Charge Transport in Nanocrystal Wires

Paul Beecher[a], Gianluca de Marzi[a], Elena Shevchenko[b], Aidan Quinn[a], Horst Weller[b], Gareth Redmond[a].

[a]Nanotechnology Group, NMRC, Ireland.

[b]Institute of Physical Chemistry, University of Hamburg, Germany.

We report on the electrical characterisation of nanocrystal-based wires assembled between micron-scale electrodes and contacted using a focused ion beam. The wires (typically 20 μm long and 1-2 μm in diameter) are formed by destabilising a solution of monodisperse 6.8 nm diameter $CoPt_3$ nanocrystals in an external magnetic field. TEM analysis of the wires reveal that the nanocrystal cores are still distinct with a mean inter-nanocrystal separation, s = 1.7-1.8 nm, due to the protecting ligand monolayers surrounding the nanocrystal cores. The wires show short range ordering, characteristic of a glassy solid.

Variable temperature dc electrical characterisation data of as-deposited wires assembled on micron-scale electrodes support this picture. The room temperature *I-V* characteristics exhibits weak non-linearity with low bias resistances, $R_{RT} \geq 1$ GΩ (equivalent resistivities $\rho_{RT} \geq 10^3$ Ωm), which increase monotonically with decreasing temperature, T. The R vs T data follow an activation law with activation energy E_c = 11 meV, as expected for transport through an assembly of monodisperse, electrically isolated nanocrystals. Low temperature (4 K) *I-V* characteristics show evidence of Coulomb Blockade, *i.e.*, complete current suppression is observed below a threshold voltage, V_T. The current above V_T follows a scaling law, consistent with charge transport through a 2-dimensional network.

A focused ion beam (FIB) has been employed to direct-write metal junction contacts between the wires and the underlying microelectrodes in order to reduce the contact resistance. FIB-contacted wires show room temperature resistances over four orders of magnitude lower than as-deposited wires. The measured activation energy, E_c = 14 meV, is comparable to values measured for as-deposited devices, indicating that the intrinsic transport mechanism within the wires is still activated tunnelling between isolated nanocrystals. Low temperature (4 K) *I-V* characteristics again show evidence of Coulomb Blockade, however the extracted scaling exponents indicate that the dimensionality of the current-carrying network is now >2D. While FIB-induced Ga^+ doping of the wire near the junction contacts cannot be ruled out, it is more likely that the measured transport characteristics are due to an increase in effective contact area between the wires and the underlying electrodes. Therefore FIB presents a rapid, flexible method for probing charge transport in these novel 1D nanostructures.