Quantum physics meets Information Technology:
The scanning tunneling microscope (STM)

by Andreas Vetter

Overview

The device, with which one could see for the first time to down there to the atoms, is called scanning tunneling microscope. It has since its invention, for which there was 1986 a Nobelpreis, which revolutionizes figure of surfaces.

A fine metal needle is the transmitter of the messages from the quantum world. Their point consists in the ideal case of only one atom.

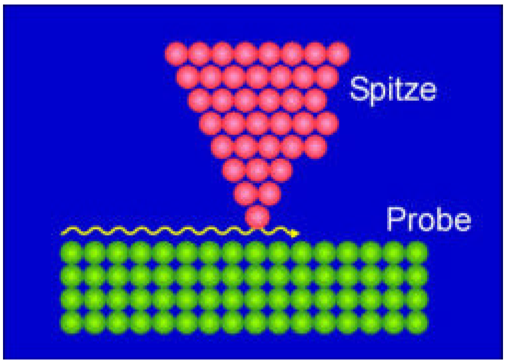
As is the case for the record player it ertastet the atomic landscape line for line. Owing to quantum physics that occurs everything without contact. Electrons branch from the point on the copper surface. It flows a tunneling current. This current is kept constant. But the distance of the needle to the surface must be kept always alike. The height adjustment functions with the help of a Piezoroehrchens *(Piezoro pipe ?),* which is controlled with the tunneling current. Thus the mountains and valleys of the atomic landscape can be illustrated exactly. The distance of the needle to the surface amounts to only few atomic diameters. So that it does not come to disturbances, therefore a thought out oscillation damping is necessary.

The principle

The principle is simple: With a fine point the surface is scanned. If an individual atom sits at the end of the point, surfaces with atomic accuracy can be illustrated. Despite the extremely high enlargement a scanning tunneling microscope is often only matchbox large.

The point of the scanning tunneling microscope is so closely over the surface of the sample that it comes to quantum-mechanical tunnels of electrons by the vacuum barrier between point and sample. If a voltage between point and surface is applied, then flows a tunneling current, which depends exponentially on the distance between point and sample. This exponential spacer dependency is the reason for the enormous sensitivity of the STM. During a change in distance of only one atomic diameter the tunneling current changes around more than tenfold.

A certain current value corresponds thus to a certain distance of the point to the surface. During the horizontal movement of the point over the sample the current is regulated by vertical descendant of the point on a fixed desired value. The correcting variable, the distance between point and sample, is recorded thereby always and corresponds to the surface morphology. If the point drives over a " obstacle ", e.g. an atom, then the tunneling current became larger. The regulation causes a withdrawing of the point, to again the desired distance (= desired current) is achieved. Thus the point of the surface morphology always follows in constant distance.

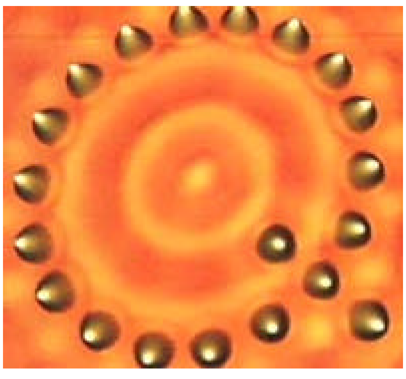


During scanning the surface the point in all three directions in space with an accuracy must be moved by fractions of an atomic diameter. In addition the point is fastened to the end of a ceramic(s) tube, whose length changes when creating an electrical voltage (piezoelectric effect). The point can be laterally moved by creation of different voltages to the different pages of the Piezoroehrchens; by creation the same voltage to all four electrodes the point is vertically moved. The compensated height of the point is now recorded, while a part of the sample is scanned. Thus results an elevator profile of the sample which can be examined, which is represented as picture. If the point is sharp enough, then individual atoms can be illustrated.

Moving atoms

The needle for scanning the atoms can fulfill even still another additional function. To do this, it must be more deeply lowered: so far, until attractive or repulsive binding forces become effective. Now an atom can be shifted by the surface either pulled to another place (attractive strength) or (repulsive strength). Physicists of the free University of Berlin in this way built the smallest Q of the world from copper atoms. It has a diameter of approximately eight nanometers, that is 0.000000008 meters.

Atomic structures are however not the only application of this new technique: The current between point and surface can be used also to loosen chemical compounds in a molecule directly on the surface and make new connections. So a chemical reaction can be executed gradually at only one molecule and examined during its.



How to build a STM by yourself

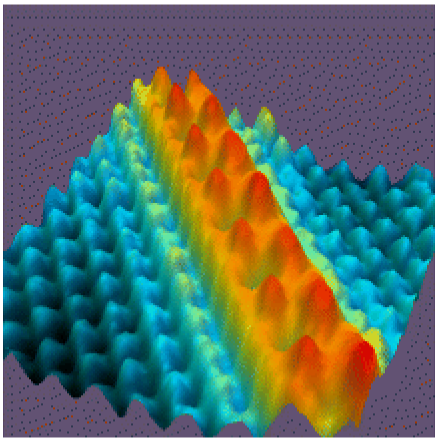
Quarks & CO and physicists of the university of Munster together with pupils of the Annette of Droste Huelshoff High School and the Wilhelm- Hittorf High School showed, how to be built such a microscope also with simple means. But the physicists from Munster sketched a particularly simple construction, whose material costs are with 500 €. To the professional version thereby a fine metal needle the transmitter of the messages from the nano-world is similar. Its point consists in the ideal case of only one atom.

As is the case for the record player: it scans the atomic landscape line for line. Owing to quantum physics that occurs everything without contact. Electrons “jumbs” from the point on the copper surface. It flows a tunneling current. This current is kept constant. But the distance of the needle to the surface must be kept always alike. The height adjustment functions with the help of a Piezoroehrchens *(Piezoro pipe ?),* which is controlled with the tunneling current. Thus the mountains and valleys of the atomic landscape can be illustrated exactly. The distance of the needle to the surface amounts to only few atomic diameters. So that it does not come to disturbances, therefore normally a aufwaendige oscillation damping is necessary. The physicists from Munster improvised: Heart of the swinging-absorption device is now an autohose (=Autoschlauch).

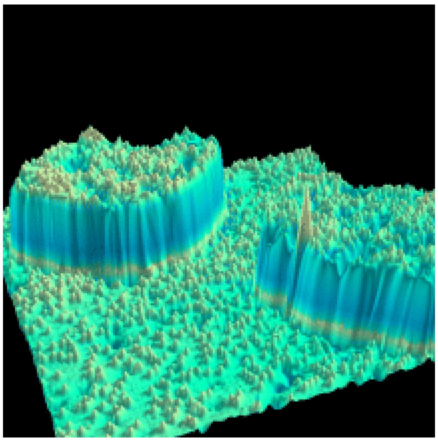
The pupils assembled everything by themselves. They formed for three working groups: A group for the mechanical components, one for electronics and one for programming the software.

They wrote an illustrated building guidance with material and tool list together with the physicists of Munster. This was revised again intensively and is callable in the Internet (http://sxm4.uni-muenster.de/).
The guidance is constantly completed and updated.

scanning tunneling microscope images

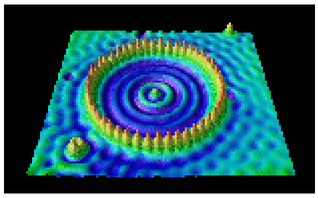


STM image, 7 nm x 7 nm, of a single zig-zag chain of Cs atoms (red) on the GaAs(110) surface (blue).



STM image, 35 nm x 35 nm, of single substitutional Cr impurities (small bumps) in the Fe(001) surface.

This STM image shows the direct observation of standing-wave patterns in the local density of states of the Cu(111) surface.



Sources

- Quarks & CO
- IBM Almaden Research Center
- Forschungszentrum Jülich
- NIST Physics Laboratory