electron can only be added to the dot, if enough energy is provided to overcome the Coulomb repulsion between the electrons. Next to this – purely classical – effect, the confinement in all three directions leads to quantum effects that strongly influence electronic transport at low temperature. In particular, it leads to the formation of a discrete (0D) energy spectrum, resembling that of an atom. This and other similarities have therefore led to the name 'artificial atoms' for quantum dots. In this talk I review electron transport measurements in semiconductor quantum dots. An introduction is given to the fabrication and low-temperature measurement techniques. Essential concepts such as Coulomb oscillations, Coulomb diamonds, Fock-Darwin levels, excitation spectroscopy are discussed and illustrated by experimental results. Analogies and differences between quantum dots and real atoms are pointed out. Several experiments on the Kondo effect in quantum dots are discussed. The Kondo effect is a widely studied phenomenon in condensed matter physics arising from the coherent interaction between a localized impurity spin and surrounding electrons. Quantum dots offer unprecedented opportunities for studying and tuning the Kondo effect. By coupling two quantum dots in series, a system is obtained with fundamentally different behavior and possibilities in comparison to a single dot, as is illustrated by a series of double dot experiments. Finally, I will discuss future possibilities for quantum dots, in particular their relevance for realizing solid state quantum bits.