CMP Pad Metrology

with NOVACAM™ Non-Contact 3D Metrology Systems

Keywords: CMP pads, grooves, channels, lands, geometrical dimensioning and tolerancing (GD&T), groove depth, groove profile, surface topography, non-destructive testing (NDT), non-contact measurement

Introduction

In semiconductor manufacture, CMP (chemical mechanical planarization or polishing) is a mechanized process for flattening and smoothing silicon wafers. To achieve perfect flatness and mirror-like finish, the wafer is mounted on a rotating fixture and pressed against a spinning CMP pad, while ultra-fine chemical slurry is sprayed onto and channeled around the pad surface. Together, the corrosiveness of the slurry and asperities on the CMP pad surface wear away the wafer surface.

CMP pad surfaces are typically patterned with narrow grooves that distribute the slurry. To ensure optimal CMP process performance, the entire CMP pad surface, including these grooves, is subject to strict quality control (QC) during pad manufacture. An example of QC inspection measurements of CMP pad grooves is shown in Figure 1.

CMP Pad Measurements: 3D, High-Precision, Non-Contact, Automated

NOVACAM 3D metrology systems bring CMP pad manufacturers unprecedented capabilities for fast and comprehensive measurements. These capabilities include:

- Non-contact 3D surface measurements with 1 µm (40 µin.) axial resolution
- Ability to scan high-aspect-ratio features such as the narrow CMP pad grooves

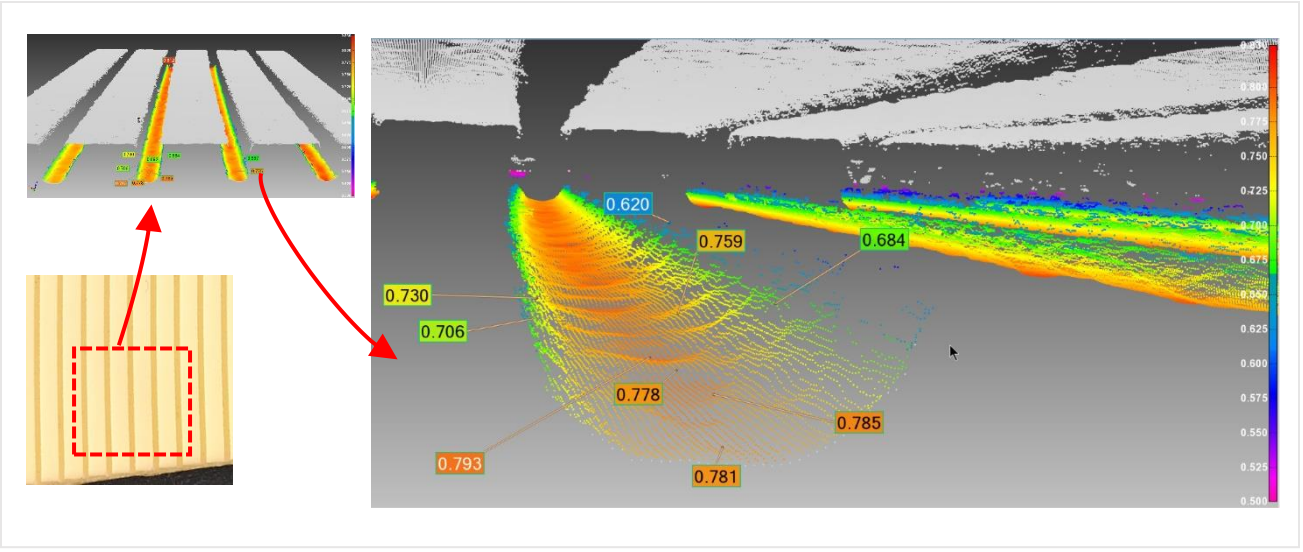

Figure 1: A 10mm x 10mm area of a CMP pad surface (bottom left) was scanned, providing a 3D point cloud of micron-precision measurements for analysis (top left). In a zoom-in view of one of the grooves (right), tool marks on the groove bottom are readily visible. The depth of the grooves is seen to range between 0.750 and 0.800 mm.

- High-speed surface acquisition - up to 100,000 3D measurements/sec
- Dimensional and roughness measurements with the same probe
- Ability to obtain long profiles
- Facility for automated measurement both in lab and in high-volume automated production.

Measuring CMP Pad Grooves

CMP pad grooves are the subject of much research. This is because the pattern, depth, and shape of these tiny channels influence slurry consumption and distribution, material removal rate (MRR), the rate of accumulation of polishing debris, as well as potential creation of scratches on wafers by this debris.

The grooves, however, pose a measurement challenge: due to the narrowness of their opening, measuring their bottoms is difficult or impossible with touch probes or with optical systems that rely on triangulation.

Fortunately, since NOVACAM 3D metrology systems scan in collinear manner – i.e., the beam of light travels up and down along the same path – even bottom corners of the steep walled grooves may be scanned completely. Figures 1 to 6 show examples of 3D data analysis following a scan of CMP pad grooves.

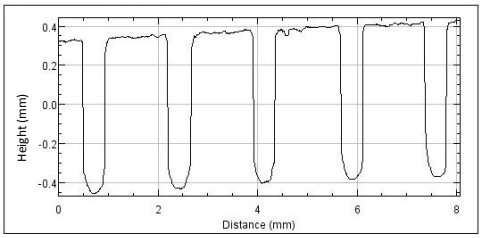

Figure 2: Example of CMP pad linear profile

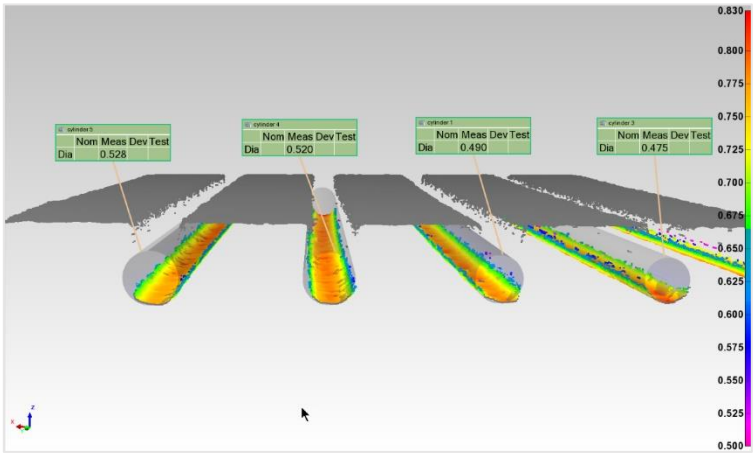

Figure 3: CMP pad 3D point cloud analysis. Using industry-standard PolyWorks® Inspector GD&T software, the bottom of each groove was fitted to a best-fit cylinder, with the calculated diameter of the cylinder shown in a green callout box.

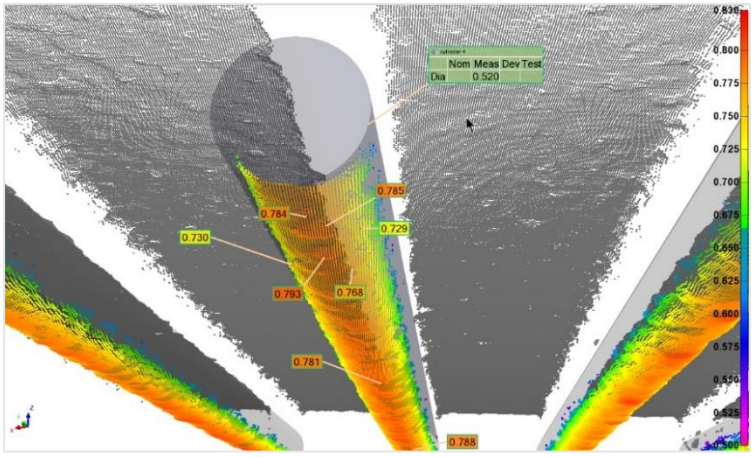

Figure 4: View from below of the same grooves clearly shows the tool marks of the bit used to machine the channels. Perfect cylinders were fitted on each groove to obtain a mean radius measurement. Here, the measured radii of curvature were found to vary between 475 and 528 µm.

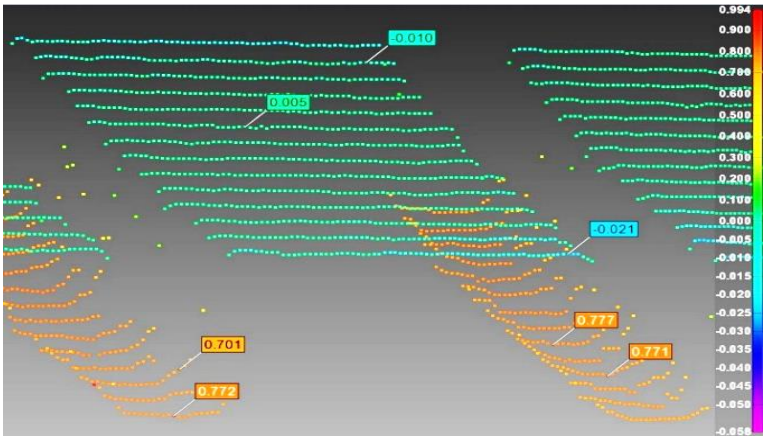

Figure 5: A sparser scan of the same pad (profile every 1 mm) may also be used to track CMP pad groove shape and depth.

Measuring CMP Pad Lands

Lands – i.e., the surfaces between grooves – may be similarly measured and analyzed. Figure 6 shows GD&T flatness parameter measurement of the CMP pad top surface.

Roughness Measurements

NOVACAM 3D metrology systems also measure roughness. This may be done with the same probe and in the same scan as for GD&T measurements.

On the above sample, linear roughness along three separate lands was measured with the Ra values listed here below.

Location	Land 1	Land 2	Land 3
Ra (µm)	1.2855	1.0865	1.0073

Long Profiles for Fast In-Process Measurements

Helping optimize the CMP pad inspection process, NOVACAM 3D metrology systems measure critical surface parameters in a fast and efficient fashion:

- Fiber-based optical probes are mounted on gantries or precision stages above the CMP pads. Manufacturers select from two basic types of probes: Standard optical probes (figure 7) or galvo scanning probes (figure 8)
- Scanning proceeds automatically along user-defined scan paths
- Measurement is done in a point-by-point manner at a rate of 100,000 3D point measurements per second.
- Long-profiles eliminate the need for time consuming tiling and stitching that would be required by microscope-type measurement systems.

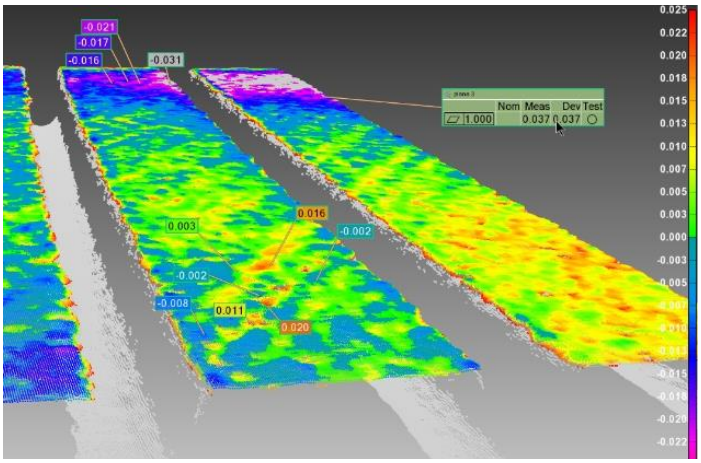

Figure 6: CMP pad top surface (land) analysis: the 3D point cloud of the measured top surface is displayed as a colour deviation map from a flat plane. The calculated GD&T flatness parameter value is shown in the green callout box.

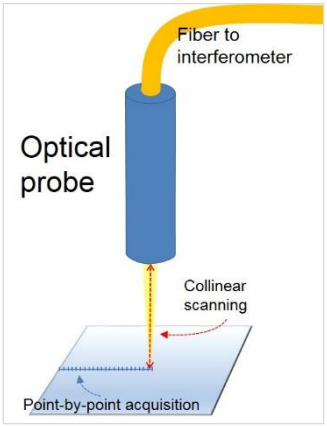

Figure 7: NOVACAM OPTICAL 3D PROFILOMETER system probe scans in a collinear manner.

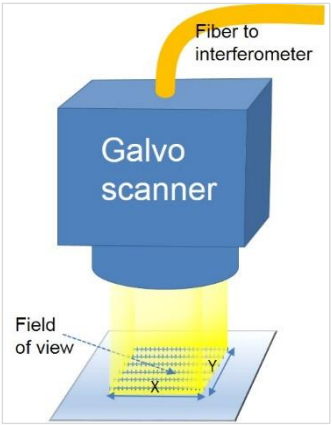

Figure 8: Galvo scanner probe scans in a raster pattern within the lens field of view (FOV). Continuous strip scanning is an option.

With scan data fed automatically and seamlessly into process control, CMP pad manufacturers are able to:

- Carry out 100% inspection of the pads
- Provide their customers with a QC report with each pad
- Log and trend measurements to optimize the use of consumables in their manufacture process.

Trending Consumables Performance

Grooves on CMP pads may be formed with lathes, routers, or CNC machines, or with stamps, presses or molds. Whichever tools are used, automated tracking of the produced CMP pad measurements enables manufacturers to determine when adjustments to their process or tools are required. Clients achieve operational savings by tracking the performance of their consumables and by cutting down on costly work stoppages.

Technology for Flexible Deployment and Automation

NOVACAM 3D metrology systems are based on low-coherence interferometry technology. An optical probe directs a beam of low-coherence light at the surface and captures the light signal reflected back. The probe is connected with an optical fiber to the system interferometer (MICROCAM™-3D or -4D), which processes the optical signal into 3-dimensional topographipcal measurements.

Since the optical fiber may be several meters long, each probe is easily integrated as an end-effector with various displacement mechanisms (stages, robot arms, gantries) and can be installed right on the plant floor, integrated within CMM and CNC machine, and can even deployed in harsh environments.

Additional Return on Investment (ROI) through Probe Multiplexing

Multiple NOVACAM probes may be connected to the same MICROCAM interferometer. With automatic switching between the probes, production lines can quickly switch between measurement of different aspects of the same CMP pad or between different CMP pads.

Conclusion

For high-precision measurements of CMP surfaces, NOVACAM 3D metrology systems bring speed, precision, and ease of deployment both in lab and high-volume automated production.

Novacam encourages managers and engineers in charge of CMP pad metrology to contact us to discuss your applications and any particular challenges.

Components of NOVACAM™ 3D metrology system used for CMP pad measurements

Component		Physical aspect	Deployment area
MICROCAM™-3D or - 4D interferometer*		19” rack-mountable instrument	Plant floor / control room
Workstation computer		Mini desktop-size PC or laptop	Plant floor / control room
Choice or combination of	Forward-looking profilometer probe(s)	As illustrated in Figure 7	Plant floor inspection station – either in manual (interactive) setup or fully automated inline inspection setup
	Galvo scanner probe(s)	As illustrated in Figure 8	

* Detailed technical specifications are available upon request

Novacam Technologies Inc.
1755 St. Regis, Suite #130
Dollard-Des-Ormeaux, QC, H9B 2M9, Canada

For more information,
visit www.novacam.com,
email info@novacam.com, or
call 514-694-4002 / toll-free: 1-866-694-4002

Document: AN-CMP -PAD-METROLOGY-1.1 (2021-04-28)