

Quantum properties of atomic-sized conductors

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When a metallic contact is gradually broken, in the final stages it consists of only a few atoms. Such atomic scale contacts can now be routinely produced and their mechanical and electrical properties can be studied using a scanning tunnelling microscope or a mechanically controllable break-junction technique. The number of conductance modes through a single atom contact is determined by the number of valence orbitals of the metal atom. This can be demonstrated by analysing the subgap structure for superconducting atomic contacts, from shot noise, and from conductance fluctuations as a function of bias voltage. We show that there is a fundamental distinction between monovalent metals (gold) where the conductance channels tend to open one by one, and multivalent metals (aluminium, niobium) where this is not the case.

Guided by this knowledge, in experiments on gold we have discovered that during the contact breaking process the atoms in the contact form stable chains of single atoms being up to 7 atoms long. Such chains constitute the ultimate one-dimensional metallic nanowires. The mechanism behind the formation of chains is the same as that giving rise to the surface reconstructions on clean gold surfaces. This has led to the discovery of similar chain formation for Pt and Ir.

For alkali metals, which are the best approximation to free-electron metals, one observes an interaction between the electronic quantum states and the configurations that the wires assume. It is shown that the most stable "magic" wire diameters have a structure that is similar to that of the magic-number metal clusters.