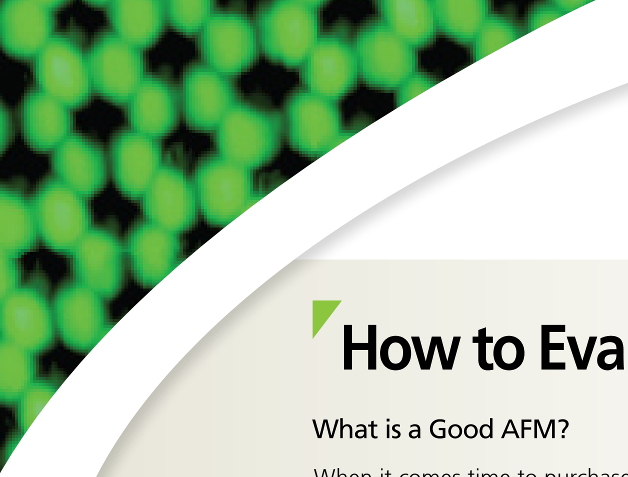


How to Evaluate an AFM

What is a Good AFM?

When it comes time to purchase an AFM, there are many features that may be important based on the final system application. These important or required features will create a long list of questions that may be unique to the user when they proceed to evaluate an AFM system. Questions that may be important to individual users may include: Is the system designed for industrial or research applications? Is the system going to be installed in a multi-user facility? Will the system support all of the available options that I require? Is the system easy to use for low-level users? Is the AFM flexible for high-end users? These and many other questions are common when a customer first begins to gather information about available AFM systems.

Once these questions have been satisfactorily answered, and a list of viable systems has been compiled, the user needs to make a fundamental comparison of the systems that best meet their overall requirements. With this goal in mind, Park Systems has compiled what we believe to be a comprehensive overview of "What is a Good AFM"

The Basics

Historically, AFM has proven to be an adequate tool that may be used to determine relative sample dimensions, but it is weak in being able to provide absolute dimensions. Even with good resolution, an AFM is often inaccurate in measuring true sample dimensions. In both research and industry, as dimensions become smaller and smaller, it is now more important than ever for AFMs to improve upon this weakness. In order to meet today's nanometrology performance requirements, an AFM must:

- Measure smaller and smaller features at the nanometer scale
- Provide higher repeatability from measurement to measurement
- Possess higher reproducibility from operator to operator
- Display smaller variations from system to system

Today, a good AFM not only provides good resolution, but also accurately images sample dimensions with good repeatability and reproducibility. It must also have good system-to-system correlation.

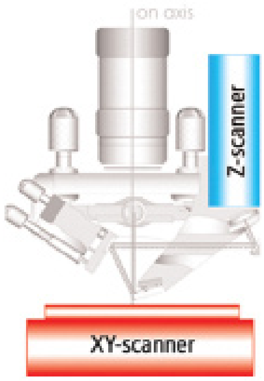
The Scanner

The AFM scanner is the most important feature of any AFM, and the scanner performance will determine the reliability of the overall results that an AFM can provide.

Tube scanners were most commonly used in the first generation of AFMs that became available to customers in the 1980's. Although this technology still has some useful applications, for the wider range of applications in today's scientific community, the tube scanner is an out-dated and inferior technology.

The inherent weakness of the tube scanner lies in the fact that it is not an orthogonal 3D actuator. When a sample is imaged with a tube scanner, the resulting data will be distorted as a result of the high-order, non-linear background motion of the scanner. Thus, the tube scanner will not produce a true image of the sample, and the scanner variability will change at different scan ranges, scan speeds, and scanner offsets.

It is possible to remove these background artifacts by software means, and sometimes the manufacturer will even apply software correction to the data without the user's knowledge. Even with the best software correction, however, it is all but impossible to reproduce data. Thus, with a tube scanner system, an AFM's overall accuracy and reliability fall into question for nanometrology applications. System-to-system correlation for tube scanner systems cannot be guaranteed without extremely detailed user protocol, and even then, the inherent error of the process becomes a significant problem for the nanometrology industry.



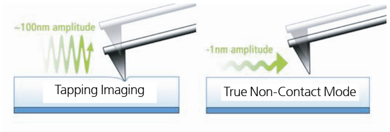
The new generation of AFM systems has incorporated flexure scanners as the new standard in the industry. The implementation of flexure scanners has resulted in AFM platforms that are optimized for today's nanometrology requirements. In comparison to tube scanners, a flexure scanner completely decouples the X/Y-scanner motion from the Z-scanner movement. Integration of flexure scanners effectively eliminates all background curvature that brings a tube scanner's data into question.

The flexure scanner design and performance highlights the scanner features that a customer should look for in evaluating an AFM:

- A scanner should produce minimal out-of-plane curvature when imaging a flat surface. Over the entire scan range, the out-of plane movement should be only a few nanometers.
- A good AFM scanner must be able to accurately and repeatably image a sample surface.
- The performance of the scanner should be independent of scan rate, scan range, and scanner offset.

Ultimately, the increase in fundamental performance that is provided by flexure scanners will translate to increased performance and accuracy for all AFM system requirements and imaging modes. Surprisingly, many AFM manufacturers still produce systems that are equipped with the same tube scanners that were first used over 20 years ago.

True Non-Contact Mode vs Tapping Imaging



Tapping imaging was first developed as a compromise between contact mode AFM which damaged soft samples and Non-Contact mode which was difficult to operate.1 This development occurred over 15 years ago. Since that time, however, technology has improved dramatically, and today we have the ability to properly implement True Non-Contact AFM as it was originally described. 2

Although tapping imaging did provide certain advantages in the past, it has always been a flawed technique. Since the tip strikes the sample surface at the end of every oscillation, immediate tip fracture occurs. This will of course reduce the ultimate resolution of the system. For softer samples, the tip will damage the sample and also result in inaccuracies of sample height measurements. 3

In True Non-Contact mode, however, the cantilever is vibrated with much smaller amplitude relative to tapping imaging. The tip is then brought to a controlled distance of a few nanometers from the sample surface. This tip-sample distance is maintained as the Non-Contact Mode image is acquired. Consequently, Non-Contact mode preserves tip integrity, and provides consistent high resolution and accurate data.

A good way to test the tip life of an AFM system is by imaging a deep trench sample. As a tip becomes blunt, it can no longer reach the bottom of the trench. In True Non-Contact Mode, the tip will be sensitive to changes in topography as it scans the sample. As a result, it is even possible to trace the steep walls of the trench without crashing into the surface and damaging the tip. This will be observed over multiple measurements. Thus, in comparison to tapping imaging, True Non-Contact Mode not only improves the overall quality of AFM data, but also preserves sharpness of the scanning tip.


Tapping imaging | True Non-Contact mode

Before | After | Before | After

Overall, when it comes time to evaluate AFM systems, there are many aspects that may be uniquely critical from one user to the next. The criteria that are important to a biologist are likely different from those of a mechanical engineer. Likewise, what is important to a manufacturing engineer will not necessarily be important to someone in academic research. The fundamental abilities of all of these systems, however, can be compared on a common ground. It is these basic factors that give insight into the capabilities of any AFM, and more importantly provide the user with a strong impression of the system's overall accuracy, repeatability, and reproducibility. Thus, it is possible to answer the question, "What Is a Good AFM?"