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Josephson junctions with tuneable single wall carbon nanotubes as barriers[1]

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Weak superconductivity induced in a barrier between two stronger superconductors constitutes the essence of a Josephson junction. The original prediction of Josephson assumed a thin potential barrier much higher than the energy gap of the superconductors on either side. The Josephson junction does, however, not require a potential barrier, a metallic barrier may be a sufficient to reduce the penetration of Cooper pairs. The barrier can also be of geometric origin as for superconducting microbridges smaller than the coherence length. In the last two situations the Cooper pair Josephson transmission is most conveniently pictured as a multiple Andreev reflection process at the barrier/superconductor interfaces. We have studied Josephson junctions, where the barrier region is a single wall carbon nanotube (CNT) with a long mean free path. The junction between the 1-dimensional CNT and the superconductor often constitutes an additional thin potential barrier, I. The Josephson junction has therefore the structure S/I/CNT/I/S. The CNT has a capacitance, C, to the external electrodes, which typically yields a Coulomb blockade energy larger than the energy gap of the superconductors and the finite length of the CNT (smaller than it's mean free path) gives rise to Fabry-Perot eigenenergies. The Coulomb blockade is only strongly developed if the resistance R of the barrier, I, is large ($R>h/e^2$). If $R\sim h/4e^2$ we have an almost adiabatic transmission, where the Josephson critical current may approach the quantized value $2\Delta e/\hbar$. In the region where $R\sim h/2e^2$ Josephson tunnelling can be observed simultaneously with charge quantization and Kondo resonance tunneling. In this regime we study gate imposed even-odd electron number effect leading to characteristic variation of the supercurrent exhibiting an alternation between 0- and π $-$Josephson junctions.

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