Controlled coupling of silicon atomic quantum dots at room temperature: A basis for atomic electronics?

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Quantum dots are small entities, typically consisting of just a few thousands atoms, that in some ways act like a single atom. The constituent atoms in a dot coalesce their electronic properties to exhibit fairly simple and potentially very useful properties. It turns out that collectives of dots exhibit joint electronic properties of yet more interest. Unfortunately, though extremely small, the finite size of typical quantum dots puts a limit on how close multiple dots can be placed, and that in turn limits how strong the coupling between dots can be. Because inter-dot coupling is weak, properties of interest are only manifest at very low temperatures (mK). In this work the ultimate small quantum dot is described – we replace an "artificial atom" with a true atom – with great benefit [1–4].

It is demonstrated that the zero-dimensional character of the silicon atom dangling bond (DB) state allows controlled formation and occupation of a new form of quantum dot assemblies - at room temperature. Coulomb repulsion causes DBs separated by less than ~2 nm to experience reduced localized charge. The unoccupied states so created allow a previously unobserved electron tunnel-coupling of DBs, evidenced by a pronounced change in the time-averaged view recorded by scanning tunneling microscopy. It is shown that fabrication geometry determines net electron occupation and tunnel-coupling strength within multi-DB ensembles and moreover that electrostatic separation of degenerate states allows controlled electron occupation within an ensemble.

Some speculation on the viability of a new "atomic electronics" based upon these results will be offered.

As new technologies require new fabrication and analytical tools, a few words about robust, readily repairable, single atom tips will be offered too. This tip may be an ideal scanned probe fabrication tool [5]. The same tip is an exquisite electron source – it exhibits 4x greater coherence than previous point sources. The same tip is evidently the best known He+ and Ne+ ion source also. It will enable a commercial critical dimension He ion microscope and it may be the source in a non-staining ion machining tool.

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