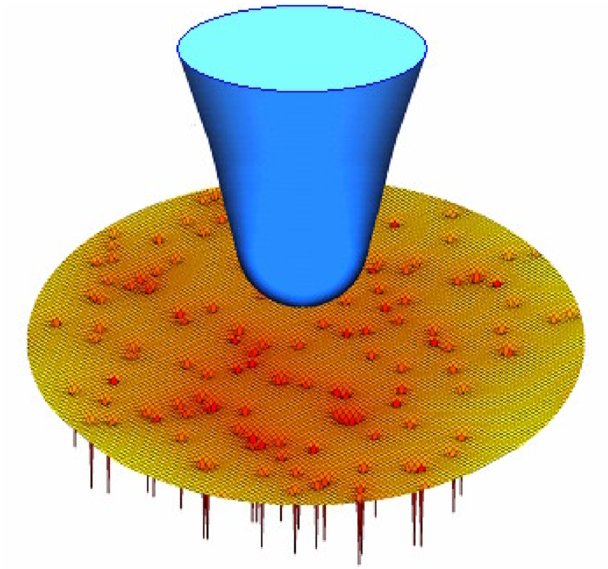

Probing the quantum levels of individual semiconductor dopants

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A transformation is occurring in electronic technologies – with the goal of developing semiconductor devices based on manipulating the charge and spin of individual dopant atoms. As the size of conventional components is reduced to nanometer scales, driven by the desire to maintain Moore's Law, the exponential improvement in the performance is determined by ever fewer numbers of dopants. The ultimate limit is that of a single atom. Elucidating the physics of these minute systems is a difficult technical challenge.

We have developed a capacitance-based scanned-probe method that can detect individual electrons entering dopants. Single-electron peaks have been observed in the capacitance-versus-voltage curves for both donors and acceptors in silicon and gallium-arsenide materials. The precise voltage position of the peaks varies with the location of the probe, reflecting a random distribution of dopants within the donor/acceptor plane. In addition, broader capacitance peaks are observed indicating clusters of electrons entering the system at approximately the same voltages. These broad peaks are consistent with the addition energy spectra of dopant molecules, effectively formed by nearest-neighbor pairs.