Measuring **Super Smooth Surfaces**

Exploiting the potential of 3D optical profilometry

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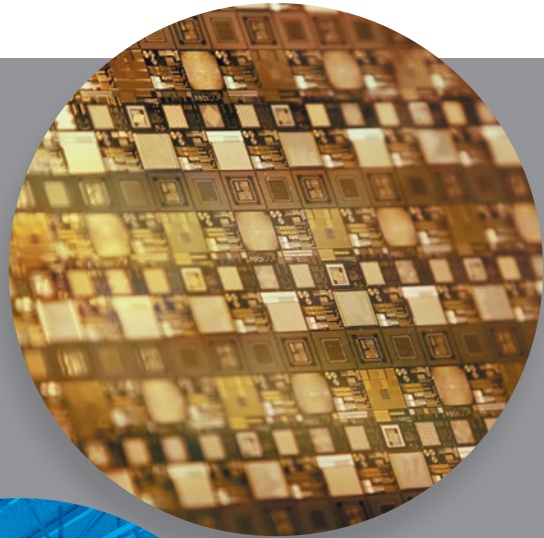

Where do we find smooth surfaces?

Smooth and super smooth surfaces find extensive applications across diverse fields and markets. The **optics market** prominently utilizes smooth surfaces, evident in the lenses, mirrors, and various other optical components used. Similarly, **consumer electronics** heavily rely on smooth surfaces, particularly in **semiconductors**' wafers, displays, and other critical components where functionality and assembly depend on impeccable smoothness. The **medical industry** also leverages smooth surfaces in medical implants, recognizing the vital role of roughness in ensuring compatibility and minimizing friction between elements.

Other fields that significantly benefit from smooth surfaces are **advanced manufacturing, aerospace, and automotive sectors**, as the roughness of numerous components directly influences the final functional performance of the respective workpieces. The multifaceted applications of smooth and super smooth surfaces demonstrate their indispensability in driving innovation and facilitating advancements across various industries.

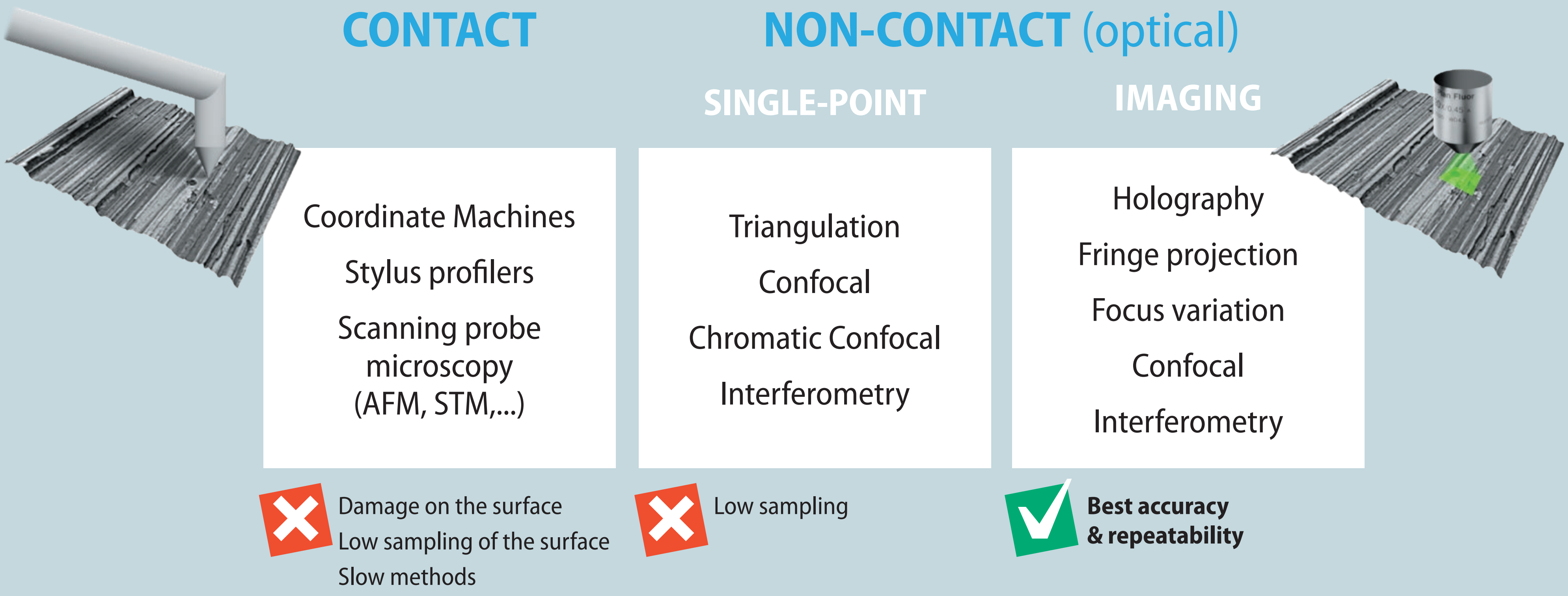

Figure 5. Classification of profilometry techniques based on contact with the surface.

They can all be classified according to different criteria, one being the distinction between contact and non-contact techniques [3]. Contact-based options encompass, for example, Coordinate Measuring Machines (CMMs) or stylus profilometers. Non-contact techniques can be further classified into single-point or imaging techniques based on their rastering technique. Optical techniques include Confocal, Focus Variation, or Interferometry, for example.

Considering the previous aspects, contact techniques are suboptimal for measuring smooth surfaces due to potential surface damage, limited surface sampling, and relatively slower speeds. Single-point imaging approaches are non-damaging but offer low sampling, providing an incomplete picture of surface characteristics.

Hence, **imaging techniques** are the preferred choice for characterizing smooth surfaces. They offer fast, non-contact measurement capabilities with improved surface sampling [4]. Among these techniques, **Interferometry** stands out for smooth surface measurement, delivering superior accuracy and repeatability.

WHEN TO USE PSI?

To compare the capabilities of CSI and PSI, let us consider an example involving the measurement of surface roughness on super smooth surfaces. Figure 6 shows the resulting measurements on a silicon carbide mirror with both CSI and PSI. The results are very different as they can be extracted from the average roughness parameter (Sa).

However, it is crucial to note that the CSI value lies within the range of noise associated with this technique; therefore, the measurement's accuracy is compromised.

On the other hand, PSI offers a significantly lower measurement noise, potentially as low as 0.01 nm. In this case, the Sa value is well above the background noise, indicating a more accurate measurement.
This is the reason why PSI is the preferred technique for measuring surface roughness of super smooth surfaces.

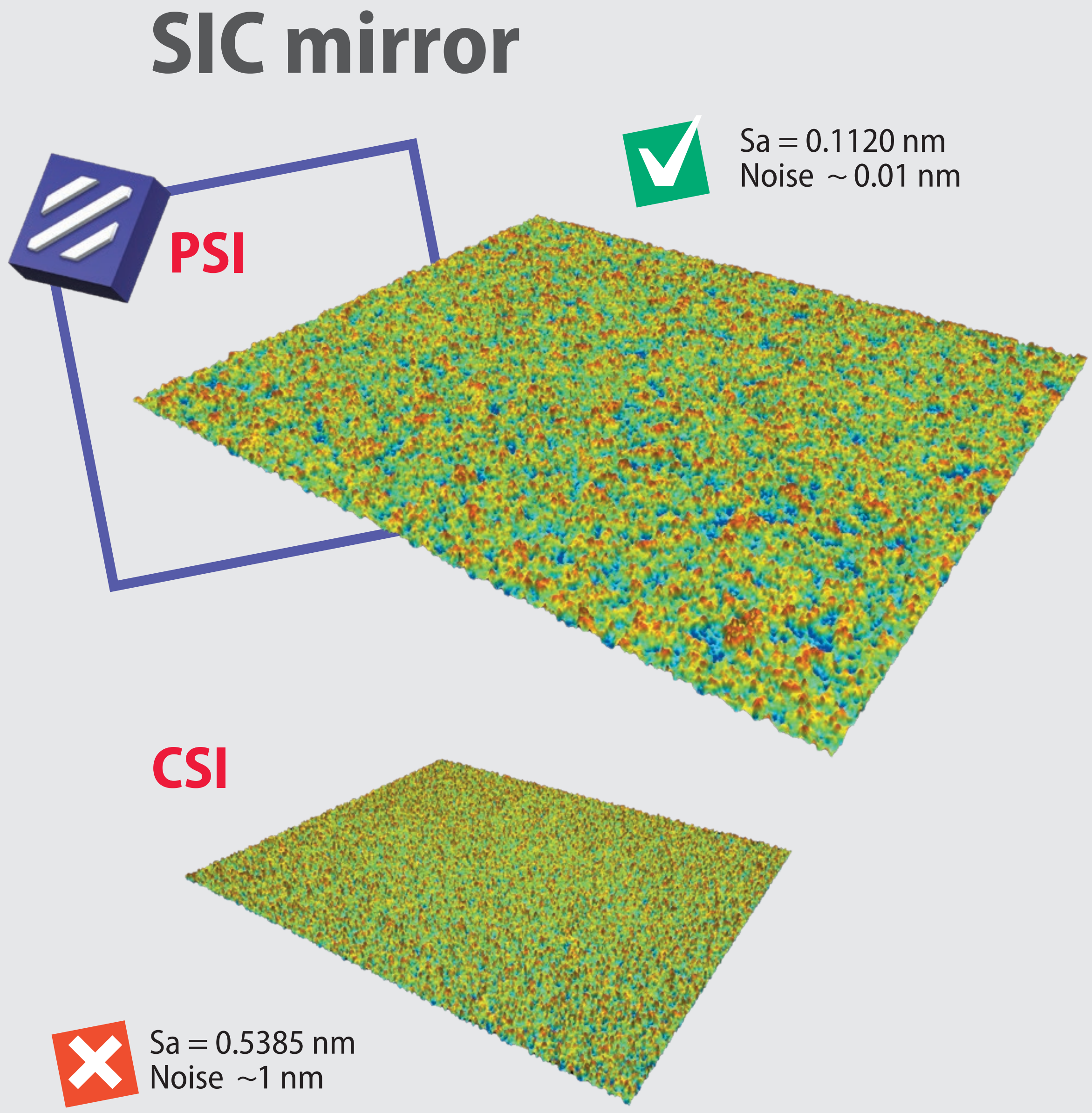

Figure 6. Measurement of a SiC mirror with CSI and PSI. Both topographies have been obtained with the same acquisition and filtering settings for comparison.

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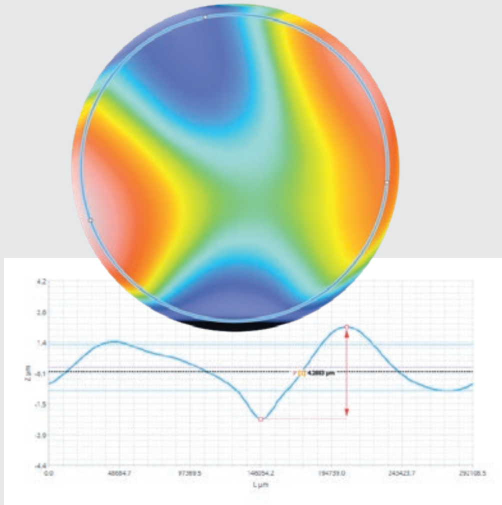
FLATNESS

In the case of flatness measurements, the hardware setup plays a critical role since flatness errors of the system will be the limiting factor for our measurements. These errors can come from the optical system or the moving stage (if image stitching is used). In the case of the example topography that we report here, we used a specialized configuration featuring a 0.65X magnification objective lens, a high stand, a granite table, and a high-precision XY stage.
The chosen technology here is ePSI, which offers the best possible vertical resolution across a wide range. We conducted a scan of a 100 mm diameter wafer, completing it in just four minutes. We applied the ISO 12781 standard to assess the flatness, which enabled us to obtain various parameters characterizing the surface.

It's worth mentioning the significance of the hardware utilized in this scenario. The Sensofar lens with 0.65X magnification offers a generous field of view while maintaining minimal flatness error. Combining this lens with a high-precision stage is crucial to ensure accurate flatness measurements. Standard stages can introduce errors on the micron scale, which can interfere with the flatness measurement.

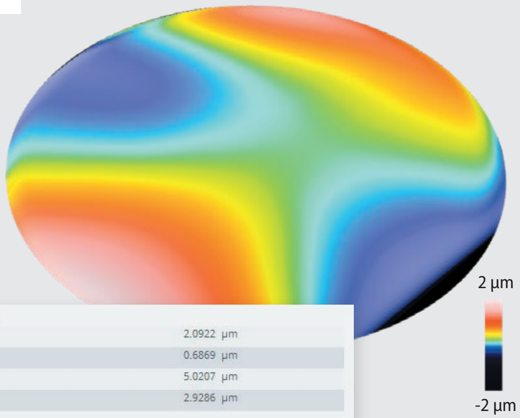
S neox

HARDWARE
Large stand
Granite table
0.65X lens
High precision stage



ACQUISITION
ePSI
100 mm x 97 mm
4'
21 µm / pixel
20 µm

ANALYSIS
S-filter: 8 µm
F-operator: Leveling plane
L-filter: –



ISO 12781 / Flatness deviation

FLTp	2.0922 µm
FLTq	0.6869 µm
FLTt	5.0207 µm
FLTv	2.9286 µm

Figure 13. Flatness characterization of a SiC wafer using S neox with a high-precision stage, 0.65X Michelson lens, and ePSI technique. Flatness parameters were obtained following ISO 12781 with an S-filter of 8 mm and a leveling plane as the F-operator.

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