Getting the highest AFM resolution location, location, location

1.0. Introduction

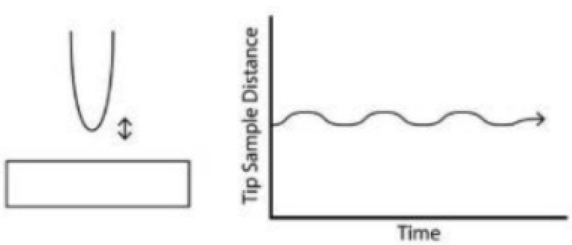
The performance (or resolution) of an atomic force microscope (AFM) depends on where the microscope is located. This is because all locations have sound and structural vibrations that can degrade the AFM's performance.

It is advantageous to install an AFM in a location with very low sound and structural vibrations. The higher the desired resolution, the more important the sound and structural vibrations. Often, for the best possible outcome, an AFM is installed on a ground floor, in a small room with no fans or foot traffic.

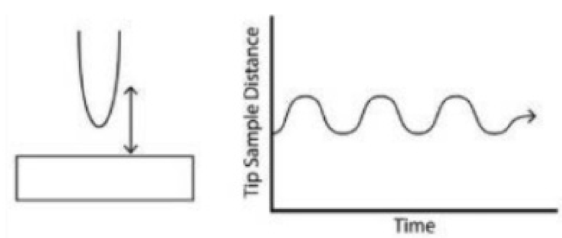
1.1. AFM Resolution

In the vertical direction (z), the resolution of an AFM depends on the ability to stabilize the position of the probe above the surface. This can be understood best when considering the ability to maintain a fixed relationship (or distance) between the probe and sample when not scanning.

When not scanning in the XY axis, if there is no vertical motion between the probe and surface, the highest resolution is achieved. However if the probe and sample move relative to each other, the resolution is degraded.



When the probe is not being scanned across the surface, if the probe moves relative to the sample, the resolution will be degraded.



The larger the relative motion, the lower the resolution of the AFM.

Both noise and structural vibration can cause unwanted vertical vibrations to occur in an AFM, and thus degrade its resolution. The same AFM will have differing resolutions, depending on where it is installed.

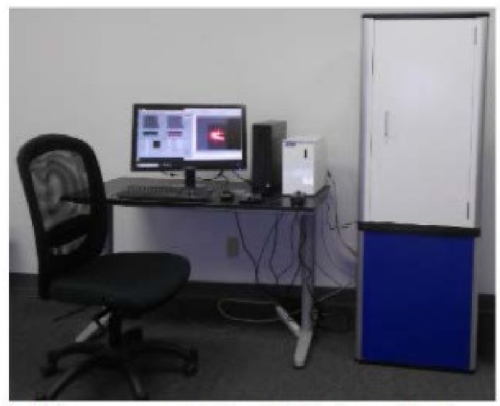
1.2. Getting the best AFM Resolution

There are two primary issues to consider to get the highest resolution AFM images*:

a. Design the AFM so that it does not absorb sound waves and structural vibrations normally present in a laboratory environment. This can be achieved by making the AFM really small or making the stage structure very rigid.
b. Operate the AFM in a location where there are no sound waves and no structural vibrations. Use anti- vibration tables for reducing structural vibrations and acoustic chambers to reduce sound waves.

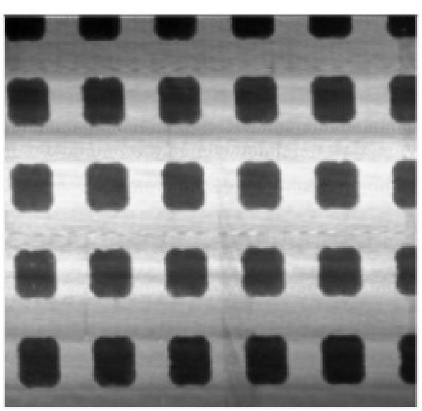
* assuming electronic noise is far less than noise created by vibrations.

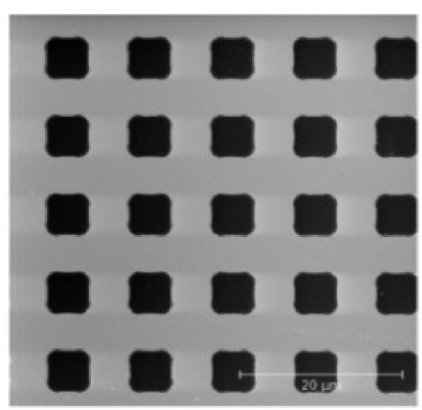
When the AFM is sitting on an unstable table, the rather poor image below is measured.



For this measurement the AFM is in cabinet with sound and 1 structural vibration damping.

Below is the same image of a test pattern measured on a table with no vibration isolation, compared to the image measured in an acoustic vibration enclosure having a passive vibration table.





2.0. Sound

When a clapper strikes a bell, you hear a sound. That is because the energy of the strike creates a vibration in the bell body, then the vibrating body creates a sound wave that is carried by the surrounding air. Finally, the sound wave causes a membrane in your ear to vibrate and a signal is sent to your brain, and you then "hear" the sound.

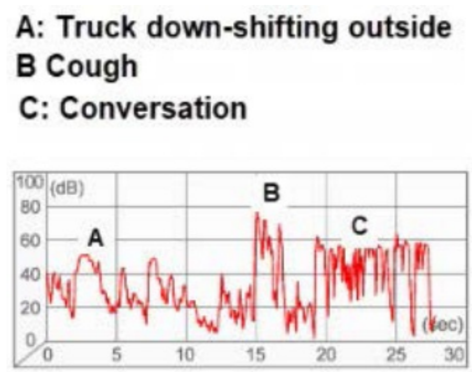
In a similar fashion to the membrane in your ear, the structures in an AFM stage respond to sound waves. Sound waves at specific frequencies are absorbed by the stage and cause the probe and sample to vibrate out of phase, and degrade the AFM's resolution.

2.1. Sources of sound

Noise can come from a myriad of sources. Outside traffic, AC fans, and conversation to name a few. All sound is not created equal. Higher frequencies sound does not excite the microscope's structure as much as lower frequencies. A high pitch sound won't affect image quality as much as a lower mid frequency. The specific frequencies that are problematic depends on the specific AFM stage. Each AFM stage absorbs sound at different frequencies.

2.2. Measuring sound

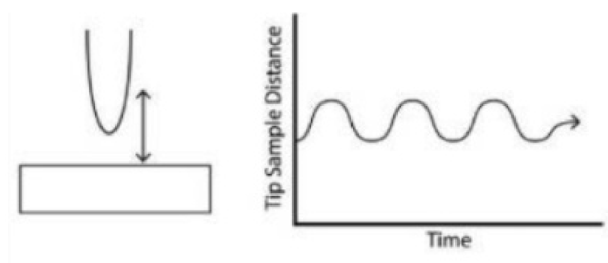
Fortunately, there are smartphone apps that can measure sound levels. The output of the apps are in dB versus time. The lower the dB level, the better. Below is an example of the output of a sound app for three different sounds.



2.3. Reducing sound noise

If possible, install the AFM in a location where the sound level is always far below 20 dB.

Placing an AFM in an acoustic chamber reduces sound noise from the environment. It is important to understand that the acoustic chamber attenuates sound noise, but does not eliminate it.



The wall of the acoustic cabinet attenuates the amplitude of the sound noise, but does not eliminate it.

3.0. Structural vibrations

Just as air transmits sound waves, mechanical structures can transmit vibrations. As an example, when a large airplane lands at an airport, you can often feel the terminal building shake. This is because when the plane touches down, it causes the runway to vibrate, and the vibration is transmitted by the earth to the terminal building, and the building vibrates.

Similarly, structural vibrations can be absorbed by an AFM stage and cause the probe to vibrate out of phase with the sample, and degrade resolution.

3.1. Resources of structural vibrations

The best resolution with an AFM is achieved when the AFM is located in a room with minimal structural vibrations. The following is a guideline for where to place the AFM:

a. Away from sources of structural vibrations

- Hydraulic equipment
- AC pumps
- Elevators
- Staircases
- Fans, electronic equipment
- External factors, such as oil drilling, noisy trucks, and trains in the neighborhood

b. Operate the AFM in a location where there are no sound waves and no structural vibrations. Use anti- vibration tables for reducing structural vibrations and acoustic chambers to reduce sound waves.

A building can also be a source of structural vibrations. For example, tall buildings sway back and forth, and floors in buildings can vibrate up and down. The amplitude and frequency depends on the thickness of the floor and the distance between structural uprights.

If a building like the schematic above has AC on the roof and an elevator shaft, the two red arrows would not be preferred placements. The green arrow indicates a potential advantageous placement (first floor by a shear wall).

The best placement for an AFM will likely be the basement floor in the center of the building. That is not always an option, therefore, think about ways to place the AFM Workshop instrument as far away from the vibration sources mentioned above.

c. On a sturdy table

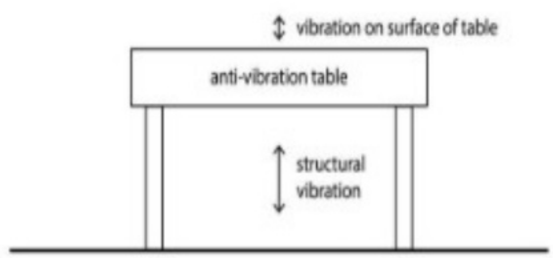
The type of table that the AFM is placed on is also important. The table must have a strong support structure and a very thick table top. If the table shakes easily, it is not a suitable table for an AFM.

3.2. Measuring structural vibrations

Structural vibrations are typically less than 50 Hz. Unfortunately, the equipment that measures this type of vibration is very expensive. Therefore, it is very difficult to know if a specific location has low structural vibrations until the AFM is installed.

3.3. Reducing structural vibrations - Anti-vibration tables

An anti-vibration table reduces the amplitude of structural vibrations. As an example, if the structure the anti-vibration table is sitting on is moving up and down 10 micron, an object sitting on top of the anti- vibration table will move up and down 1 micron.



There are two types of anti-vibration tables: active and passive. Active tables have a sensor that measure vibrations, and useshas active motion generators to cancel out the vibrations. Passive tables use a spring like material to dampen vibrations.

4.0. Reducing structural vibrations - Anti-vibration tables

The most successful type of anti-vibration table for an AFM is the bungee cord support. In a bungee system, the AFM is placed on a platform that is suspended by bungee (elastic) cords. The longer the cords and the heavier the suspended plate, the better the vibration isolation.

TT-2 AFM supported on a platform that is suspended by bugee cords.

Additionally, the enclosure can be made from a dense material such as medium density fiberboard, and the insides walls of the enclosure can be covered with sound absorbing foam.