How to Choose your MAC Lever

Support Note

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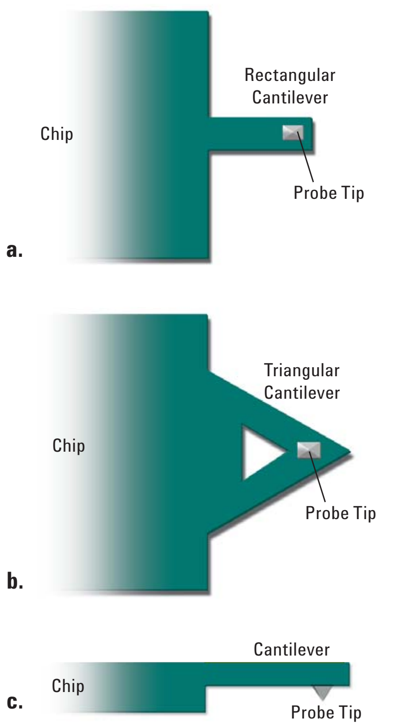


Figure 1. Schematic diagrams of typical AFM probes. a) Top view of a rectangular AFM probe. b) Top view of a triangular AFM probe. c) Side view of an AFM probe.

Introduction

Atomic force microscopy (AFM) is a sub-nanometer scale imaging and measurement tool that can be used to determine a sample's surface topology and measure its mechanical properties.

AFM imaging relies on a small AFM probe that is raster scanned over a surface to generate an AFM image. As shown in Figure 1, AFM probes have two major components; a flexible cantilever, which is attached to the probe chip, and a sharp probe tip near the end of the cantilever. The cantilevers generally have either triangular or rectangular geometries. AFM probes can be manufactured from a variety of materials, but most are made of silicon and/or silicon nitride (Si_3N_4).

The tip of the probe comes into contact or near contact with the sample surface. The tip diameter can vary, depending on its specific application, but it is generally extremely sharp, usually on the order of a few nanometers to tens of nanometers in diameter at the tip apex. Various novel techniques have been developed for creating even sharper tips; for example, carbon nanotubes have been added to the end of the probes. The deflection of the cantilever as it is scanned over the sample is monitored and plotted to generate high-resolution AFM images. The images can be obtained under a variety of environments, including ambient and physiological conditions. Although the samples must be immobilized to relatively flat substrates to permit imaging, more complex sample preparation techniques such as staining or fixation can usually be avoided.

Contact Mode vs Dynamic (AC) Mode AFM

Contact mode and dynamic (AC) mode are two major AFM imaging modes. In contact mode, the AFM probe tip is in continuous contact or near contact with the sample as it is raster scanned across the surface. Relatively large vertical and lateral forces are conveyed to the sample during contact mode imaging and these forces can often cause damage to delicate samples.

In contrast, in AC mode the AFM probe is oscillated up and down at a predetermined frequency as it is scanned over the sample. AC mode can have certain advantages over contact mode; mainly because, as the probe tip oscillates up and down over the sample, it only makes intermittent contact with the sample surface. One result of the intermittent contact, is that the lateral forces and the loading forces between the probe tip and the sample are minimized compare to contact mode. Consequently, AC mode is often preferred for very soft and delicate samples such as polymers and biological materials.

AAC Mode

There are two main AC mode imaging techniques, acoustic AC (AAC) and magnetic AC mode (MAC Mode). In AAC mode, a piezoelectric transducer is used to oscillate the AFM probe at or near its resonant frequency. In liquids, such as aqueous buffers or water, an amplitude vs frequency resonance sweep for an AFM probe that is driven to resonance in AAC mode is often described as a "forest of peaks" (Figure 2). This is because the

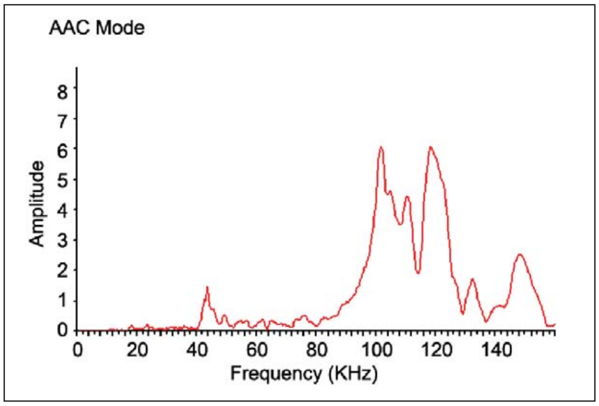


Figure 2. AAC mode amplitude vs frequency sweep in liquid. The AAC mode transducer oscillates the surrounding environment as well as the AFM probe, generating a "forest of peaks".

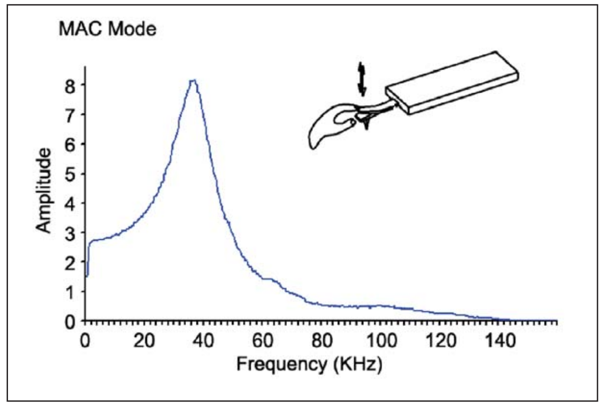


Figure 3. A MAC Mode amplitude vs frequency sweep in liquid. Unlike AAC mode, only the cantilever and the probe tip oscillate in MAC Mode, so a single resonance peak is resolved and there is no "forest of peaks".

transducer tends to vibrate not only the AFM probe, but also the surrounding environment and items that happen to be in close proximity to the transducer. This "forest of peaks" effect can make it difficult to find the true resonant frequency of the probe and also to optimize other imaging parameters.

MAC Mode

MAC Mode is another AC imaging technology in which the AFM probe is oscillated at or near its inherent resonant frequency, but, compared to AAC mode, there is much less system noise and less confusion in determining the probe's resonance frequency in fluids. For example, as demonstrated in Figure 3, there is no "forest of peaks" for an amplitude vs frequency sweep using MAC Mode in liquids. In contrast, the resonant frequency is cleanly resolved as a distinct single peak. This makes it much easier to choose the correct probe oscillation frequency and it makes MAC Mode particularly useful for imaging delicate polymers and biological samples in fluids. MAC Mode is only available on Agilent AFM systems.

MAC Levers

An important component of MAC Mode is an assortment of specially designed, proprietary AFM probes, called MAC Levers. MAC Levers contain a paramagnetic film which covers the backside of the cantilever. The paramagnetic film permits the cantilever to be driven precisely at its inherent oscillation frequency in air and even in liquids through the application of an external magnetic field. The coil for the magnetic field can be placed either above the sample (Top MAC) or below the sample (Bottom MAC). Compared to regular AC mode probes, MAC Levers can be oscillated at more precise frequencies. The result is more accurate and simpler probe tuning, especially in liquids, along with improvements in topography and phase image resolution. Importantly, lower imaging forces and much less damage to soft, delicate samples occur in MAC Mode compared to other AFM imaging modes. In fact, MAC Mode is the gentlest topographic AFM imaging technique. It was specifically designed with delicate materials, such as soft polymers and biological samples, in mind. MAC Mode allows researchers to study samples on the molecular level and image delicate samples which often cannot be resolved with any other AFM imaging technique.

Types of MAC Levers

As mentioned above, MAC Levers are AFM probes that have a proprietary paramagnetic coating on the backside of the cantilever and which are specifically designed, produced and optimized for use in imaging applications utilizing Agilent's MAC Mode. Figure 4 shows a schematic diagram of a MAC lever.

There are five types of MAC levers, TYPE I, TYPE II, TYPE V, TYPE VI, and TYPE VII currently available. Each MAC Lever can be used with Agilent's MAC Mode and they have been optimized for various applications.

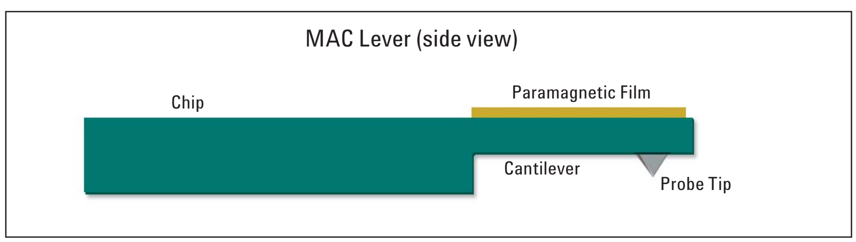


Figure 4. Schematic diagram of a MAC Lever. A proprietary paramagnetic film covers the backside of the cantilever. The paramagnetic film allows MAC Levers to be driven precisely at their inherent oscillation frequency through the application of an external magnetic field.

MAC Levers, along with MAC Mode, offer the most precise AC mode control available and they provide a tremendous benefit over other AFM probes for imaging soft samples, especially in fluids. MAC Levers are compatible with other Agilent AFM accessories and options, including, but not limited to, environmental control, temperature control, electrochemical control, and Agilent's standard liquid cell or the unique flow-through liquid cell.

Choosing MAC Levers for Specific Applications

TYPE I MAC Levers (PN: N9811x)

TYPE I MAC Levers have silicon cantilevers and silicon tips. There are three different rectangular AFM cantilevers on each TYPE I chip. Each TYPE I cantilever has a different spring constant and resonant frequency which can be selected based on the user's specific application. This makes TYPE I MAC Levers especially useful in applications where a range of spring constants might be required.

Recommended Applications: various imaging applications in air or liquid; including, but not limited to soft polymers and biological samples.

Schematic diagram of a TYPE I MAC Lever

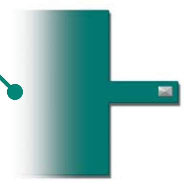
Probe	A	B	C
Cantilever Shape	Rectangular	Rectangular	Rectangular
Cantilever Material	Silicon	Silicon	Silicon
Probe Tip Material	Silicon	Silicon	Silicon
Cantilever Length	110 µm	90 µm	130 µm
Cantilever Width	35 µm	35 µm	35 µm
Cantilever Thickness	1.0 µm	1.0 µm	1.0 µm
Force Constant	0.95 N/m	1.75 N/m	0.6 N/m
Resonant Frequency Air	105 kHz	155 kHz	75 kHz
Resonant Frequency Water	45 kHz	70 kHz	35 kHz
Tip Radius	10 nm	10 nm	10 nm

All values are nominal.

TYPE II MAC Levers (PN: N9812x)

TYPE II MAC Levers have silicon cantilevers and silicon tips. There is one rectangular AFM cantilever on each probe chip. TYPE II MAC Levers are particularly useful for imaging stiffer samples, such as block copolymers, in air or liquid.

Recommended Applications: useful in various imaging applications in air or liquid, including, but not limited to block copolymer samples.



Schematic diagram of a TYPE II MAC Lever

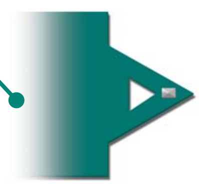
Cantilever Shape	Rectangular
Cantilever Material	Silicon
Probe Tip Material	Silicon
Cantilever Length	225 µm
Cantilever Width	30 µm
Cantilever Thickness	3.0 µm
Force Constant	2.8 N/m
Resonant Frequency Air	75 kHz
Resonant Frequency Water	30 kHz
Tip Radius	<10 nm

All values are nominal.

TYPE V MAC Levers (PN: N9815x)

TYPE V MAC Levers have silicon nitride cantilevers and silicon tips. There is one triangular AFM cantilever on each probe chip. TYPE V MAC Levers are particularly useful for imaging soft polymers or biological samples such as DNA in liquid.

Recommended Applications: imaging soft samples such as polymers or DNA in aqueous buffers.



Schematic diagram of a TYPE V MAC Lever

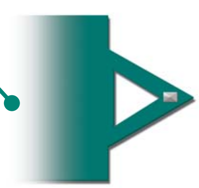
Cantilever Shape	Triangular
Cantilever Material	Silicon Nitrate
Probe Tip Material	Silicon
Cantilever Length	100 µm
Cantilever Width	25 µm
Cantilever Thickness	0.6 µm
Force Constant	0.4 N/m
Resonant Frequency Air	66 kHz
Resonant Frequency Water	22 kHz
Tip Radius	10 nm

All values are nominal.

TYPE VI MAC Levers (PN: N9865x)

TYPE VI MAC Levers have silicon nitride cantilevers and silicon tips. There is one triangular AFM cantilever on each probe chip. TYPE VI MAC Levers are particularly useful for imaging soft polymers or biological samples such as proteins in liquid.

Recommended Applications: soft samples such as soft polymers or proteins in aqueous buffers.



Schematic diagram of a TYPE VI MAC Lever

Cantilever Shape	Triangular
Cantilever Material	Silicon Nitrate
Probe Tip Material	Silicon
Cantilever Length	100 µm
Cantilever Width	18 µm
Cantilever Thickness	0.6 µm
Force Constant	0.2 N/m
Resonant Frequency Air	66 kHz
Resonant Frequency Water	22 kHz
Tip Radius	10 nm

All values are nominal.

TYPE VII MAC Levers (PN: N9866x)

TYPE VII MAC Levers are made from silicon. There is one rectangular AFM cantilever on each probe chip. TYPE VII MAC Levers are particularly useful for imaging very soft biological samples in liquid as well as topography and recognition imaging using PicoTREC.

Recommended Applications: useful in various imaging applications in air or liquid, including, but not limited to block copolymer samples.

Schematic diagram of a TYPE VII MAC Lever

Cantilever Shape	Rectangular
Cantilever Material	Silicon
Probe Tip Material	Silicon
Cantilever Length	125 µm
Cantilever Width	35 µm
Cantilever Thickness	0.8 µm
Force Constant	0.14 N/m
Resonant Frequency Air	43 kHz
Resonant Frequency Water	18 kHz
Tip Radius	10 nm

All values are nominal.

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