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Quantum interference effect in anthraquinone solid-state junctions

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Quantum interference results from the wave properties of electrons and is a well-known quantum effect in mesoscopic physics [1]. The ability to control quantum interference at the molecular level could improve knowledge of electron transport through molecular systems and provide novel electronic behavior of molecular junctions. Furthermore, the nanometric size of a molecular system implies large energy scales, making it possible to address quantum effects at room temperature. Consequently, quantum interference in molecules has recently attracted great interest, both theoretically [2] and experimentally [3,4].

Generally, such effect is predicted to occur with cross-conjugated molecules, systems are composed of three unsaturated groups, two of which are conjugated to the third but not conjugated to each other. The anthraquinone (AQ) molecule (whose structure is shown in the inset of Figure 1) is of particular interest, because it is intrinsically cross-conjugated as long as contact between the bottom and top electrodes involves the two peripheral aromatic rings. The expected signature of quantum interference in transport through a molecule is a reduction of the transmission resulting from destructive interference, with a clear antiresonance at the energy where interference occurs.

I will present our work on the investigation of quantum interference on AQ molecular layers embedded in large-area, CMOS compatible solid-state devices [5]. We have found direct experimental evidence of a large quantum interference effect through measurement of the differential conductance. We have demonstrated that quantum interferences are present at room temperature and are enhanced as temperature is lowered for molecular layers thicker than a monolayer (Figure1). Furthermore, the experimental signature of the electron-phonon coupling appears at low temperature as the major source of decoherence, extinguishing interference effects. The visibility and robustness of this quantum effect on large area junction confirms the dominant intramolecular charge transport mechanism occurring in the molecular layer, and it paves the way for the development of practical devices based on the control of the coherent electron transport through conjugated systems.

Moreover a giant thermoelectric effect has been predicted for single molecule junctions in the vicinity of a node of the transmission function [6]. This is extremely interesting since the electrical energy is here directly converted in thermal energy. In particular the thermopower is predicted to reach a universal temperature independent maximum value of ~±156μV/K, This enhancement arises because the flow of entropy, which is an incoherent quantity, is not blocked by destructive quantum interference, unlike the flow of electrical current, which can be completely coherent. I will discuss the possibility to realize Seebeck coefficient measurements on AQ based planar junctions.

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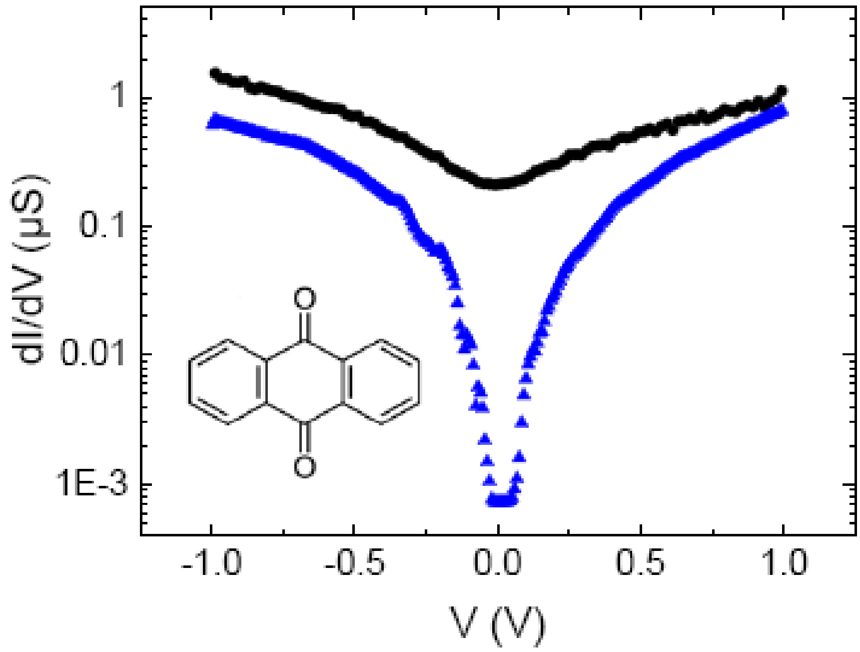

Figure 1. Measured dI/dV vs V data for an AQ-based junction at 300 K (black circles) and 4 K (blue triangles) with an area of 30×30μm^2. A pronounced antiresonance is present at low voltage.