



Dimensional Metrology Calibration of Photomasks for Optical Coordinate Metrology

Optical coordinate measuring machines are used increasingly in industrial production to enable efficient measurement of complex components. Glass line scales and two-dimensional photomasks are used to calibrate such measurement systems. The Federal Institute of Metrology (METAS) calibrates structure positions and roundness of circular structures using a photomask measuring system that it developed especially for this task.

Acceptance and reverification tests for coordinate measuring machines with imaging probing systems are described in the standard EN ISO 10360-7 [1]. Using suitable standards and a diverse set of measurements, it is possible to determine meaningful parameters and therefore to verify the manufacturer specifications during acceptance or to check the measurement accuracy during regular inspections. For this the length measurement error and the squareness error are determined. There are also three additional quantities used to characterise the imaging probing system. All of these parameters are critical for estimation of the measurement uncertainty.

Calibrated Photomasks

For determination of the length measurement error and squareness error, the simplest approach involves the use of calibrated glass line scales or two-dimensional photomasks with point or line gratings. In order to test an imaging probing system in a standards-compliant manner, calibrated test circles of different sizes and of known roundness are additionally required. With the aid of these structures, the length measurement error and the probing error of the imaging probe are determined. The quality of the used test circles is critical in this measurement since the probing error of the measuring machine cannot be specified beyond what is supported by the roundness deviation of the available test circles.

The Photomask Measuring System at METAS

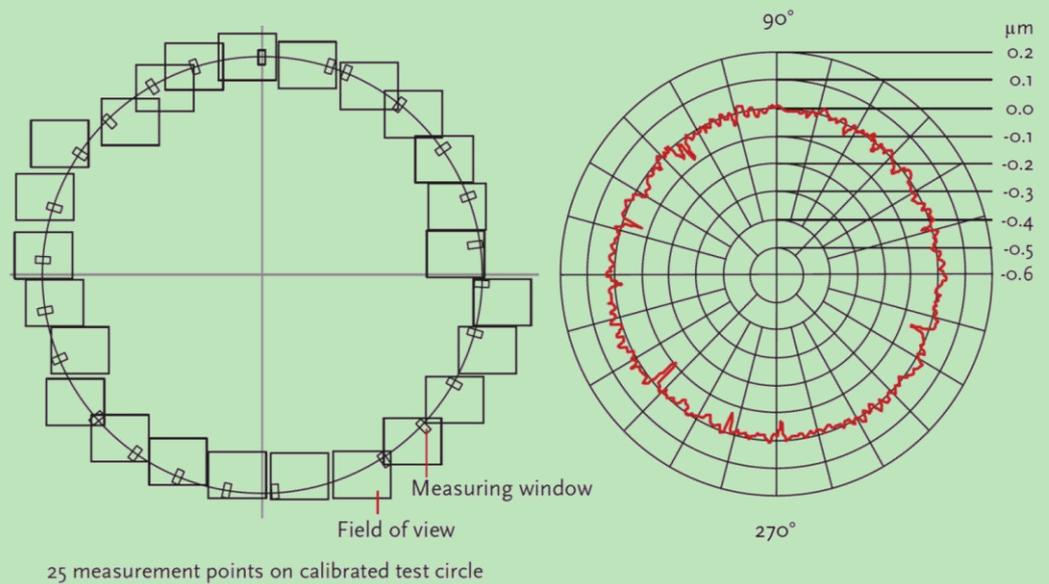
The photomask measuring system developed at METAS makes it possible to precisely localise and measure structures on glass. It consists of a high-precision, air bearing x-y table, a microscope and a two axis, differential plane mirror interferometer. The interferometer measures the position of the photomask relative to the microscope

Measurement Capabilities for the Calibration of Photomasks

Object/Measurand	Measurement Range/Parameters	Measurement Uncertainty ^a
Glass line scales		
Line spacing	0 ... 400 mm	0.05 µm
Photomasks^b with point or line gratings		
Structure position	300 mm × 400 mm	0.05 µm
Test circles: filled, empty, positive, negative		
Position	300 mm × 400 mm	0.05 µm
Diameter	0.01 mm ... 50 mm	1 µm
Roundness	500 UPR, 150 UPR, 50 UPR and 15 UPR filters	0.05 µm

^a best possible measurement uncertainty (k = 2); see www.metas.ch/length

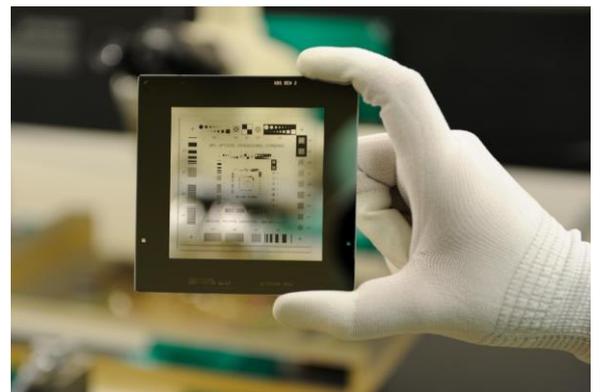
^b including MaskEvaluationTool; see www.metas.ch/nano



Left: possible point pattern for measurement of P_{F2D} in accordance with EN ISO 10360-7; right: test circle with diameter (1.9994 ± 0.0009) mm and roundness (0.15 ± 0.07) μm ; 150 UPR filter.

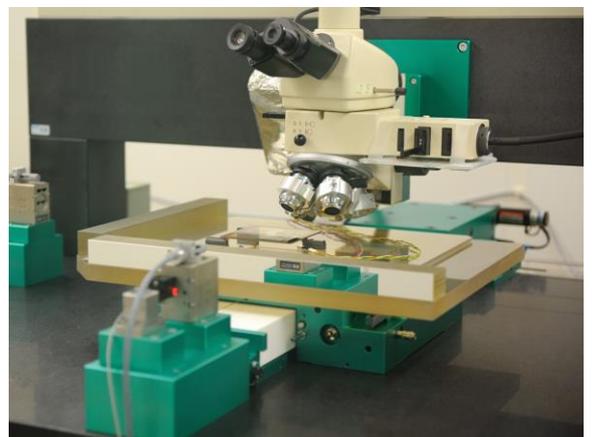
objective. The structures are recorded by a video microscope and their positions computed using digital image analysis. The measurement range is 400 mm x 300 mm.

Using a technique developed at METAS, it is possible to calibrate the diameter and the roundness of test circles. Usage of the parameters and specification operators for roundness is in accordance with the standards EN ISO 12181-1 and EN ISO 12181-2 [2]. Also filtered roundness parameters can be determined with 500 UPR, 150 UPR, 50 UPR and 15 UPR. The measurement uncertainty is in the range from 0.05 μm to 1 μm depending on the quality and size of the test circles.



Photomask with test circles and other patterns.

- [1] EN ISO 10360-7: Geometrical Product Specifications (GPS) – Acceptance and reverification tests for coordinate measuring machines (CMMs) – Part 7: CMMs equipped with imaging probing systems.
- [2] EN ISO 12181-1 and EN ISO 12181-2: Geometrical product specifications (GPS) – Roundness – Part 1: Vocabulary and parameters of roundness, and Part 2: Specification operators.



Photomask measuring system in the clean room at METAS.