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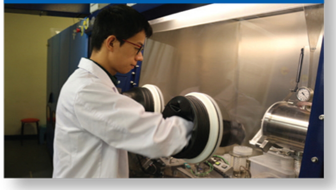
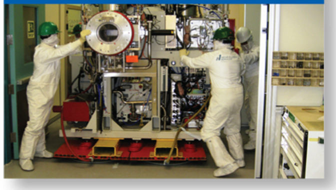
Volume 38 Issue 3 2016 @siliconsemi www.siliconsemiconductor.net

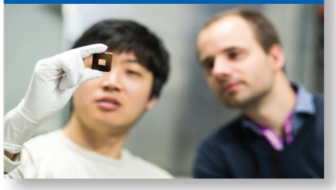
Mastering III- Vs and silicon



Managing relocations



EUVL high volume manufacturing



Reduce gold usage

Advances in nanotechnology

Wafer defects can't hide from **Park Systems**

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Park NX-3DM

Simplifying 300 mm silicon wafer defect review with automated high-resolution Atomic Force Microscopy 3D imaging

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Article published in Issue 3 2016

Wafer defects can't hide from Park Systems

Atomic Force Microscopy (AFM) leader Park Systems has simplified 300mm silicon wafer defect review by automating the process of obtaining high-resolution 3D images, making it faster and simpler than ever before.

SEMICONDUCTOR MANUFACTURERS have options for defect review once inspection tools have identified potential flaws on bare silicon wafers. While conventional AFM provides data-rich 3D images, the process is slow compared to 2D, SEM-based techniques. A new AFM process developed by Park Systems changes that equation like none other.

Park Systems (Suwon, Korea and Santa Clara, California, USA) is one of the leading pioneers of atomic force microscopy (AFM) for semiconductor manufacturers and researchers. The company's founder (Sang-Il Park, PhD) led early efforts to commercialize the technology after being an integral part of AFM's development team at Stanford University in the 1980s.

Park Systems made the extreme, high-resolution 3D imagery of AFM commercially practical, going on to develop products and software for surface roughness measurement in hard disk media that became an industry standard (the Park HDM series product family). Park's AFMs are also 'non-contact' review tools, which eliminates the possibility of tool tips accidentally touching surfaces and possibly damaging wafers under review.

While quality, data-rich images have been a hallmark of Park's AFMs from the beginning, this extreme quality came at the price of speed and simplicity. The company subsequently automated AFM scanning for disk media and has now brought a similar approach to reviewing defects of interest (DOI) on silicon wafers up to 300mm. Its hardware and software also support extreme ultraviolet (EUV) reticle photo masks, a critical step in creating future 450mm silicon wafers.

Finding silicon wafer DOIs is challenging. All bare silicon wafers have a unique crystalline structure that is prone to small defects (Figure 1)that may be one nanometer or smaller. Manufacturers determine threshold sizes of interest along with shape and

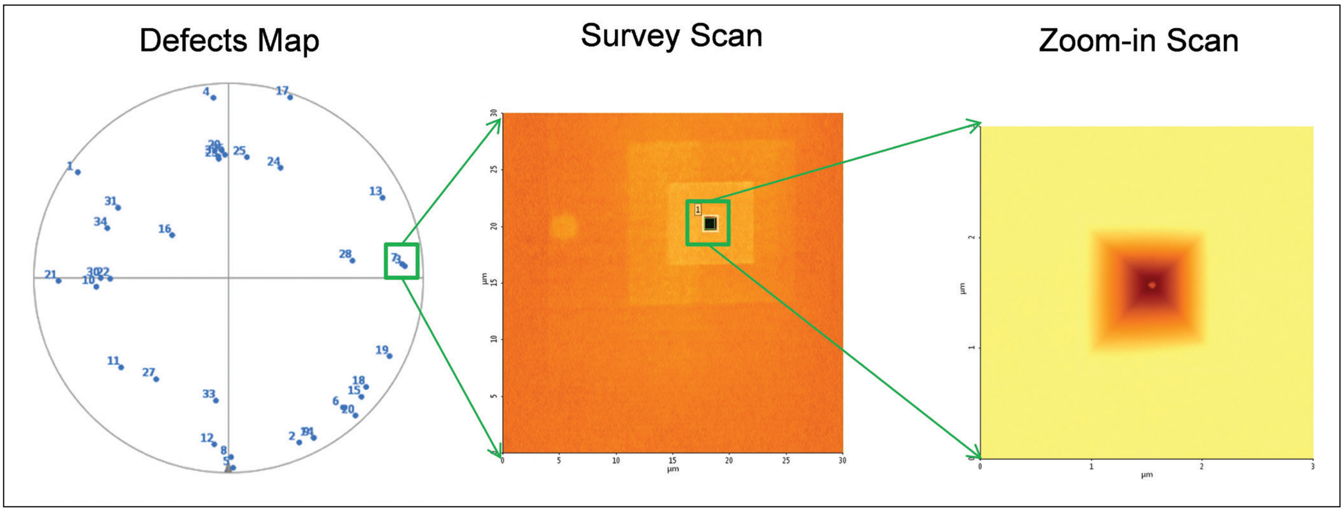


Figure 1: After coordinate mapping, ADR AFM will automatically perform a survey scan, zoom-in, processing, analysis and classification of each defect.

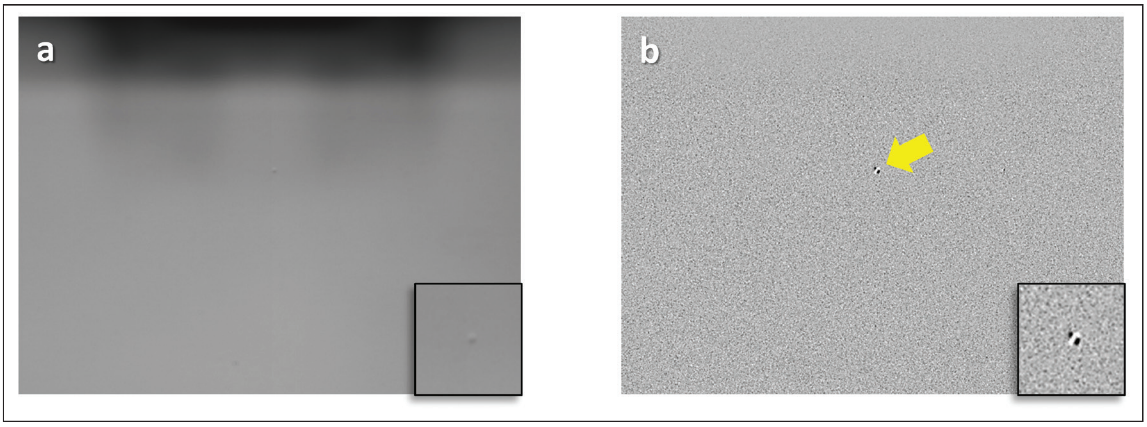


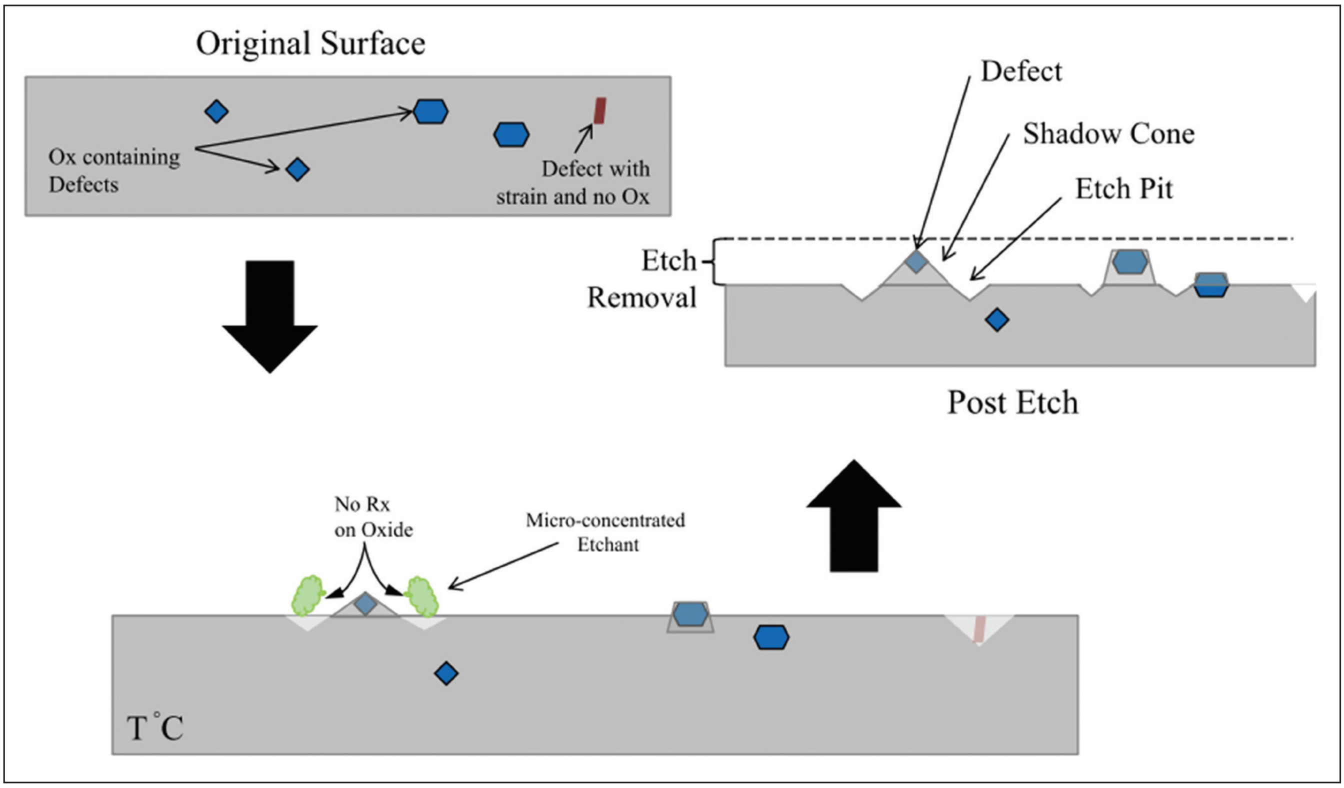
Figure 2: Images collected via (a) standard vs. (b) enhanced vision of a bare silicon wafer with one small defect. The insets show magnified views. The small defect is easily observable in enhanced vision.

depth characteristics that need attention. But while thresholds vary by manufacturer, it is clear that shrinking device geometries will impact whether defects once considered too tiny for concern could present problems for next-generation devices. There are a variety of laser light scattering techniques and process tools for inspecting wafers quickly, scanning hundreds or even thousands per hour. But inspection is just the beginning. A follow-up review by scanning electron microscope (SEM) or AFM takes inspection coordinates and zeros in on each location to image the defects. While SEM review is relatively quick, it cannot reveal much detail beyond a 2D image: a defect's 'X' and 'Y' dimensions. AFM goes much farther, creating X, Y and Z 3D images along with detailed topographic maps that further help identify and characterize an imaged DOI. AFM reveals defect details that SEM can routinely miss.

Park's AFM defect review is highly accurate, which is a key ingredient for success in an industry that measures in microns and nanometers. The accuracy of their AFMs is so great that the company holds a roughly 90 percent share of the market for hard disk drive defect review systems.

"Whether the defect is on a silicon wafer or the surface of hard drive media, the key is how accurately the review device locates it and delivers the information needed for proper defect classification. SEM may give

Figure 3: Schematic of the process used to decorate crystal imperfections for defect inspection.



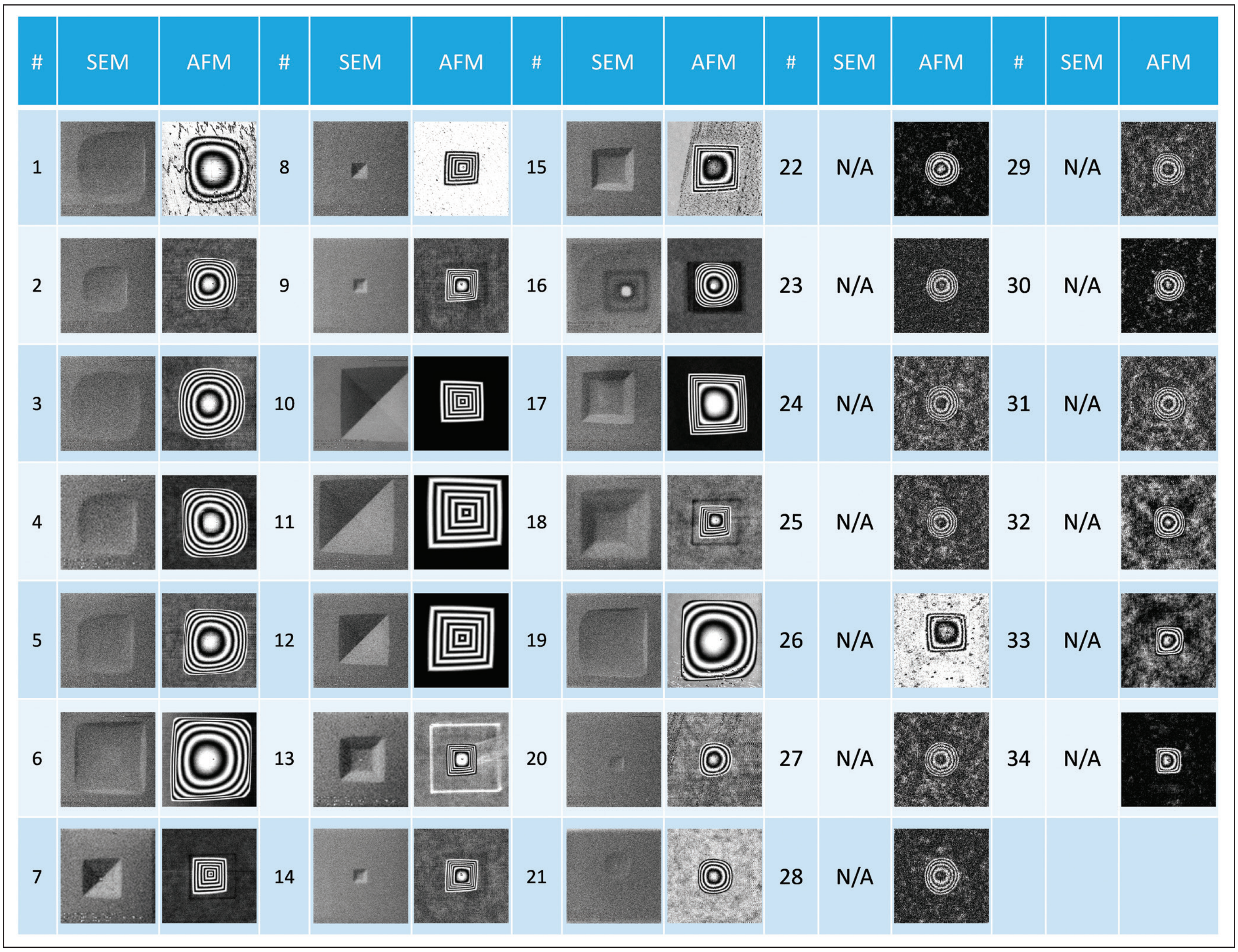


Figure 4: Defect review results with ADR AFM vs. SEM are shown. ADR AFM was able to locate and image all defects; SEM did not find defects 22 to 34. AFM and SEM images are rotated 180 degrees with respect to each other.

a quick image, but it lacks the information that can be provided by AFM (see figure 4).

“As a reference tool, AFM is the ‘go-to’ technology. Other AFMs can be a challenge to operate, so Park Systems addresses the problem with ADR: automatic defect review. We automated defect review and simplified it, so any technician can start the review process, and then simply walk away to do other tasks while the ADR AFM is operating,” said Ardavan Zandiatashbar, PhD, Park’s senior applications scientist.

While different manufacturers have varying approaches to how they handle silicon wafer defects, all likely agree that better data about a particular defect determines whether it is serious enough to affect lithographic processing, or whether defects are so great in number and size that a wafer should be rejected outright.

“We started with hard drive media defect review. Manufacturers needed to know the source of defects for failure analysis purposes. While SEM can give a quick image, its image can’t easily tell you if a defect is a pit or a bump or how tall or how deep it is. This is where AFM comes in; it helps you to identify and classify defects accurately and completely. We do what others cannot do,” Zandiatashbar said.

Wafer defects in Park’s study typically fall into eight basic categories—additional categories in different wafer surface reviews are possible. Some defects can’t be classified at the inspection stage and may not fit into a typical category even after AFM review. But through AFM, the manufacturer will definitely know a defect’s size and depth; they can apply their own standards to determine what actions should be taken.

“Many manufacturers want to use AFM routinely, but locating the defects and linking the AFM to inspection tools were critical issues previously. Results from conventional AFMs depend on the skill of the operator. We eliminated those issues by automating the process. Now, instead of reviewing just a few defects per day through laborious efforts and changing

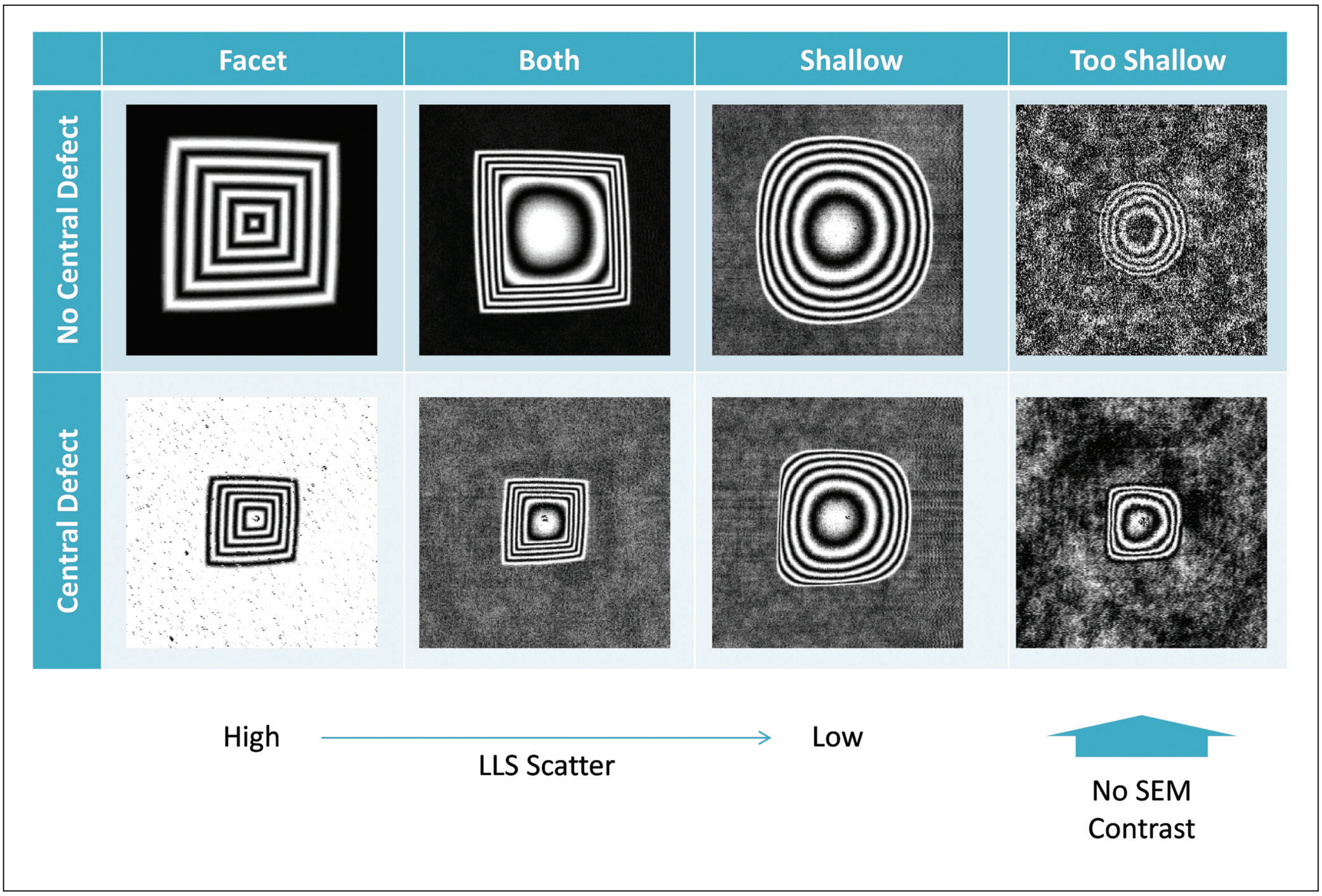


Figure 5: Defect classification based on the AFM data.

numerous tool tips, Park's ADR AFM can image and fully characterize between four and 10 defects per hour. A technician can start ADR and let it run 24/7. Manual AFM review proceeds only as quickly as a skilled operator can function," he added. "Park's ADR AFM is a turn-key solution."

In addition to automating the review process, Park's non-contact approach to AFM does not alter the wafer's surface in any way, meaning every wafer reviewed can go onto further processing as needed. SEM-based review processes have another issue beyond quality of data. Their electron beams also have the potential to 'burn' scan areas (see figure 6). This effect is typically more critical for photo-resist layers, but any disruption of a wafer's surface area can affect yield or other important factors.

The differences in results obtained using Park Systems ADR AFM compared to SEM-based results are dramatic. In a test conducted by Park, a wafer containing surface defects was reviewed using both SEM and AFM-based techniques. The ADR AFM utilized was from Park's NX-WAFER family of products. 34 defects identified at the inspection stage were candidates for review. The first 21 defects were imaged by SEM, which delivered aerial, 2D views without sufficient information about the depth or out-of-plane dimensions. The remaining 13 defects were not found by SEM despite identification during a laser light scattering (LLS) inspection (see figure 4).

Park's ADR AFM was able to find all 34 defects. The SEM had found defects down to a certain size threshold; those imaged by ADR AFM were typically

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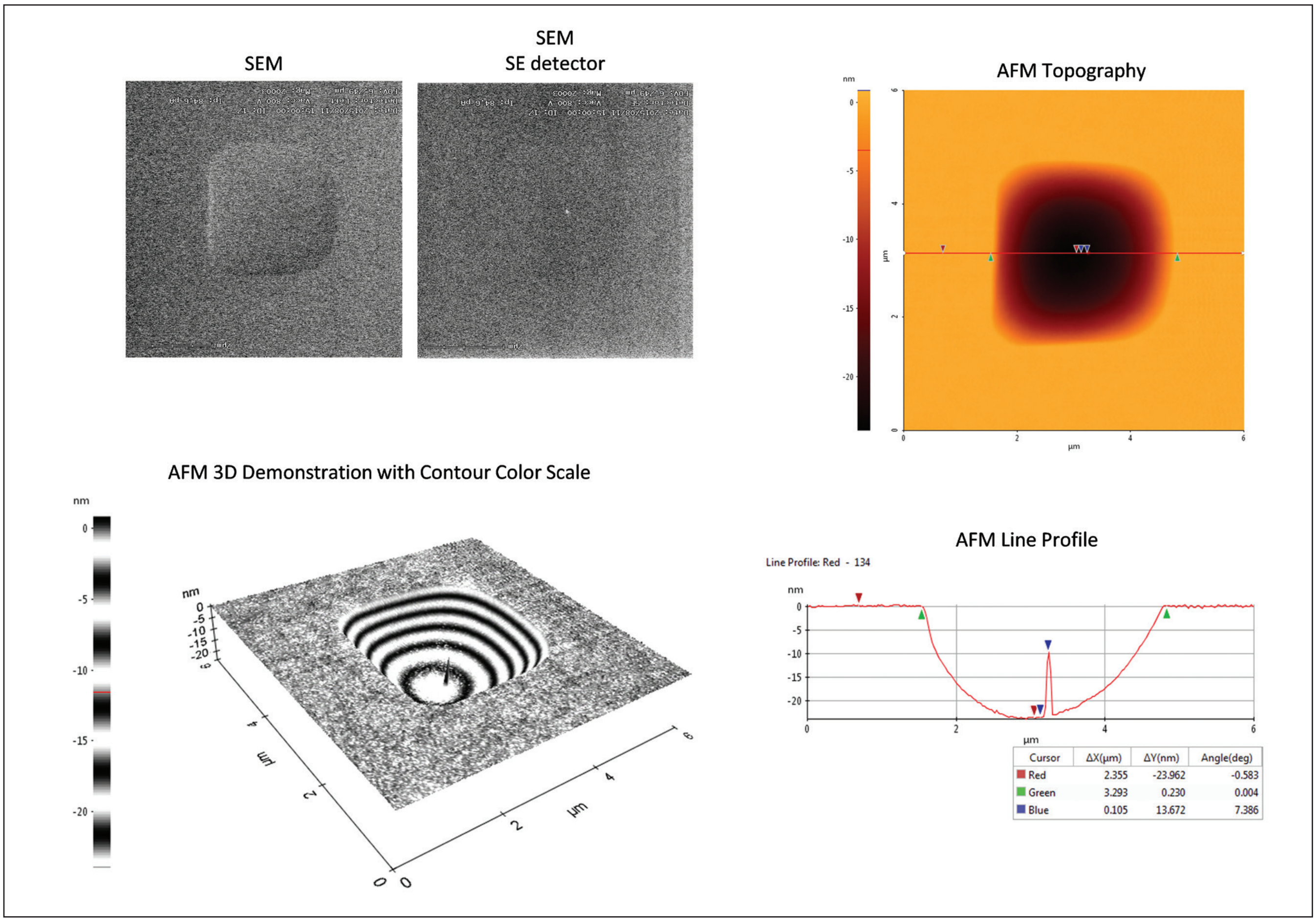


Cursor	ΔX(µm)	ΔY(nm)	Angle(deg)
🟥 Red	2.355	-23.962	-0.583
🟩 Green	3.293	0.230	0.004
🟦 Blue	0.105	13.672	7.386

Figure 6: Comparison of data collected by SEM vs. ADR AFM. SEM shows a 2D, aerial view, while ADR AFM includes 3D data, thereby enabling a line profile, 3D construct and contoured colour scale.

smaller or shallower than defects that the SEM could identify. The SEM also had issues identifying defects that had less edge sharpness, whereas the AFM in its automated scanning mode found everything (see figure 6) .

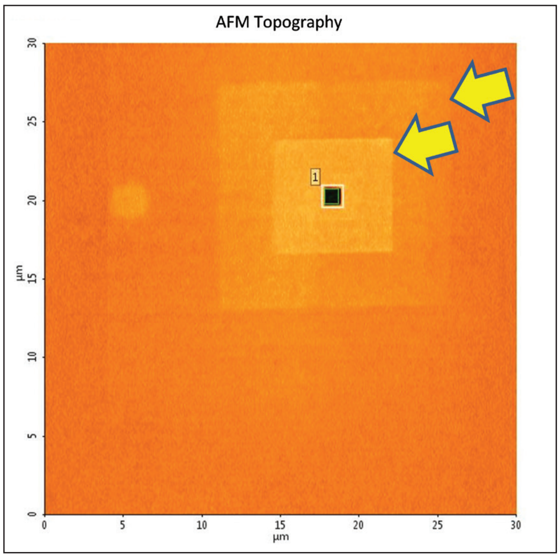
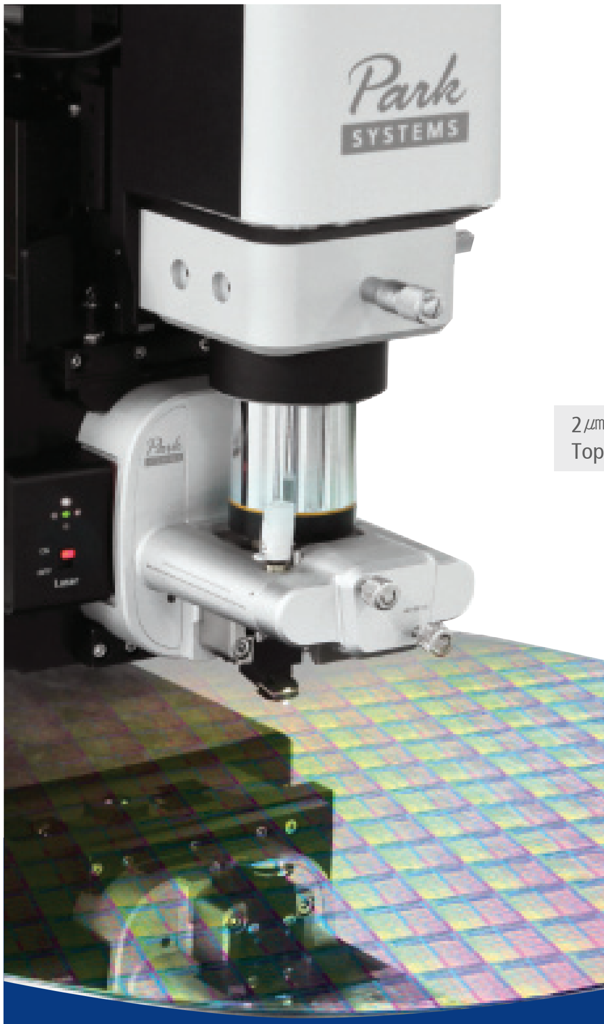
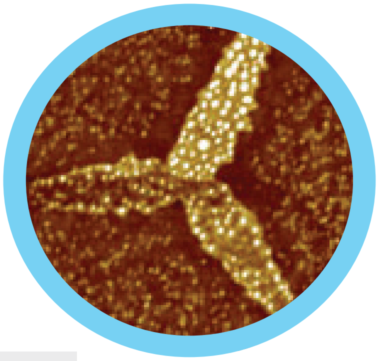


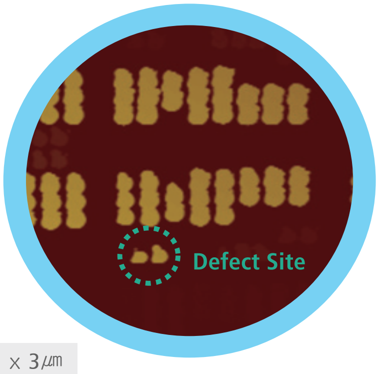
Figure 7: AFM image of a facet defect with several SEM burn-marks is shown; burns are marked by arrows.

“From the customer perspective, locating the defects of interest during the review process and determining size and depth can be critical. While SEM-based techniques can locate larger defects, it does not find them all and in fact missed 13 of 34 in this case. The lack of 3D information and SEM’s inability to image the shallow and small defects matters to manufacturers. With Park’s automatic defect review manufactures can have high quality 3D data of DOIs more quickly using a turn-key solution that any technician can operate,” said Zandiatashbar. Automatic defect review from Park Systems maximizes productivity by up to 1,000 percent as reported by customers. But what satisfies customers most is the unprecedented level of accuracy including 3D imagery and detailed topographic information of even the smallest defects. With ever-shrinking semiconductor device geometries reaching beyond 14nm, defects critically impact microelectronic device performance. Park’s approach to automating 3D imaging is revolutionary because it makes the benefits of AFM practical for leading device manufacturers and researchers pushing future product generation boundaries.

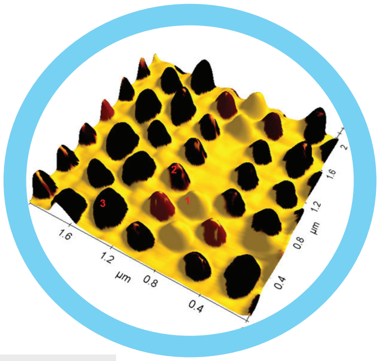




2㎛ x 2㎛
Topography of MoS_2 on SiO_2



3㎛ x 3㎛
Failure analysis of contact plugs



2㎛ x 2㎛
Topography of SRAM Device

Power, Versatility, ease of use brilliantly combined for large sample AFM

Park NX20

Accurate large sample AFM solution for research and FA laboratories

- Surface roughness measurements for media and substrates
- Large 300mm x 300mm sample size increases possibilities
- Defect review imaging and analysis
- High resolution electrical scan mode
- Accurate AFM topography with low noise Z detector

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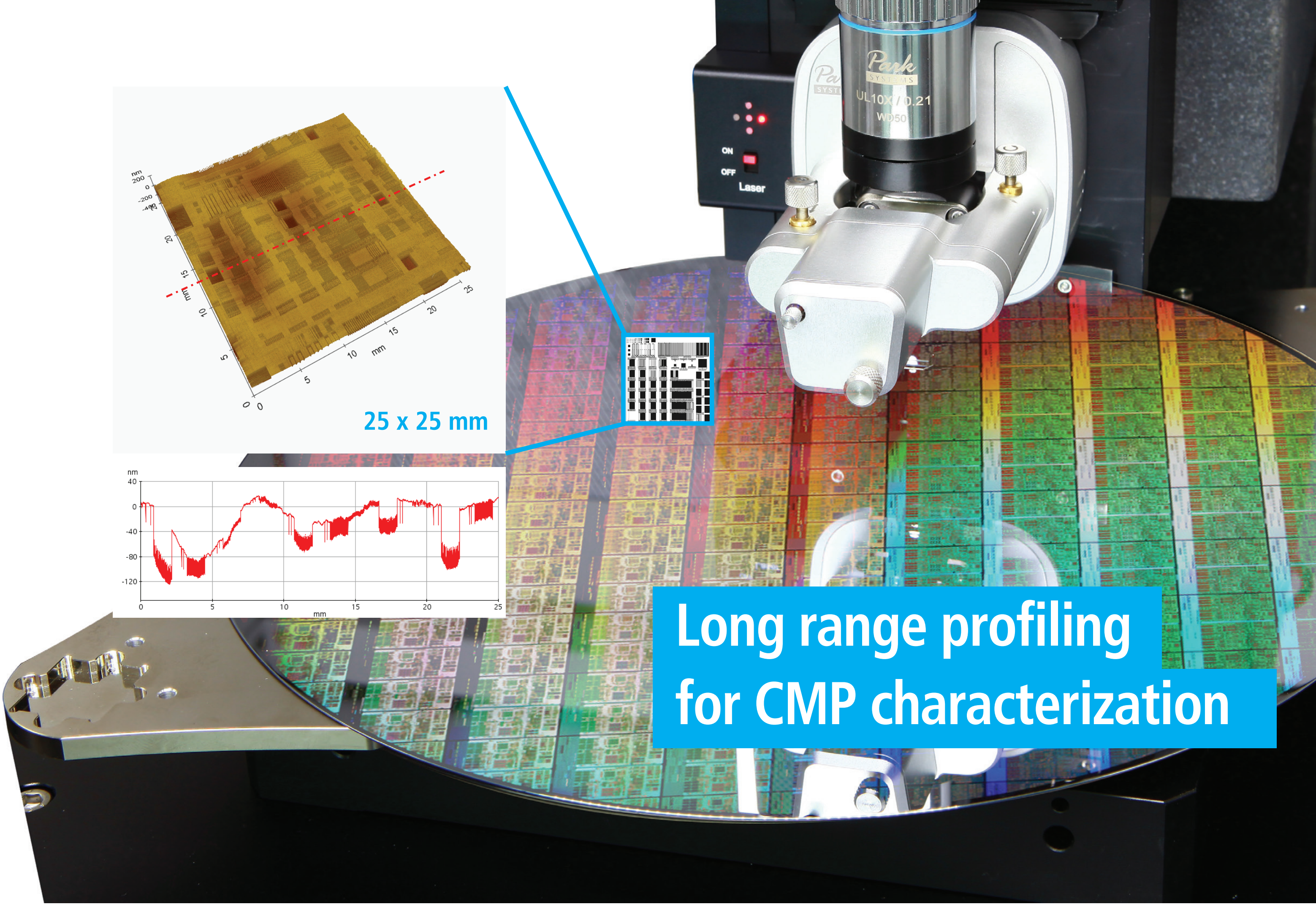
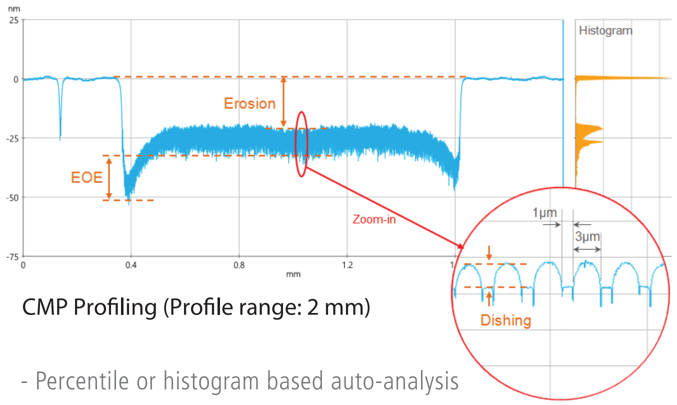


Long range profiling for CMP characterization

Park NX-Wafer

Low noise, high throughput atomic force profiler for CMP characterization

- Low noise atomic force profiler for more accurate CMP profile measurements
- Sub-angstrom surface roughness measurements
- Fully automated AFM solution for defect imaging and analysis
- Capable of scanning 300 mm wafers
- Can improve defect review productivity by up to 1000%
- Minimal tip-to-tip variation



CMP Profiling (Profile range: 2 mm)

- Percentile or histogram based auto-analysis
- Erosion, EOE (Edge-Over-Erosion) and Dishing

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