Atomic Force Microscopes

Park Systems

Nanotechnology Solutions Partner

XE-3DM

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Atomic Force Microscopes
Park Systems
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XE-3DM
Decoupled XY & Z Scanners

Automated

Industrial AFM for
High-Resolution 3D Metrology

Park Systems has introduced the revolutionary XE-3DM, the completely automated AFM system designed for overhang profiles, high-resolution sidewall imaging, and critical angle measurements. With the patented decoupled XY and Z scanning system with tilted Z-scanner, it overcomes the challenges of the normal and flare tip methods in accurate sidewall analysis. In utilizing our True Non-Contact Mode™, the XE-3DM enables non-destructive measurement of soft photoresist surfaces with high aspect ratio tips.

1 High Resolution Access to Undercut and Sidewall

- Unique decoupled XY and Z scanning system with tilted Z scanner
- Z-scanner is tilted sideways from -19 to +19 degrees and -38 to +38 degrees
- Use of normal high aspect ratio tips for high resolution imaging
- XY scan of up to 100 µm x 100 µm
- Up to 25 um Z scan range by high force scanner

2 Complete 3D Metrology of Sidewall

- Sidewall roughness measurement
- Critical angle measurement of sidewalls
- Critical dimension measurements of vertical sidewalls

3 Non-destructive CD and Sidewall Measurements by True Non-Contact Mode™

- In-line measurement of the smallest features in the industry.
- Non-destructive measurement of soft photoresist
- Less tip wear for prolonged high-quality and high-resolution imaging
- Immunity from parameter-dependent results observed in tapping imaging

4 High-Throughput Inline Automation

- Automatic measurement and analysis of trenches, overhangs, and undercuts
- Cleanroom compatibility and remote control interface
- Automatic tip exchange (optional)
- Equipment Front End Module (EFEM) for wafer handling (optional)

5 Nanotechnology Solutions Partner

- Partnering with customers to meet the fast changing requirements
- Flexible software and hardware modifications to the modular platform
- Enable rapid response to customers' needs

PROBLEMS

As the dimensions of device structures continue to decrease and newer 3D structures emerge, the methods for critical dimension metrology are no longer adequate to characterize process variables. For the traditional techniques such as CD-SEM, OCD, and FIB/SEM, the limitations are becoming more apparent. For example, due to the sidewall roughness, the CD-SEM does not provide a clear definition at the structure edge, the OCD only provides an average value of the critical dimension, and the FIB/SEM provides only a single point measurement and does not provide a complete picture of the structure dimensions.

PARK SYSTEMS SOLUTION

Park Systems provides a reference metrology system for the critical dimension and sidewall analysis. As a fully automated AFM system, the 3DM allows for sidewall, undercut, and line/trench width characterization. With our True Non-Contact Mode™, our XE-3DM is capable of imaging the most challenging structures such as soft photoresists and 3D multilayer topologies.

BENEFIT

The XE-3DM provides the unique advantage of a non-destructive in-line imaging tool capable of providing a) high resolution, b) direct, and c) repeatable measurements with complete three dimensional information for lines, trenches, and multilayer 3D devices.

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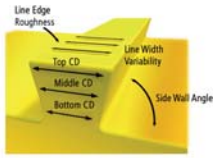
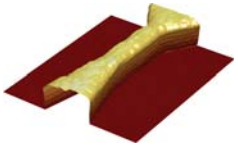
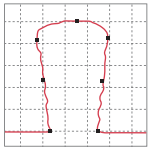
APPLICATION

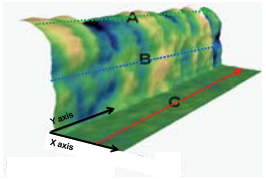


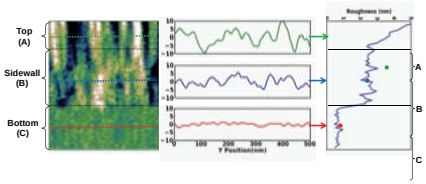




CD Measurements of Undercut & Overhang

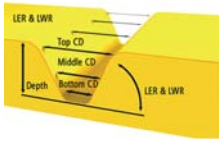
XE-3DM's Z-head tilting mechanism allows an unique access to the undercut and overhand structures of photoresist.

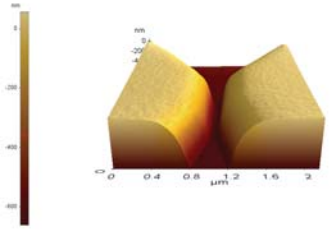




High-Resolution Sidewall Roughness

XE-3DM's Z-head tilting mechanism allows access to the sidewalls using an ultra sharp tip to obtain high resolution and details of the sidewall roughness.

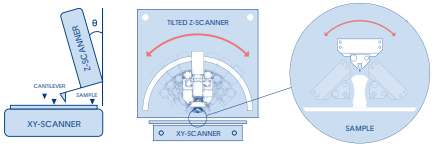




CD Measurements of Photoresist Trench

Unique True Non-Contact mode enables nondestructive in-line measurement of etch features as small as 45 nm.

FEATURES



Tilted Z-scan System

The unique design of the XE-3DM is made possible by deliberately and independently tilting the Z-scanner in its patented Crosstalk Eliminated (XE) AFM platform where XY and Z scanners are completely and independently decoupled. It allows users to access the vertical sidewalls as well as undercut structures at various angles. Unlike systems with flared tips, high resolution and high aspect ratio probes can be used.

Fully Automated Pattern Recognition

Utilizing a powerful combination of high resolution digital CCD camera and pattern recognition software, a fully automated pattern recognition and alignment is made possible for user applications.

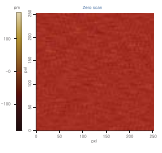
Automatic Measurement Control

Automated software makes the XE-3DM operation effortless. Measurement recipes provide multi-site analysis with optimized settings for cantilever tuning, scan rate, gain, and set point parameters.

Industry's Lowest Noise Floor

To detect the smallest sample features and image the flattest surfaces, Park Systems has engineered instruments which hold the industry's lowest noise floor specification of < 0.5Å. Noise floor data is determined using a "zero scan". With the cantilever in contact with the sample surface, the system noise is measured at a single point under the following conditions:

- 0 nm x 0 nm scan, staying in one point
- 0.5 gain, in contact mode
- 256 x 256 pixels



Typically 0.3 Å rms or lower

Statistics

Region	Min(pm)	Mean(pm)	Rpv(pm)	Rq(pm)	Ra(pm)
Red	0.000	-0.011	359.496	30.025	19.177

XE-3DM
Decoupled XY & Z Scanners

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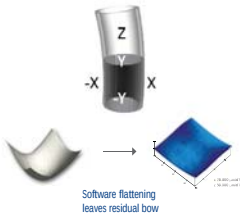
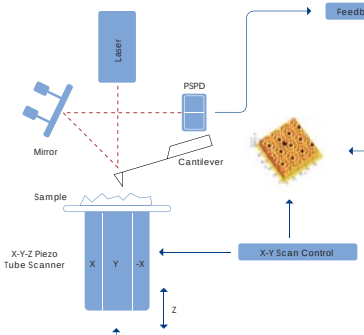
CROSSTALK ELIMINATION (XE)

Challenges of Accurate AFM Measurement



Artifact Free Imaging: Flat XY Scan Without Scanner Bowing

The conventional AFM uses a piezoelectric tube for the x-y-z scanner, where x-y motion relies on the bending of the tube. The bending motion, however, introduces background curvature and therefore causes z position errors. Conventional systems regularly use software flattening to hide the background curvature; this can be an impossible task since the amount of curvature depends not only on scan size and scan speed, but also on x-y offset, z position, etc. Therefore, even after software flattening, a flat surface does not "look" flat as shown in the figure.

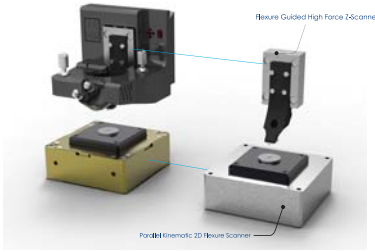


Non-destructive Scan:
Tip and Sample Preservation by Non-Contact AFM

The tube scanner is a slow actuator with highly limited Z-scan bandwidth of only 500 Hz or so. Therefore, the Z-servo response is too slow to implement Non-Contact Mode, a critical requirement for preservation of sharp tips and non-destructive imaging of soft biological samples.

XE Technology: Park Systems' Answer to Accurate AFM Measurement

Challenges of accurate AFM measurement calls for a completely new approach in the design of an AFM. Park Systems developed the Crosstalk Eliminated (XE) AFM based on decoupled flexure scanners where the XY scanner only moves the sample and the Z Scanner drives the probe. The XE-AFM fundamentally removes the scanner bowing, hence attaining flat XY scan, and dramatically improves the Z-servo response, resulting in superb tip preservation by True Non-Contact Mode™.

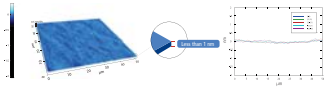


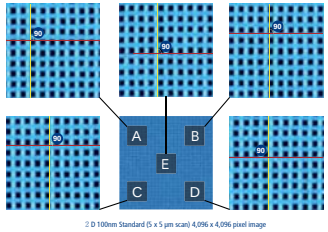
Mechanical Design	Features	Advantages
Decoupled XY and Z Scanners	XY scanner only moves the sample and the Z scanner drives the probe	Flat XY Scan Without Scanner Bow
2D XY Flexure Scanner	Minimal Z Runout (Out-of-plane Motion)	Highly Linear and Orthogonal XY Scan
High Force Z Scanner	Large Z Servo Bandwidth	Enabling True Non-Contact Mode™
Super Luminescent Diode (SLD)	Low Optical Coherence	Eliminates Optical Interference

ACCURATE AFM RESULTS BY CROSSTALK ELIMINATION (XE)

Artifact Free Imaging

- ☑ Low residual bow
- ☑ Results less dependent on scan location
- ☑ No need for software processing (raw data)
- ☑ Accurate height measurements and sample imaging





Flat XY Scan Without Scanner Bowing

The Crosstalk Elimination (XE) fundamentally removes the scanner bowing, hence attaining flat XY scan with out-of-plane motion less than 1 nm regardless of scan locations, scan rates, and scan sizes. It shows no background curvature even on scans of the flattest samples such as that of an optical flat as shown in the figure, also with various scan offsets. Thus, the XE-AFM enables very accurate height measurement and precision nanometrology for the most challenging problems in research and industry.

Highly Linear and Orthogonal XY Scan

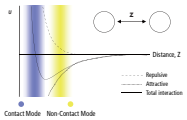
The flexure XY scanner decouples the X and Y scan motion so that the coupling between X and Y movement is minimized regardless of scan locations, scan rates, and scan sizes. Position sensors provide linear feedback control for the high accuracy and high precision measurements.

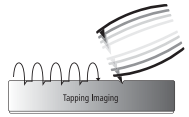
Non-destructive Scan

- ☑ Less tip wear for prolonged high-resolution imaging
- ☑ Minimized sample damage or modification
- ☑ Immunity from parameter-dependent results
- ☑ Imaging of soft sample surface

True Non-Contact Mode™ is Now a Reality

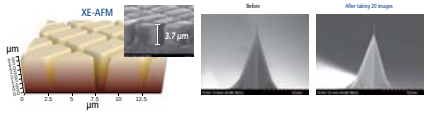
True Non-Contact Mode™, one of the distinctive advantages only realized by Park Systems' Crosstalk Eliminated (XE) AFM, is a powerful method that enables AFM users to image and measure samples.





In True Non-Contact Mode™, the tip-sample distance is successfully maintained at a few nanometers in the net attractive regime of inter-atomic force. The small amplitude of tip oscillation minimizes the tip-sample interaction, resulting in superb tip preservation and negligible sample modification.

Longer Tip Life and Less Sample Damage



The sharp end of an AFM tip is so brittle that once it touches a sample, it becomes instantly blunt and limits the resolution of an AFM and reduces the quality of the image. For softer samples, the tip will damage the sample and also result in inaccuracies of sample height measurements. Consequently, preserving tip integrity enables consistent high resolution and accurate data. True Non-Contact Mode™ of the XE-AFM superbly preserves the tip, resulting in much longer tip life and less sample damage. The figure, displayed in 1:1 aspect ratio, shows the unprocessed raw data image of a shallow trench isolation sample imaged by the XE-AFM, whose depth is also confirmed by scanning electron microscope (SEM). The same tip used in the imaging of the sample shows no tip wear even after taking 20 images.

XE-3DM
Decoupled XY & Z Scanners

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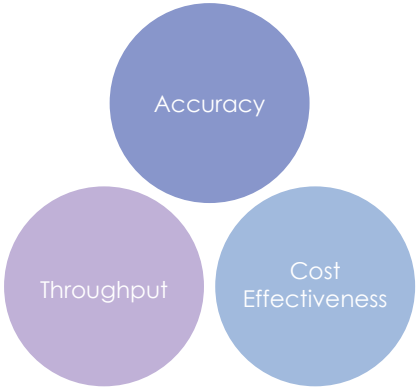
AFM SOLUTIONS

Semiconductor

With its ability to accurately measure critical dimensions in the micrometer to nanometer regime, Atomic Force Microscope (AFM) is becoming the tool of choice for applications involving surface roughness, trench depth, and line width characterization of various samples features and materials.



Accuracy Like Never Before

Shrinking form factors are driving the need to design at the nanoscale level in the semiconductor markets. Traditional metrology tools have lacked the accuracy needed for nanoscale design and manufacturing. Park Systems has met this challenge in industrial metrology with enabling breakthroughs.

- Crosstalk Elimination (XE) enables artifact-free and non-destructive imaging
- New 3D AFM enables high resolution imaging of sidewall or undercut features

Throughput Like Never Before

AFMs that have enabled nanoscale design have traditionally not been fast enough for use in production quality control. All that has changed with Park Systems revolutionary gains in throughput enabling AFMs for use in automatic in-line manufacturing.

These include automatic tip exchange where our novel magnetic approach has a 99% success rate, higher than traditional vacuum techniques. Also, full access to raw data and a true partnership with customers are required for any process and throughput optimization.

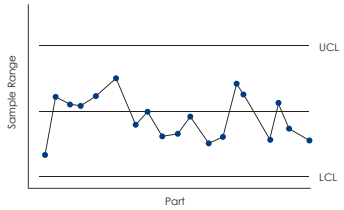
Cost-Effectiveness Like Never Before

Accuracy and throughput in nanometrology must be delivered in a cost-effective solution to move successfully from research to inline manufacturing. Park Systems have met this cost challenge with industrial AFM solutions that address the need for faster, efficient automation and longer tip life.

We cut costs by replacing slower and expensive SEM with efficient, automatic, and affordable 3D AFM for industrial in-line manufacturing. To pinpoint defects in new designs, manufacturers today need 3D information to characterize trench profiles and sidewall feature variation. Modular AFM platform allows rapid software and hardware changes, enabling cost-effective upgrades and better optimization for the most complex and demanding measurements in production quality control.

Also, we lower the cost of ownership with at least 200% longer AFM tip life. The tapping forces of conventional AFMs cause faster tip wear, but our True Non-Contact Mode™ AFMs maintain tip quality resulting in the lower total cost of ownership.

PARK SYSTEMS RELIABILITY

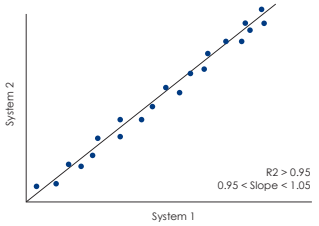


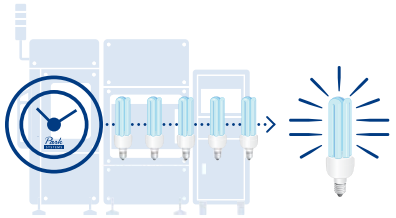
Gage Repeatability and Reproducibility

Due to the ever-decreasing size of components, manufacturers now require the highest level of quality control. Park Systems can provide 1 gage sigma (σ) of less than 1 Angstrom.

Correlation

Thanks to its revolutionary platform designed for industrial metrology, the XE-AFM will correlate with any existing Park industrial AFMs that have been previously used for manufacturing, inspection, analysis, or research.



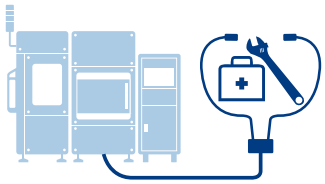


System Uptime

Our engineers and scientists adopted the most rigorous industry standard of product development to ensure the highest level of system reliability. The XE-3DM can be seamlessly incorporated as either an inline or offline inspection tool with minimal maintenance requirements.

Service & Maintenance

Park Systems is committed to the highest level of service and support, and every effort is made to understand our industrial customers' needs. We place the utmost importance on meeting promised delivery dates, guaranteed quality, and faithful after-sales service.



XE-3DM
Decoupled XY & Z Scanners

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XEA & OPTIONS

Software & User Interface

XEA - Industrial Automation & Analysis

XEA is a system software for automation that carries out the AFM measurement of a sample following the preset procedure written in a recipe file. User-friendly XEA architecture provides flexibility to operator to perform various system-wide functions.

- Supports auto, semi-auto, and manual mode
- Editable measurement method for each automated procedure
- Live monitoring of the measurement process
- Automatic analysis of acquired measurement data

XEP – Data Acquisition

All the user controls on AFM measurements are operated through XEP, the data acquisition program. The user-oriented interface provides easy operation of AFM.

- Simultaneous data acquisition of up to 16 images
- Maximum 4096 × 4096 image size
- Dedicated Force-distance and I-V spectroscopy with batch processing
- Cantilever spring constant calibration
- Script-level control through external program (LabVIEW, C++)

XEI – Image Processing and Analysis

XEI is the AFM image processing and analysis program. The powerful processing algorithms make the analysis easy and streamlined. With its most advanced and versatile imaging features, XE users can obtain essential and critical information from their experiment.

- Image analysis of line profile, region, 3D rendering
- Spectroscopy data analysis module (F-d, I-V)
- Directly copy/paste to presentation program
- Multiple image comparison
- Image overlay of two different images

Options

Automatic Tip Exchange (ATX)

Automatic Tip Exchange performs fully automated tip exchanges in order to seamlessly continue automated measurement routines. It automatically calibrates cantilever location and optimizes measurement settings based on measurements of a reference pattern. Our novel magnetic approach to the tip exchange yields a 99% success rate, higher than the traditional vacuum techniques.

Automatic Wafer Handler (EFEM or FOUP)

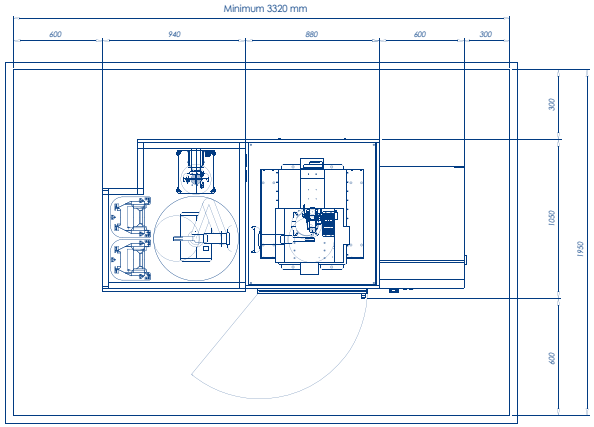
The XE-3DM can be further customized by adding an automatic wafer handler (EFEM or FOUP or other). The high-precision, nondestructive wafer handler robot arm fully ensures XE-3DM users to receive fast and reliable wafer measurement automation.

Ionization System

The XE-3DM can be equipped with an Ionization system which effectively removes electrostatic charges. It ionizes the charged objects and is very reliable since the system always generates and maintains an ideal balance of positive and negative ions without causing any contamination to the surrounding area. It also reduces the accidental electrostatic built-in charge that may occur during sample handling.

SPECIFICATIONS

Footprint



• System Specification

200mm Motorized XY stage:
travels up to 275 mm × 200 mm, 0.5 μm resolution
300mm Motorized XY stage:
travels up to ~375 mm × 300 mm
0.5 μm resolution, <1 μm repeatability
Motorized Z stage:
~30 mm Z travel distance
~0.08 μm resolution, <1 μm repeatability
Motorized Focus Stage:
11 mm Z travel distance for on-axis optics
Motorized Angle Range:
-19 degree and +19 degree
-38 degree and +38 degree
<0.5 degree angle repeatability
Sample Thickness Allowance:
up to 20 mm
Full scan range Z run-out:
< 2 nm, repeatability <1 nm
COGNEX Pattern Recognition:
pattern align resolution of 1/4 pixel

• Scanner Performances

XY Scanner Range:
100 μm × 100 μm (large mode)
50 μm x 50 μm (medium mode)
10 μm × 10 μm (small mode)
XY Scanner Resolution:
1.5 nm (high voltage mode)
<0.2 nm (low voltage mode)
Z Scanner Range:
12 μm (high voltage mode)
1.7 μm (low voltage mode)
Z Scanner Resolution:
< 0.2 nm
Z Scanner Noise Floor:
<0.05 nm (w/ Active Vibration Isolation System)

• AFM and XY Stage Control Electronics

Controller Processing Unit:
600 MHz and 4800 MIPS
Signal ADC & DAC: 16-bit
500 kHz bandwidth, internal lock-in

• Vibration, Acoustic Noise, and ESD Performances

Floor Vibration:
< 0.5 μm/s
(10 Hz to 200 Hz w/ Active Vibration Isolation System)
Acoustic Noise:
>20 dB attenuation w/ Acoustic Enclosure

• Dimension & Weight

200mm System:
880(w) × 1050(d) × 2024(h) w/o EFEM
800 kg approx. (incl. XE-3DM main body)
1820(w) × 1050(d) × 2024(h) w/ EFEM
1010 kg approx. (incl. XE-3DM main body)
Control Cabinet:
800(w) × 800(d) × 1000(h)
160 kg approx. (incl. controllers)
600(w) x 800(d) x 2000(h) tower type
220 kg approx. (incl. controllers)
System Floor Space:
1780(w) × 980(d) w/o EFEM
System Floor Space:
3050 (w) × 980 (d) w/ EFEM
Ceiling Height:
2000 or more
Operator Working Space:
3300(w) x 1950(d), minimum (dimension unit: mm)

300mm System:
1220(w) × 1200(d) × 2024(h) w/o EFEM
1150 kg approx. (incl. XE-3DM main body)
2490(w) × 1720(d) × 2024(h) w/ EFEM
1450 kg approx. (incl. XE-3DM main body)
Control Cabinet:
800(w) × 800(d) × 1000(h)
160 kg approx. (incl. controllers)
600(w) x 800(d) x 2000(h) tower type
220 kg approx. (incl. controllers)
Wafer Handler (EFEM):
1270(w) x 1720(d) x 2024(h), 300 kg approx
System Floor Space:
1220(w) × 1200(d) w/o EFEM
System Floor Space:
2490 (w) × 1720 (d) w/ EFEM
Ceiling Height:
2000 or more
Operator Working Space:
4500(w) x 3120(d) (dimension unit: mm)

• Facility Requirements

Room Temperature (Stand By):
10 °C ~ 40 °C
Room Temperature (Operating):
18 °C ~ 24 °C
Humidity:
30% to 60% (not condensing)
Floor Vibration Level:
VC-E (3 μm/sec)
Acoustic Noise:
Below 65 dB
Pneumatics:
Vacuum: -80 kPa
CDA: 0.7 Mpa
Power Supply Rating:
208~240V, single phase, 15A (max)
Total Power Consumption:
2 KW (typical)
Ground Resistance:
Below 100 ohms

XE-3DM
Decoupled XY & Z Scanners

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