Surface Characterization and Roughness Measurement

with Low Coherence Interferometry

Keywords: surface roughness, 3D industrial inspection, low coherence interferometry, roughness parameters, white light interferometry, fiber-based profilometry, hard-to-reach surfaces, high aspect ratio, metrology, long-stroke profilometry, high precision, non-contact profilometry.

Introduction

Manufacturers in various industries require precise and reliable indicators of surface quality. Surface measurements are typically acquired in quality control laboratories.

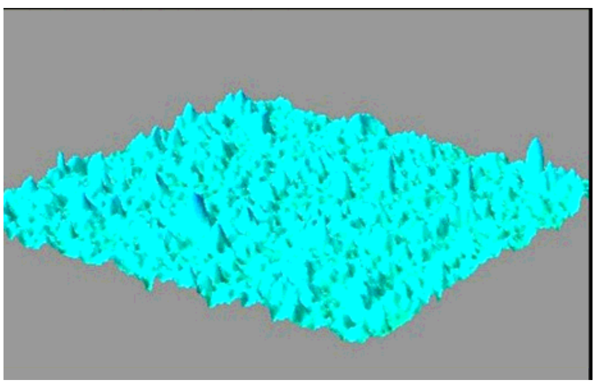

Figure 1: 3D representation of a plasma-coated cast metal strip surface

Preferably, they are acquired on the production line where they can provide feedback on the manufacturing or coating process. Unlike microscope-type profilometers, fiber-based profilometers are suitable for acquiring surface maps (Figure 1) in both lab and production environments. Fiber-based profilometers can acquire data with micron precision. Their small, rugged probes (Figure 2) can withstand harsh environments and extremely high temperatures. These non-contact probes can be used at a standoff distance of 30-150 mm and can be positioned far from the profilometer enclosure. The probe can also be mounted on a slide for scanning across a web-based production line.

Figure 2: Standard probe (16mm diameter)

For products that are more than a meter wide or long, a single probe or multiple probes can be mounted on an existing X-Y table for measuring surface roughness separately in the X and Y directions.

How Surface Roughness is Measured

A low coherence interferometer is an optical device that splits a beam of broadband light in the infrared range (1300nm) into two separate beams. One beam is directed at the object surface, and the other at a mirror in the interferometer's reference arm. The probe receives and recombines the reflected light from the sample and reference arms and records the resulting interference from which a wide range of information about the object can be retrieved: its surface shape, roughness and waviness, as well as single or multi-layer coating thickness.

Data Processing

The profilometer processor application software converts optical interference data into high-precision roughness measurements. In the production context, this stream of data is typically forwarded to process control software.

Measuring the Measuring Tape

A Mitutoyo roughness gage block (Figure 3) was scanned with a fiber-based profilometer.

Figure 3: Mitutoyo roughness gage block

Used as reference pieces, gage blocks are manufactured so that their micrometer-scale roughness conforms to precise gagemaker tolerance grades across their entire surface (Figure 4).

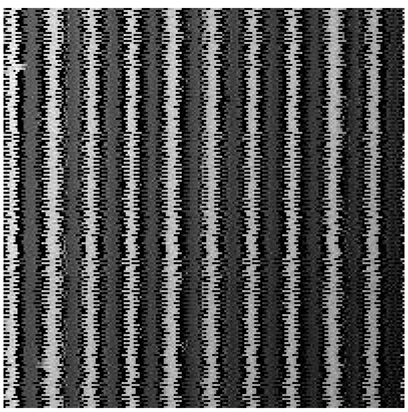

Figure 4: 1mmx1mm sample area of a roughness gage block, height encoded in gray scale

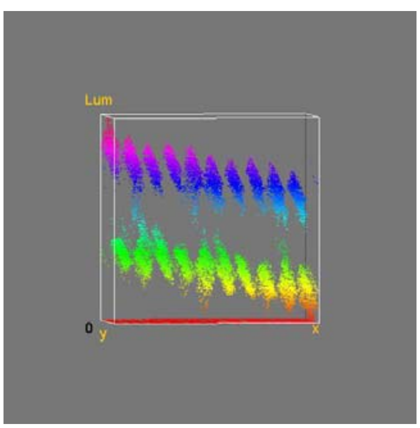

Figure 5: 3D representation of a 1mmx1mm sample area of a roughness gage

How Rough Does It Get? Characterizing a Fuel Cell

Sample fuel cell plates were scanned and imaged with the fiber-based profilometer (Figure 6). In addition to calculating the average roughness of the sample, other parameters were obtained (Table 1) expressing more precise surface roughness characteristics.

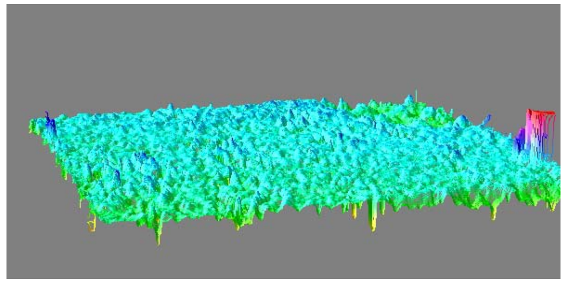

Figure 6: 3D representation of a 3mmx3mm sample of a fuel cell plate

Roughness indicator		Measurement
Ra	Average roughness	0.01 mm
Rq	Root mean square roughness	0.01 mm
Rsk	Skewness	-0.05 mm
Rku	Kurtosis	13.03
Rv	Maximum profile valley depth	-0.06 mm
Rp	Maximum profile peak height	0.09 mm
Rt	Maximum height (distance from highest peak to lowest valley)	0.16 mm

Table 1: Fuel cell roughness parameters

Why look beyond Ra?

Average roughness (Ra), a commonly used and well-established roughness parameter, is frequently inadequate for describing the specific character of material roughness. Surfaces with identical Ra's but dissimilar character may exhibit different properties when it comes to

- maximizing or minimizing contact with neighbouring substance or material
- ability to retain or shed fluids
- ability to resist certain kinds of wear
- ability to resist pressure and stress cracking

In the case of fuel cells, surface properties impact the fuel cell efficiency and must therefore be kept between specified target parameters. In addition to imaging the overall roughness of the fuel cell sample (Figure 7), the profilometer roughness application software can characterize the sample waviness and can separate waviness from the overall roughness.

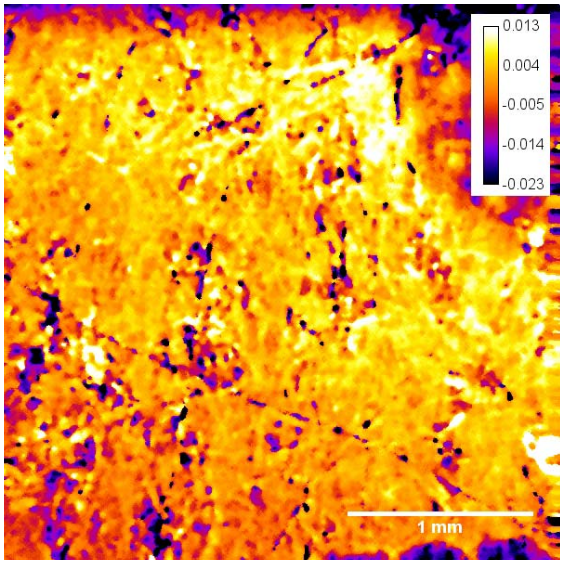

Figure 7: image of the 3mm x 3mm sample of fuel cell plate, 600pix x600pix, depth expressed by color

Watch your step - Measuring High Aspect Surface Roughness of CMP Pads

In the electronics industry, the surface of Chemical Mechanical Polishing (CMP) pads, used for smoothing interlevel dielectric layers, is patterned with high aspect channels for guiding abrasive chemical slurry around the polished wafer surface. The surface condition of the CMP pad, including the depth of its channels and the roughness of the surface between them, has direct effect on the pad's polishing performance. By measuring actual roughness parameters, technicians in charge of CMP pad monitoring can make the most cost-effective decisions on the timing of pad conditioning or pad replacement.

Too hot to handle - Measuring Plasma Coating in Metal Casting

Plasma coating is one of the most versatile methods of altering surface properties of metal cast elements. In a production environment, metal elements are sprayed with a plasma gun on a continuous basis as they move along a belt at several feet per second. Currently, plasma coating roughness and thickness are inspected in random samples, offline (as in Figure 1)

Fiber-based optical profilometers offer in-process roughness measurement, a significantly more comprehensive and cost-efficient inspection method. A probe is mounted on a slide for scanning across a web-based production line, where it scans and analyzes the roughness of passing elements in real time, in both X and Y directions. This results in a much faster detection of coating anomalies, more timely correction of system problems, and thus significantly higher savings.

Conclusion

Fiber based profilometers are ideally suited to surface characterization in both lab and manufacturing environments where high speed and micron precision are required:

- photovoltaic industry: wafer, cell and panel characterization
- semiconductor surfaces
- metal casting, metal plasma coating
- fuel and solar cells
- high grade glass such as in the optical industry
- multi-layer plastics and films
- high grade (single or multi-layer) polymer tubing
- pitting damage in particle accelerators and explosive labs

Novacam encourages technicians and engineers in charge of surface characterizations to send us samples for measurement.

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