Dark states in Si atomic chains

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Coherent superposition of atomic states can lead to so-called Dark State (DS) which originally was discovered in the fluorescence of sodium atoms [1]. In quantum optics DS is decoupled from the laser radiation and cannot be excited into other state. This physical effect can be explained in a model of atomic states driven in time by external electromagnetic fields which lead to three-level destructive resonance in the system. Recently DSs were analyzed also for purely electronic systems like artificial atoms i.e. in the stationary triple quantum dot (QD) systems where an electron can be trapped in such a DS. As a consequence, the electron current flowing through the QD system vanishes.

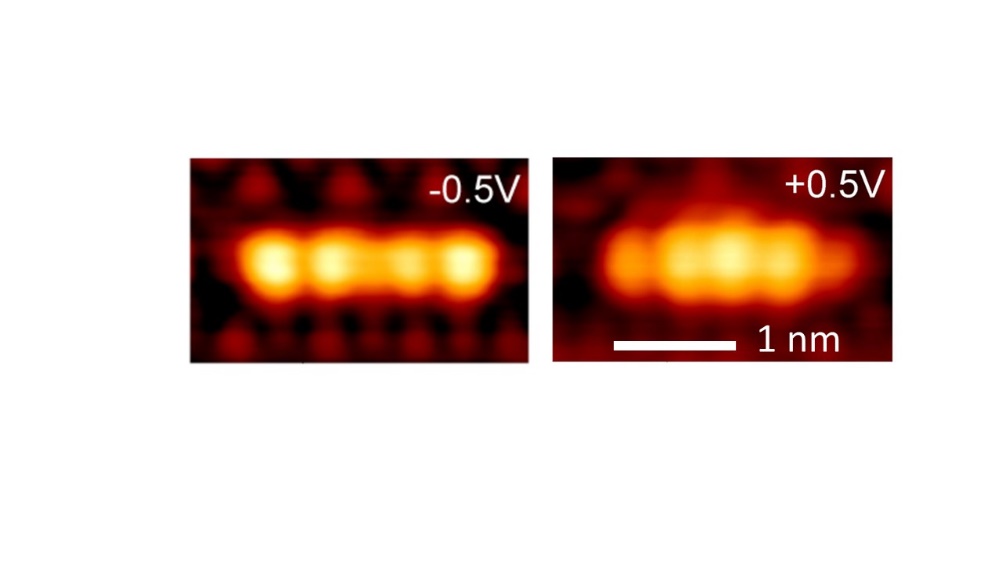
We analyze theoretically and experimentally the existence of DS in short chains of only a few atoms on the surface of a semiconductor. We study the electronic properties of such structures in the presence of the STM tip, focusing on the local density of states (LDOS) and on topographic images of this system. Our theoretical calculations show that DSs are reflected on the LDOS characteristics and thus they have a strong influence on the STM current, namely that some atoms in the chain may be much less visible for a given polarity than others.

The subject of the experimental research were chains of Si atoms on the Si (553)-Au surface composed of alternately arranged double chains of Au atoms on Si (111) terraces with a width of 1.45 nm and single chains of Si atoms at their edges. Si chains behave as an insulator with well localized or weakly dispersed states being well suited to study of DS in atomic chains.

Our results give new insight into the STM topography images interpretation for positive and negative voltages, especially for atomic structures where DSs appear and some chain states can be decoupled from the surface. For such states the current intensity at a given atomic site drastically changes for different STM sample bias, see Figure 1

Contrary to the previous theoretical studies of DS in quantum dots with characteristic energies in the meV range, we focus on ultimately small systems consisting of several atoms with characteristic energies in the eV range.

Figure 1. Topographic STM images of the atomic chain of 5 Si atoms. Note the effect of dark states on the contrast of individual atoms for different sample biases.



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[1] G. Alzetta, A. Gozzini, L. Moi and G. Orriols, *An Experimental Method for the Observation of R.F. Transitions and Laser Beat Resonances in Oriented Na Vapour*, Il Nuovo Cimento, **36**, No.1, p.5 (1976).