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Scanning Tunneling Microscopy

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Scanning Tunneling Microscopy is a very young method for studying surfaces of conductors in real space, including adsorbates. A review article recently appeared in this journal [1], so here we only give a short account of the main steps in the development of the technique, and briefly mention the most recent results.

In a first step towards the Scanning Tunneling Microscope (STM), the feasibility of performing vacuum tunneling was demonstrated [2] by measuring the exponential dependence of the tunnel current on gap width. This required control of the gap width within a fraction of an angström. In a next step, scanning at constant tunnel current provided the first real-space pictures of mono-steps on metal surfaces [3]. These experiments were all performed in moderate vacuum. For reaching the optimum resolution, and for operation under well-defined conditions, a new STM working in ultra-high vacuum was built up. In this configuration, surface mono-steps on Au(110) [3,4] and Si(111) [5], the 2 × 1 reconstruction on Au(110) [4], the 7 × 7 reconstruction on Si [6], the island growths of Au on Si(111) [5], the island growth of Si monoxide on Si(111) [7] and resonance tunneling [1] were observed. A computer-processed topographic picture of the most spectacular of all our measurements, the 7 × 7 reconstruction, is given in Fig. 1. We believe that the 12 maxima observed per unit cell are formed by 12 adatoms. Here, the signal-to-noise ratio for observing a single atom is remarkable.

New developments in the technique address, what we should like to call, differential surfaces. The tunnel current is a measure of the overlap of tip and sample wave functions. The main contribution comes from the electron densities roughly in the middle of the gap, with electron energies lying between the Fermi levels of the two electrodes. Thus, measuring with different gap widths, i.e. different tunnel currents, at constant tunnel voltage gives essentially a 3-D picture of the electron densities of those electrons selected by the energy window, which is in turn determined by the applied voltage. That

means, e.g., that a dangling bond with well-defined energy on a Si surface is "ignored" by the tip for a certain applied voltage, and becomes "visible" for a higher voltage. In this way, a set of "different surfaces" related to different voltages contributes to a better understanding of the surface structure.

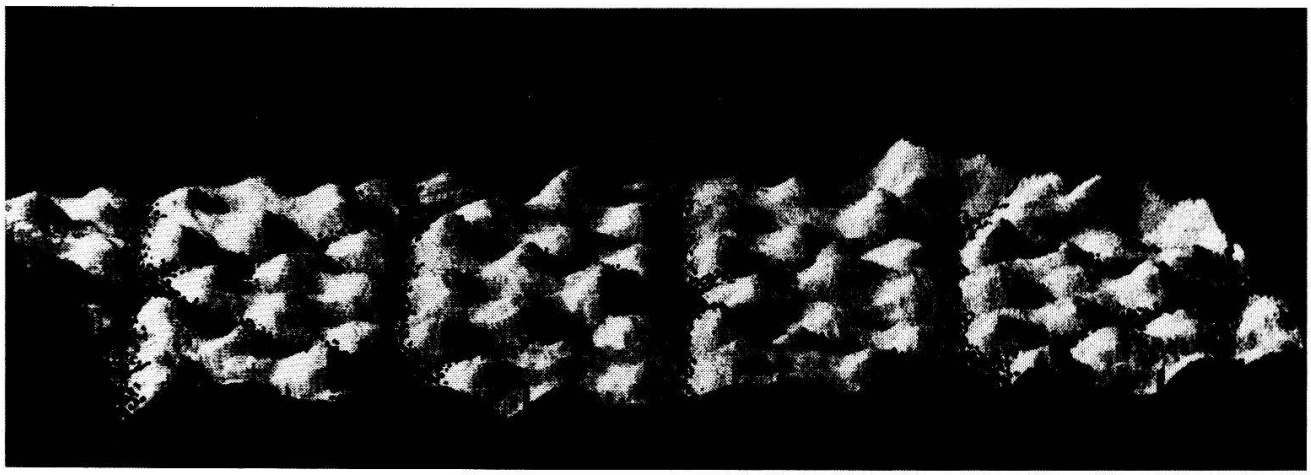

Figure 1

Image-processed measurement of the 7 × 7 reconstruction in Si(111). The edges of the unit cells are visualized by dotted stripes. Image processing: Hartwig Thomas.

Now, in our latest version, the completely new STM has been combined with Auger and low-energy electron diffraction (Leed) surface tools. Just for testing this combination, we have investigated a Au(100) surface. After having detected a 1 × 5 reconstruction in the Leed pattern, this structure was resolved by the STM in the first run. This speaks for the simplicity of the instrument.

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