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単一分子・原子による量子干渉波の減衰

Damping on Quantum Interference by single molecules and single atoms

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The quantum mechanical interference patterns from surface state electrons scattering off steps on noble metal Cu(111) has been studied by means of scanning tunneling microscope (STM) and spectroscopy (STS) at low temperatures. Since the s-electrons of the outermost orbital of most noble metal, behaves like free electron gas at surface state, quantum interference occur at crystal imperfections (e.g., steps edges, impurities etc.). Standing wave patterns can be observed near these imperfections as a result of the surface state electron scattering process by measuring the differential conductance (*dI/dV*) mapping on the surface. Single molecules and single atoms are also a type of imperfections of this scattering site of the electrons, also being the smallest material to fabricate near-future molecular electronic devices. In this study, we focus on scattering of surface state electrons by single magnetic Fe atoms and single CO molecules adsorbed on fcc-Cu(111) substrate which acts as this so-called scatterer as mentioned and compare the reflection amplitude of the respective cases.

All STM/STS experiments have been performed by using a home-built low-temperature ultra-high vacuum (UHV) STM set up ($<1\times10^{-8}$ Pa) at stable temperature of 6 K. STM tips were prepared by electrochemical etching of tungsten wires (0.3 mm, purity 99.95%). The Cu(111) was cleaned by repeated cycles of Ar+ sputtering (+1.0 kV, +800 nA) and annealing (820 K) with cleanliness monitored by low-energy electron diffraction (LEED) patterns. Single Fe atoms were deposited at ~15 K and CO single molecules were adsorbed at ~15 K by introducing 0.1 L CO-gas into the chamber.

Inelastic scatterings of surface state electrons by surface imperfections cause spatial damping of the standing waves, which can be directly observed in *dI/dV* mappings. The cross section of the *dI/dV* map (dI/dV–x line profile) can be fit by using the energy dispersion equation of the surface state electron ($E(k) = E_0 + (\hbar^2/2m^*)k^2$, where $k = \pi/\lambda$) and further analyzed by fitting with Bessel functions of the 2D electron gas ($\rho_{2D} = L\{1-rJ_0(2kx)\}+ c$), deducing the effective mass of electrons and the reflection amplitude of the wave. For all cases that we study, the s-electrons are lighter and have similar effective electron mass and k_F. (i.e ; step edges (m^*/m_e=0.39, k_F=0.22), enclosed island (m^*/m_e =0.39, k_F =0.21), single Fe atom (m^*/m_e =0.40, k_F =0.20), single CO molecule (m^*/m_e =0.44, k_F =0.23). However, we found that the reflection amplitude, *r* of the waves caused by single CO molecule are larger (*r* >0.8 at ~ -200mV) at lower energy but smaller (*r* =0.13 at ~ -200mV) for single Fe atom. Nevertheless, at higher energies the *r* values for both cases are similar. This shows that damping by CO molecules is larger, and small for Fe atoms.

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