Lecture-22-26: Atomic Force Microscope

22.1. What is the advantage on an AFM over other microscopes?

Ans: There are several advantages of using an atomic force microscope. Some are:

- It is non destructive (unlike TEM)
- True Vertical height measurement is possible, with a sub nm resolution.
- Material property characterization, such as topography, adhesion, hardness, friction etc., can be done
- It is not necessary for the surface to be conducting, which is mandatory for STM (scanning tunneling microscope)
- Dip pen nano lithography and tip induced oxidation enables creation of surface patterns with very low lateral resolution (few nm).

22.2. Discuss the sequence of alignment of an AFM cantilever tip.

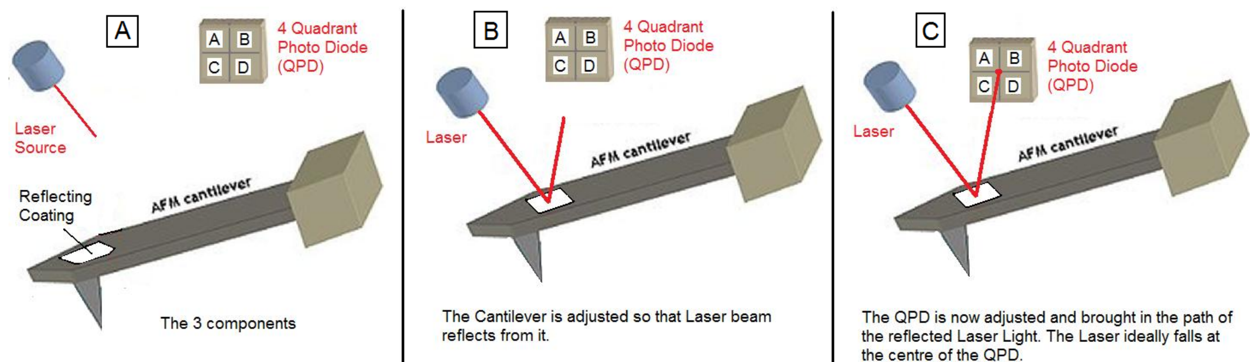
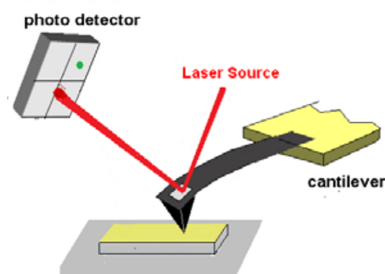


Figure: Sequence of Alignment

Ans: The process of alignment involves aligning three things: QPD (Quadrant Photo Diode), Cantilever and Laser source. These alignment is controlled through a set of screws which controls the position of the cantilever. First the Cantilever (more precisely, the back side of the tip) is brought in the path of the laser, so that the laser can get reflected from there (schematic B). Subsequently, by means of the adjustment screws the QPD is brought in the path of the reflected laser, so that the laser light falls ar the centre of the QPD (schematic C). Once aligned, the AFM is now ready to approach the sample.

22.3. What is "jump to contact"?



Ans: During the approach of the AFM tip towards the surface, as the distance between AFM tip and sample surface becomes less about 100nm, the tip experiences van der waals force induced attraction from the surface and deforms. Consequently, the tip comes in very rapid contact with the substrate experiences an attractive force and comes in contact with the sample surface, this is known as jump to contact (shown in the figure).

22.4. Why is contact mode AFM imaging done in the repulsive regime?

Ans: The tip comes into direct contact with the surface in contact mode. If adequate force is not imparted, then while rustering along a rough surface if a depression is encountered in the path then in case of attractive regime the distance between the tip and the depression may exceed the minimum distance for active van Der Waals attraction. Therefore attractive regime cannot be used. Hence contact mode scanning is done in the repulsive regime.

22.5. What does a set point of "3 mV" mean for Tapping (intermittent contact) mode AFM imaging?

Ans: Set point of 3 mV means that the vibration (or oscillation) of the cantilever tip corresponds to a variation of 3 mV on the QPD surface. Typically in intermittent contact mode, the approach limit is set of a fraction of the free amplitude. Thus, if approach is set at 90% and the free amplitude corresponds to 3 mV, then the stepper motor will stop when the amplitude of the cantilever becomes 2.7 mV. The amplitude starts reducing as the oscillating cantilever comes close to the sample surface and starts tapping it.

22.6. Discuss how an AFM can generate the topographic information of the surface being scanned in Tapping or intermittent contact mode. You can assume that the set point is 3 mV to write your answer.

Ans: In tapping mode, the tip oscillates with a frequency and scans the surface. The set point is given as 3 mV that is after approach the tip oscillation corresponds to deflection of 3 mV on the QPD. Now, as the scan starts, the tip oscillation changes due to topography of the sample substrate. This leads to a change in the voltage on the QPD. The error voltage is fed to the feedback controller, which feeds the voltage to the piezo. The piezo expands or shrinks to adjust itself and the deflection of the tip goes back to 3 mV. At every point during rustering, this sequence of event takes place. This change is recorded and the data is converted into a surface map.

22.7. What mode would you use to image a micro contact printed surface and Why?

Ans: Contact mode will be used to characterize micro contact printing. Micro contact printing helps in formation of chemical patterns, which are surface tension variations and not height variations, therefore cannot be characterized by tapping mode which takes into account of the difference in height of the surface morphology. So contact mode is used here where the tip touches the surface and atomic resolution is obtained on the hard surface.

22.8. What kind of surfaces cannot be scanned using an AFM?

Ans: Every piezo has a limit to what it can expand in the vertical direction. For most commercial AFMs, for a scanner with 100 μm square lateral range, the vertical range is ≈ 8 μm. For a smaller scanner with about 10 μm square lateral range, the vertical range is about 2 μm. Thus, if the sample is rougher than the maximum vertical range of the piezo, it cannot be scanned. Trying to scan such a sample may lead to likely tip damage.

Additionall, a non planar sample is difficult to scan with an AFM, though there has been some isolated reports of imaging non planar surfaces with change in mounting.

Very sticky and adhesives alos cannot be scanned with an AFM as it makes the tip stick to the sample surface, which is known as tip crash.