Carbon nanotube electronic quantum devices

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Single wall carbon nanotubes (SWCNT) are ideal 1-dimensional electronic systems with atomic precise structure. Dependent on the molecular chirality the nanotubes can be metals, semiconductors or narrow gap semiconductors. At liquid helium temperatures the electronic mean free path can be many micrometers and contacts or artificial boundaries within these length scales give rise to electronic quantum effects. Electronic contacts to SWCNTs vary from ideal single contact resistances of $h/8e^2$ over intermediate resistances of $h/2e^2$ to very high resistances. If the distance between a source and a drain contact is about a micrometer we observe in these 3 regimes and at low temperatures (1) adiabatic transport through the contacts, (2) Co-tunnelling (Kondo) behaviour, and sharp Coulomb blockades. We have studied the 4-electron shell effects and the effect of renormalization level shifts in the Kondo regime. The strong effect of a back gate makes studies of SWCNTs with superconducting and magnetic contacts particularly interesting. With superconducting contacts we tune the number of electrons to be even and odd and thereby shifts between 0 and π phase difference in the Josephson current-phase relation. With magnetic contacts we are able to control the sign of the exchange field in the quantum dot with the gate voltage. With narrow gates we have been able to study the interactions of several SWCNT quantum dots. The so-called honeycomb 3-d plot, where conductance is plotted versus the two gate voltages is studied and fitted to calculations. The combination of several quantum dots is of importance on the route towards the first simple qubit circuits.