Practical file

Quantum physics

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Technology

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To

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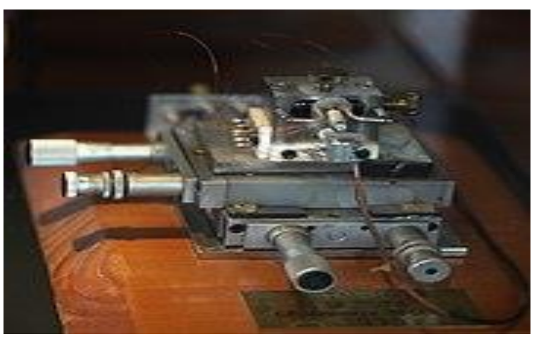
First and foremost, we would like to express our gratitude to our Mentor, Dr. Divyanshu Bhatnagar , who was a continual source of inspiration. He pushed us to think imaginatively and urged us to do this homework without hesitation. His vast knowledge, extensive experience, and professional competence enabled us to successfully accomplish this project. This endeavour would not have been possible without his help and supervision. We could not have asked for a finer mentor in our studies. This initiative would not have been a success without the contributions of each and every individual. We were always there to cheer each other on, and that is what kept us together until . Last but not least, I would like to express my gratitude to my team and I am deeply grateful to everyone who has contributed to the successful completion of this project

AIM : The scanning tunneling microscope is widely used in both industrial and fundamental research to obtain atomic- scale images of metal surface.

INTRODUCTION :



A **scanning tunneling microscope** (**STM**) is a type of microscope used for imaging surfaces at the atomic level. Its development in 1981 earned its inventors, Gerd binning and Heinrich Roher then at IBM Zurich the Nobel Prize in physics in 1986.STM senses the surface by using an extremely sharp conducting tip that can distinguish features smaller than 0.1 nm with a 0.01 nm depth resolution.This means that individual atoms can routinely be imaged and manipulated. Most scanning tunneling microscopes are built for use in ultra high vaccum at temperatures approach absolutely zero variants exist for studies in air, water and other environments, and for temperatures over 1000 °C.

STM is based on the concept of Quantum tunneling. When the tip is brought very near to the surface to be examined, a bias voltage applied between the two allows electrons to tunnel through the vaccum separating them. The resulting *tunneling current* is a function of the tip position, applied voltage, and the local density of state (LDOS) of the sample. Information is acquired by monitoring the current as the tip scans across the surface, and is usually displayed in image form.

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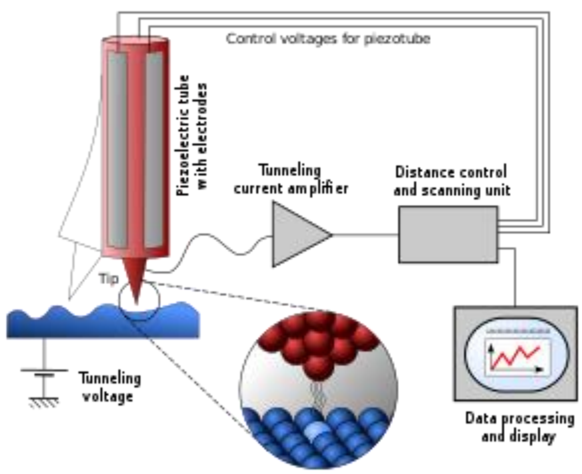
COMPONENTS :

(1) Probe : It is made of tungsten or platinum – iridum alloy

(2) Piezoelectric tube (PZT)

(3) feedback units

PROCEDURE :



The tip is brought close to the sample by a coarse positioning mechanism that is usually monitored visually. At close range, fine control of the tip position with respect to the sample surface is achieved by piezoelectric scanner tubes whose length can be altered by a control voltage. A bias voltage is applied between the sample and the tip, and the scanner is gradually elongated until the tip starts receiving the tunneling current. The tip–sample separation *w* is then kept somewhere in the 0.4–0.7 nm range, slightly above the height where the tip would experience repulsive interaction (w < 3 Å), but still in the region where attractive interaction exists (3 < w < 10 Å).The tunneling current, being in the sub-nanoamphere range, is amplified as close to the scanner as possible. Once tunneling is established, the sample bias and tip position with respect to the sample are varied according to the requirements of the experiment.

As the tip is moved across the surface in a discrete *x*–*y* matrix, the changes in surface height and population of the electronic states cause changes in the tunneling current. Digital images of the surface are formed in one of the two ways: in the *constant-height mode* changes of the tunneling current are mapped directly, while in the *constant-current mode* the voltage that controls the height (*z*) of the tip is recorded while the tunneling current is kept at a predetermined level.

In constant-current mode, feedback electronics adjust the height by a voltage to the piezoelectric height-control mechanism. If at some point the tunneling current is below the set level, the tip is moved towards the sample, and conversely. This mode is relatively slow, as the electronics need to check the tunneling current and adjust the height in a feedback loop at each measured point of the surface. When the surface is atomically flat, the voltage applied to the *z*-scanner mainly reflects variations in local charge density. But when an atomic step is encountered, or when the surface is buckled due to reconstruction, the height of the scanner also have to change because of the overall topography. The image formed of the *z*-scanner voltages that were needed to keep the tunneling current constant as the tip scanned the surface thus contain both topographical and electron density data. In some cases it may not be clear whether height changes came as a result of one or the other.

In constant-height mode, the *z*-scanner voltage is kept constant as the scanner swings back and forth across the surface, and the tunneling current, exponentially dependent on the distance, is mapped. This mode of operation is faster, but on rough surfaces, where there may be large adsorbed molecules present, or ridges and groves, the tip will be in danger of crashing.

The raster scan of the tip is anything from a 128×128 to a 1024×1024 (or more) matrix, and for each point of the raster a single value is obtained. The images produced by STM are therefore

Grayscale, and color is only added in post-processing in order to visually emphasize important features.

In addition to scanning across the sample, information on the electronic structure at a given location in the sample can be obtained by sweeping the bias voltage (along with a small AC modulation to directly measure the derivative) and measuring current change at a specific location. This type of measurement is called scanning tunneling spectroscopy (STS) and typically results in a plot of the local density of state as a function of the electrons' energy within the sample. The advantage of STM over other measurements of the density of states lies in its ability to make extremely local measurements. This is how, for example, the density of states at an impurity site can be compared to the density of states around the impurity and elsewhere on the surface.

PRINCIPLE OF (STM)

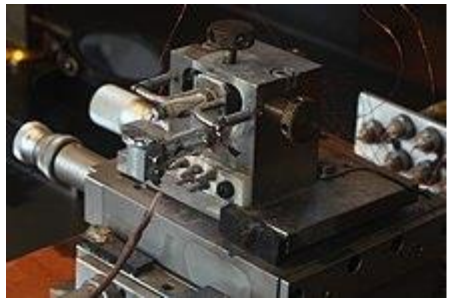
Scanning tunneling microscopy works in the principle of quantum mechanical electron tunneling. If a bias voltage is applied between two metals separated by an insulating barrier or medium of thickness less than 1nm, there is a finite probability of flow of tunneling current. i.e electrons can tunnel across the barrier.

A scanning tunneling microscope uses an atomically sharp tip, usually made of tungsten or Platinum-Iridium. When the tip is within a few **Å** of the sample's surface and a bias voltage is applied between the sample and the tip, quantum mechanical tunneling takes place across the gap. It is called the tunneling current.

Tunneling current depends exponentially on the separation d between the tip and the sample and linearly on the local density of states. The quality of STM images depends critically on the mechanical and electronic structure of the tip.

In a typical experiment, a conductive tip made up of tungsten(W) or Pt-Ir mounted to a piezoelectric material is scanned very close to a conductive sample by applying a bias voltage in the range of 0.01-1V. A feedback loop operates on the scanner to maintain a constant separation between the tip and the sample. Monitoring the position of the scanner provides a precise measurement of the tip's position in three dimensions.

INSTRUMENTATION :



A 1986 STM from the collection of musee

The main components of a scanning tunneling microscope are the scanning tip, piezoelectrically controlled height (*z* axis) and lateral (*x* and *y* axes) scanner, and coarse sample-to-tip approach mechanism. The microscope is controlled by dedicated electronics and a computer. The system is supported on a vibration isolation system.

The tip is often made of tungsten or platinum-iridum wire, though gold is also used.Tungsten tips are usually made by electrochemical etching, and platinum–iridium tips by mechanical shearing. The resolution of an image is limited by the radius of curvature of the scanning tip. Sometimes, image artefacts occur if the tip has more than one apex at the end; most frequently *double-tip imaging* is observed, a situation in which two apices contribute equally to the tunneling. While several processes for obtaining sharp, usable tips are known, the ultimate test of quality of the tip is only possible when it is tunneling in the vacuum. Every so often the tips can be conditioned by applying high voltages when they are already in the tunneling range, or by making them pick up an atom or a molecule from the surface.

In most modern designs the scanner is a hollow tube of a radially polarized piezoelectric with metallized surfaces. The outer surface is divided into four long quadrants to serve as *x* and *y* motion electrodes with deflection voltages of two polarities applied on the opposing sides. The tube material is a lead zirconate titanate ceramic with a piezoelectric constant of about 5 nanometers per volt. The tip is mounted at the center of the tube. Because of some crosstalk between the electrodes and inherent nonlinearities, the motion is calibrated, and voltages needed for independent *x*, *y* and *z* motion applied according to calibration tables.

APPLICATION OF (STM)

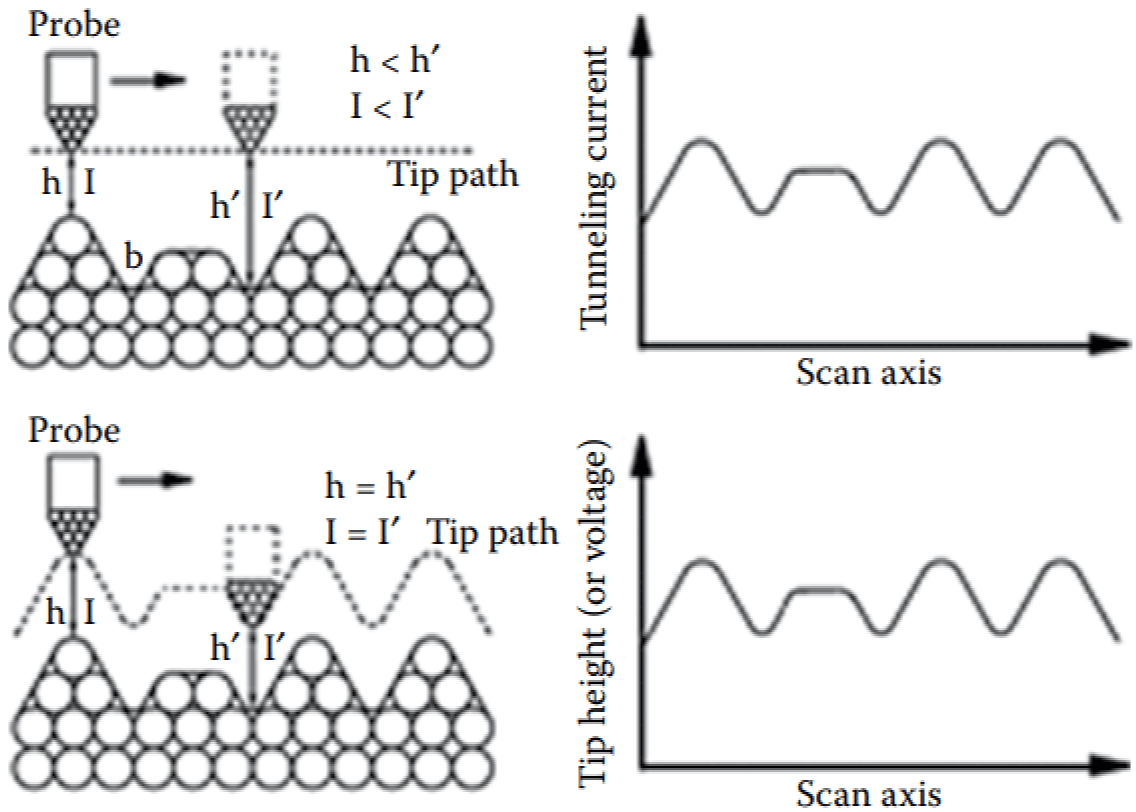
1. Shape, size, and organizations of individual particles or molecules along with the topographical information can be determined.
2. The topographical information obtained from the analysis of STM helps to characterize the surface roughness of the samples.
3. Electronic information of various conducting surfaces can be determined.
4. A large charge in tunneling current is an indicator of the presence of atoms of different types or the presence of contaminants like absorbed gas

MODE OF OPERATION :

The STM microscope can be operated in two modes.

1. Constant current mode: In this mode, the current is made constant during scanning by changing the distance between the tip and surface.

2. Constant height mode: In this mode, tip height is made constant and tunneling current at every step of scanning is measured.



MERITS AND DEMERITS

ADVANTAGES :

1) STM are versatile. They can be used in ultra high vaccum, air, water and other liquids and gasses.
2) STM give three dimensional profile of a surface, which allows researchers to examine a maltitude of characters, including roughness, surface defects and molecule size.
3) Lateral resolution of 0.1 nm and 0.01 nm of resolution in depth can be achived.

DISADVANTAGES :

1) It is very expensive.

2) It need specific tranning to opperate effectively.

3) STM need very clean surface, excellent vibration control while operation, single atom tip.

RESULT :

The result is the creation of opposite charge on the sides. The effect can be reversed as well by applying a voltage across a piezoelectric crystal, it will elongate or compress. These materials are used to scan the tip in an scanning tunneling microscopy and most other scanning probe techniques