Switching Dynamics of a Single Bistable Dopant Atom

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The dynamic behavior of single bistable Si dopants in the (110) surface layer of GaAs was studied with a scanning tunneling microscope (STM). The Si atom acts as either a positively charged substitutional donor or a negatively charged interstitial. Its charge configuration can switch under influence of a local biased STM tip.

The dynamics of this system were investigated combining STM topography data with real-time analog electronics to sample the switching frequency and the occupation of the two charge states. The switching frequency as a function of applied bias voltage reveals that the Si dopant switches its charge state most often around a critical voltage. At this voltage, the occupation of both charge states is one half, showing that under these conditions escape and capture processes of electrons are of equal importance. Furthermore, increasing the tunneling current increases the switching rate and drives the system more into the negative charge state, because more electrons are available for capture. To describe the switching dynamics with a physical model, we took into account the relevant tunneling barriers, tip induced band bending and the tunneling current. The model is in good agreement with the measurements.

The bistability of the Si dopant was further explored to demonstrate memory operations on a single atom, using the STM tip as a static electrical gate for “reading” and “writing” the information. Three different tunneling conditions were applied that enabled (a) writing the negative charge state “0”, (b) writing the positive charge state “1” and (c) reading out the charge state without affecting it. This shows the potential for using properties of single dopants in atom-scale devices.