Electron coupling states in quantum dots in nanocrystalline silicon

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We have investigated coherent electron coupling effects at 4.2 K in silicon quantum dots, formed by the nano-scale grains within a point-contact transistor defined in a ~40 nm thick nanocrystalline silicon film. The point contacts are ~30 nm × 30 nm × 40 nm in size, with two side-gates (Fig. 1). The grain size varies from sub-10 nm to 25 nm. Low temperature (650 °C – 750 °C) oxidation is used to selectively oxidise the grain boundary tunnel barriers. The process is optimised to obtain strong tunnel coupling between the grains. A plot of the device conductance at 4.2 K as a function of the two side gate voltages (Fig. 2) shows single-electron conductance peaks which partially form an electron stability diagram for two charging grains [1]. The peak lines in this plot (e.g. white dotted lines, Fig. 2) show strong splitting (e.g. region ‘r’, Fig. 2) caused by electrostatic interactions when the energy levels in the two grains are in resonance. Fig. 3 shows theoretical fits (solid lines) to selected experimental sweeps (circles) across region ‘r’. The fits consist of a sum of four Lorentzian peaks (dashed lines, A1 and A2, and dotted lines, B1 and B2). These peaks may be associated with resonant tunnelling through bonding-like (A1 and A2) and anti-bonding-like (B1 and B2) levels [2], formed due to the wave function coupling of energy levels on adjacent nanoscale silicon grains in the point contact.

References:

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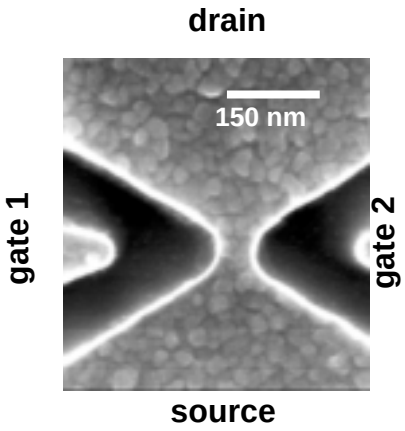

Fig. 1 Scanning electron micrograph of a nanocrystalline silicon point contact transistor.

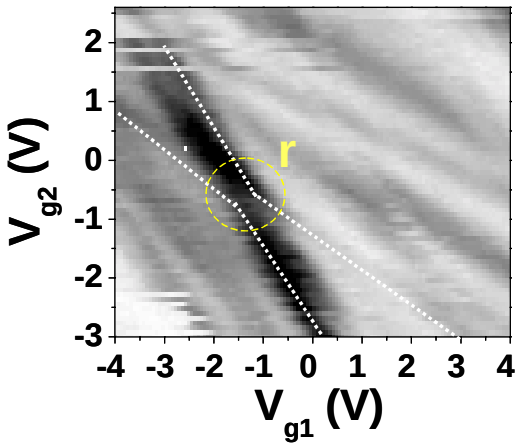

Fig. 2 Grey scale image of the point contact conductance (Max. 1.2×10^{-10} S) as a function of the side gate voltages V_{g1} and V_{g2} at 4.2 K and a source-drain voltage V_{ds} = -2 mV. The oscillation peak lines, shown by the white dotted lines, intersect at region 'r' where the energy levels in two adjacent grains interact strongly.

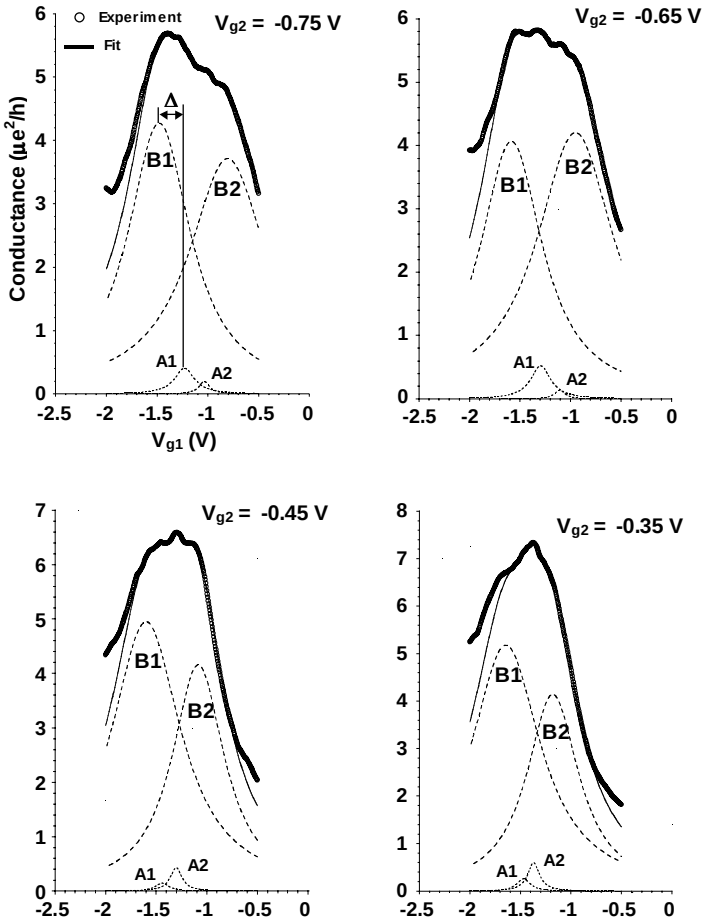

Fig. 3 Selected sweeps (circles) across region 'r', Fig. 2. The fits (Solid lines) are the sum of the Lorentzian peaks A1, A2, B1, and B2.