

called a probe hole, can be made in the screen so that electron emission from a surface region composed of only ~ 15 – 30 atoms passes through the hole and then into the energy analyzer. This allows electron spectroscopy studies to be performed on the emission from just these few atoms. Deflection grids are used to focus the emitted current from a chosen portion of the surface over the probe hole. This experimental arrangement is shown in Fig. 1.

When a single atom, molecule, or cluster is adsorbed onto that portion of the surface emitting through the probe hole, if the adsorbate has an electron quasibound state near the Fermi level of the tip, then a substantial increase in the probe-hole current can occur as a result of resonance-tunneling enhancement through the adsorbate. New adsorbate-induced structure in the observed TED reflects the local density of electronic states of the adsorbate, which in turn leads to an unambiguous electron spectroscopy of single adsorbed atoms.

The physical origin of the effect can be understood from the potential energy diagram and wave functions shown in Figure 2. The “triangle barrier” field-emission configuration suggested earlier is here augmented by a potential well whose width $2w$ is roughly the diameter of the adsorbed atom, which is located a distance s from the surface. The electronic state of this atom is characterized by a discrete level which has been broadened into a band, referred to as the local density of states and labeled $\rho_a(\epsilon)$ in Fig. 2. Enhanced tunneling occurs for

those tip states ψ_m whose energy is resonant with $\rho_a(\epsilon)$, in which case the coherent process of tip-to-atom tunneling constructively interfering with atom-to-free space tunneling occurs with much greater probability (by factors sometimes as large as $\sim 10^2$ – 10^4) than for direct tip-to-free space tunneling. It is this magnification or amplification that is responsible for the collimated emission from the single adsorbate rising far above the background emission from other parts of the field emitter surface and, as detailed years later [3], is the underlying principle that enables atomic resolution in the scanning tunneling microscope.

In considering the spectroscopic characteristics of emission from the composite surface, it is most informative to measure and display R , the ratio of the change in TED to the original TED, as a function of energy. For typical adsorbate conditions, the theory outlined in the initial communication [1] shows that this ratio, for emission from the adsorbate-covered surface area, is

$$R(\epsilon) \approx \sum_a [\rho_a(\epsilon)/\rho_m(\epsilon)] \exp[2\kappa(\epsilon)(s+w_a)]$$

where the summation includes all the adsorbate states contributing to the tunneling, $\rho_a(\epsilon)$ is the adsorbate density of states derived from state a , usually represented by a Lorentzian lineshape [4]

$$\rho_a(\epsilon) \equiv \frac{1}{\pi} \frac{\Delta_a}{(\epsilon - \epsilon_a)^2 + \Delta_a^2}$$

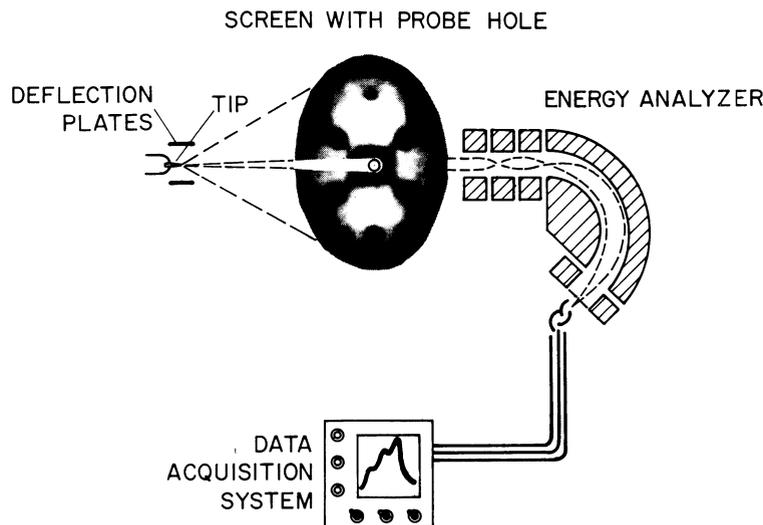


Fig. 1. Schematic drawing of a field emission microscope adapted for energy distribution measurements. The (110) plane of the emitter is positioned over the probe hole. Note that although an electrostatic deflection analyzer is shown here, the data reported in [1] were acquired with a retarding potential analyzer.