Scanning Tunneling Microscopy Imaging

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Abstract

Scanning tunneling microscopy (STM) was used to probe a surface of graphite. The STM image of graphite was obtained. The brief description of set up and easyscan STM software was discussed.

Introduction

The scanning tunneling microscope is an electron microscope with high resolution, which is enough to resolve single atoms. Since electron moves through the potential barrier between atoms with average distance between them of 5 angstrem, the electron density reaches its maximum near the atomic sites in semiconductors and is uniformly distributed in metals (gold). Even though for metals because of interaction between tip and sample (fig. 1) tunneling current increased when tip is directly above the atom. So it is possible to observe periodic structure of the sample for both semiconductors and metals.

In our case the tip under a voltage (U=0.1 V) and tunneling current of about 1 nA was used to probe surface which was 1 nm close to the tip.

Experiment

New surface microscopy leads to new kind of problems to solve:

1) The isolation of the measurements from the natural vibrations that are present in lab
2) The sample approach to the probe tip
3) The scanning of the probe across the sample surface
4) The sharpening the tip

First, extreme small distances between sample and tip require avoiding existence of vibration, what in our case was done using thick ribbon platform.

The special approach of the tip to the sample was the following (fig. 1):
The sample holder was moved towards the scanning tip by piezo motor with indication of whether sample is close to the tip or not. In both cases holder moved backwards when piezo motor was turned of for a very small period of time (less then 0.1 sec) due to its significant large mass. After a small delay motor again caused the holder to approach the tip until there is a conformation of presence of high tunneling current. The probability to find tunneling electrons, which create tunneling current, increases exponentially as the distance from the surface increases $I \propto \left(\dfrac{V}{s}\right) \exp(-As\sqrt{\Phi})$, where V is the bias voltage, s-

gap size, Φ- average barrier height between the electrodes (sample and tip) and A-constant.

After the approach was done there are two ways to scan the surface of the sample:

1. While scanning the surface we recorded the movements of the tip and by using software Easyscan 1.1 [2] we simultaneously drew the atomic surface on the computer screen line by line.
2. The second (constant height) mode could be done by turning the feedback loop off, so that the tip scans at the fixed distance from the sample and different values of the tunneling current are measured and again drawn the atomic surface on the computer screen line by line. We used the following values of parameters (P-Gain =0, I-Gain=2). Their meaning we explain in the next section.

The Easyscan STN software could allow us to obtain not only generation topographical images but also spectroscopy modes with curves such as I/V and I/Z.

Finally it is necessary to underline the importance of tip preparation. The tip should have the sharpest edge and be a good conductor. For this purpose was used the platinum tip, which was cut as sharp as possible by wire cutters and cleaned with alcohol.

The important feature of easyscan STM is that a platform with sample can be moved in all 3 dimensions. Our trials to obtain the best image of graphite confirmed the idea that the resolution also depends on the slope of sample surface. The best results included parallel motion of the sample.

For test of the system the graphite sample was used. There is a list of the most important parameters with their explanations according to the easyscan STM manual:

Z-Range: fixes the displayed range in z-direction. For example to be able to observe atomic features on a surface the signal in z-direction has to be amplified. This is achieved by diminishing the 'Z-Range'.

ScanRange: fixes the scan size in x and y direction [nm] where (x=y). The value is doubled or halved when using -.

Time/Line: sets the time taken to acquire a data line.

By using the next three parameters, the plane on which the tip is scanned (scan-plane) and the surface of the sample are aligned (see also schematics):

Z-Offset: raises the scan-plane in z-direction [nm].

X-slope: tilts the x-axis of the scan-plane counterclockwise.
Y-slope: tilts the y-axis of the scan-plane counterclockwise (when viewed at 90°
rotation).

With the help of these alignments the performance of the feedback circuit can be
optimized so that only deviations from this inclined scan-plane have to be compensated.
Therefore a much better resolution is achieved.

Rotation: rotates the scanned area clockwise by the given angle.
Samples: sets the number of measured datapoints per line.
By changing the X-/Y-Offsets the scanned area can be shifted. The values are always
relative to the center of the entire scan range:
X-Offset: sets displacement of the measured area in x-direction [nm].
Y-Offset: sets displacement of the measured area in y-direction [nm].

SetPoint: sets the tunneling current [nA].

P-Gain: sets the proportional feedback value.
I-Gain: sets the integral feedback value of the z-distance con-troller.
If both P-gain and I-gain are set to 0, the feedback loop is switched off. when P-gain or I-
gain are set to 16, it has maximum proportional gain or integrator speed.

GapVoltage: sets the voltage of the tunneling gap between tip and sample [V]. A positive
'GapVoltage' means that the tip has a positive potential relative to the sample's surface
and hence the electrons tunnel from the sample to the scanning tip.

Our values for these parameters are given in fig.3 and fig.5.

To obtain the highest resolution we did the following:
First we probed the whole available surface of the sample (499x499nm). Then the most
flat area was chosen to enlarge. This procedure was repeated several times until we
reached the highest resolution of (fig.3) only after drawing the atomic line by line at least
3 full screens, so that to use averaged image, we could obtain the best image (fig.5) only
with the very good tip (we tried more than 10 different tips) and appropriate values of
parameters. In our case I-Gain and P-Gain (fig.5) played the crucial role, because they are
e responsible for sensitivity.

The measurement of the structure of lattice gave us the following results:

D1=0.21 nm with uncertainty .03nm (14%)– averaged distance between two diagonal
white spots (fig. 6). D2=0.11 nm with uncertainty .03nm (30%) – averaged distance
between adjacent white and gray spots. The expected values are D1=0.25 nm and
D2=0.14 nm.

Conclusion

Our experiment showed the good result s, which are close to the known ones for the size graphite atom. This fact points out that easyscan STM was appropriately set up, which means we can probe different samples with expectation to estimate size of their atomic structure with high resolution.

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References

1. Scanning Tunneling Microscopy I, H. -J. Güntherodt and, R. Wiesendanger (Eds.), Springer-Verlag, 1992.

2. Easyscan, Introduction and Software manual, NanoSurf AG, 1998, www.nanosurf.com