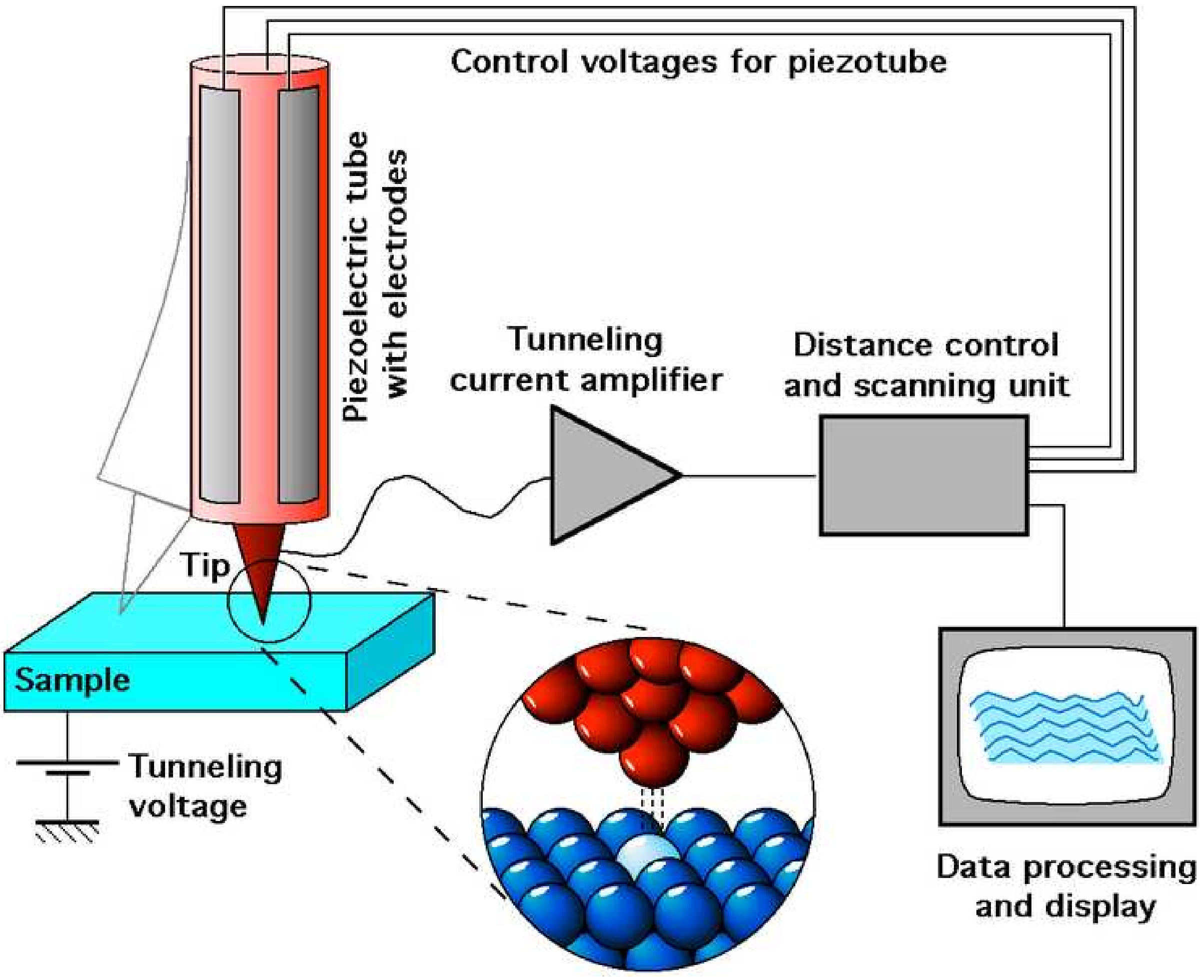
Scanning Tunneling Microscope (STM)

Traditional microscopy or imaging techniques employ lenses to focus light, this results in diffraction. Due to diffraction effect, it is not possible to get a resolution better than half-wavelength of the radiation used. STM is an instrument which does not use radiations to image the objects and study of molecule of few Angstrom size with high resolution became possible. It is an electron microscope that uses a single atom tip to attain atomic resolution. It gives the topographic (real space) and spectroscopic (electronic structure, density of states) images.

Principle: STM scans an electrical probe over a surface to be imaged, to detect weak electric current flowing between the tip and the surface. It allows visualizing regions of varying electron density and inferring the position of individual atoms on the surface of lattice. It employs the principle of quantum tunneling.

Working: Scanning Tunneling Microscope works on the basis of tunneling effect.

The electrons can tunnel from tip to the sample (or vice versa) through a nano gap maintained between them. The tunneling current is measured and converted to surface profile of the sample using image processing technique. As shown in the magnified image of the tip, the sharpness is up to a single atomic dimension so that the resolution tunneling current signal and the images are also up to atomic dimensions. Tip is connected to a electrically controlled piezo electric tube, which moves along all the three axes to adjust the position of the tip while scanning over the sample. The sample is supplied with a bias voltage (usually in the range of 5 mV) to maintain the direction of the tunneling current. When the probe is given a potential, electrons from the atom of the specimen tunnel through the gap to reach the probe and generate a weak tunneling current. As the tunneling current will be in the range of micro amperes, it is amplified by tunneling current amplifier. The probe is scanned over the surface of the specimen. Variation in tunneling current gives an image of the surface atoms of the specimen. The schematic diagram of the STM is as shown below.



Modes of operation: STM operates in two different modes; they are

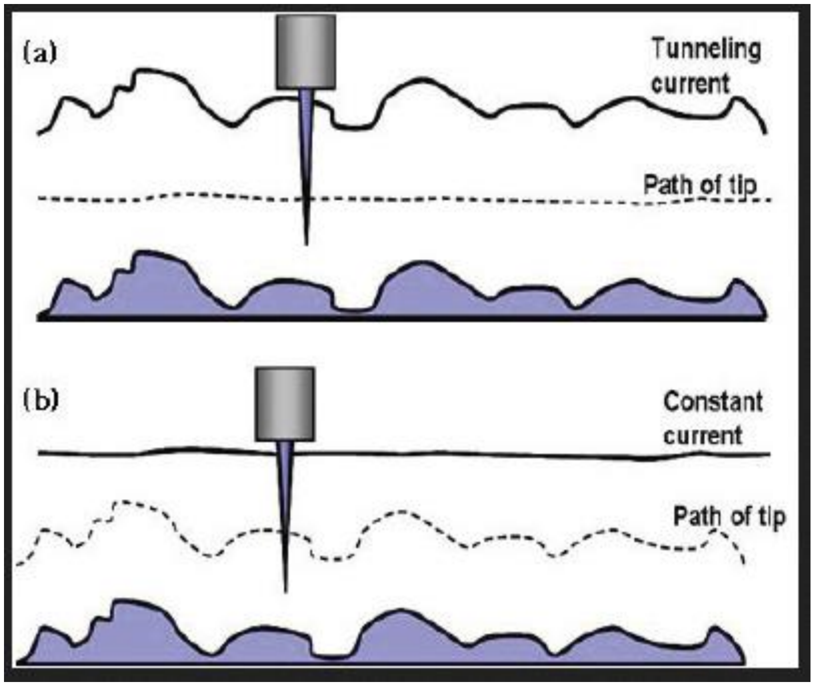
1. Constant height mode and

2. Constant current mode.

These are explained as shown in the schematic diagram below.

Constant height mode:

If the probe scans the surface at a constant height, the tunneling current fluctuates as the tip passes over different atoms. Depending on the nature of the atoms, tunneling current varies and the image recorded gives the atom by atom variation over the specimen.



Constant current mode:

When the probe scans over the atoms, the tunneling current varies which makes the feedback electronics to change the height of the probe above the specimen surface to get constant current.

Advantages: STM provides 3-D profile of the surface which helps in

1. Determining surface roughness
2. Governing the size and arrangement of atoms on the surface
3. To detect surface defects

Disadvantages:

1. Tunneling current changes exponentially with distance between the probe and specimen surface. Therefore, surface should not be contaminated.
2. Specimen should be conducting for the tunneling current to flow
3. Cannot be done in liquid medium.
4. Can be used only in vacuum environment.
5. Designing atomic size probes is expensive and challenging.