

The Quantum Interference Effect Transistor

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From the vacuum tube to the modern CMOS transistor, devices which control the flow of electrical current by modulating an electron energy barrier are ubiquitous in electronics. In this paradigm, switching the current on and off requires dissipating a minimum energy of $k_B T$ per cycle, leading to incredible power demands at device densities approaching the atomic limit. A possible alternative is to exploit the wave nature of the electron to control current flow on the nanoscale [1–5]. We propose a solution [6] that exploits perfect destructive interference stemming from molecular symmetry, and controls quantum transport by introducing decoherence or elastic scattering from a third lead.

As daunting as the fundamental problem of the switching mechanism, is the practical problem of nanofabrication. In this respect, single molecules have a distinct advantage over other types of nanostructures, in that large numbers of identical “devices” can be readily synthesized. Single-molecule devices with two leads have been fabricated by a number of techniques [7]. Our transistor requires a third terminal coupled locally to the molecule, capacitively or via tunneling (see Fig. 1). To date, only global gating of single-molecule devices has been achieved [7], although there has been significant progress recently toward a locally coupled third terminal [8].

This talk reports the results of our recent theoretical investigations into the use of interference effects to create molecular transistors, leading to a new device concept, which we call the Quantum Interference Effect Transistor (QuiET). We demonstrate that for all monocyclic aromatic annulenes, particular two-terminal configurations exist in which destructive interference blocks current flow, and that transistor behavior can be achieved by supplying tunable decoherence or scattering at a third site. We also propose a realistic model for introducing scattering in a controllable way, using an alkene chain of arbitrary length (*cf.* Fig. 1).

The QuiET’s operating mechanism, tunable coherent current suppression, occurs over a broad energy range within the gap of each monocyclic aromatic annulene; it is thus a *very robust effect, insensitive to moderate fluctuations of the electrical environment of the molecule.* Although based on an entirely different, quantum mechanical, switch-

ing mechanism, the QuiET nonetheless reproduces the functionality of macroscopic transistors on the scale of a single molecule.

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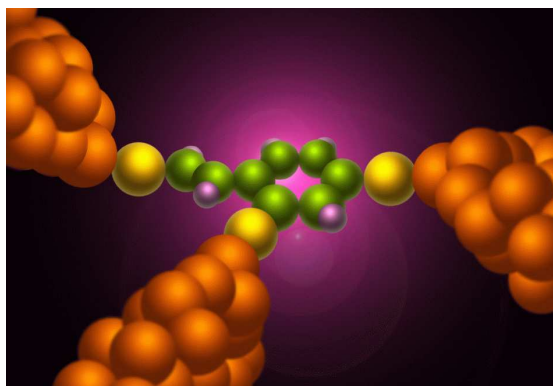


FIG. 1: Artist’s conception of a Quantum Interference Effect Transistor (QuiET). The colored spheres represent individual carbon (green), hydrogen (purple), and sulfur (yellow) atoms, while the three gold structures represent the metallic contacts. The vinyl linkage attached to the phenyl moiety can be replaced with alkene groups of arbitrary length. A voltage applied to the leftmost contact regulates the flow of current between the other two. From Ref. [6].