中央大學物理學系

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Colloquium

Revealing quantum trapping in STM junction through correlated two-electron tunneling in field emission resonance

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Date: 2024/04/02 (Tue)
Venue: S4-625
Time: 14:00-16:00

Abstract

The linewidth of the field emission resonance (FER) observed on the surfaces of MoS2 and Ag(100) using scanning tunneling microscopy (STM) can vary by up to one order of magnitude. This phenomenon originates from quantum trapping, in which the electron relaxed from a resonant electron in the FER is momentarily trapped in a potential well beneath the STM tip on the surface due to its wave nature. Because the relaxed electron and the resonant electron have the same spin, through the action of the Pauli exclusion principle, the lifetimes of the resonant electrons can be substantially prolonged when the relaxed electrons engage in resonance trapping, leading to a sharp resonance. The coexistence of the resonant electron and the relaxed electron requires the correlated tunneling of two electrons, which can occur through the exchange interaction. Due to this mechanism, the quantized state in FER is occupied by two electrons of opposite spin, different from the conventional viewpoint that FER quantized state is occupied by only one electron since field emission is one-electron tunneling process. Prominent linewidth variation vanishes on the Ag(111) surface because the probability of the two-electron tunneling is largely reduced due to no energy gap above the vacuum level. Because FER electrons are excited electrons, the relaxation of FER electrons emits light. We investigate whether the light emission of FER provides evidence regarding paired electrons. The optical spectra on the Ag(100) surface indeed reveal two types of peak signal that can be related to the formation of the triplet state and the Auger-type excitation requiring two electrons.