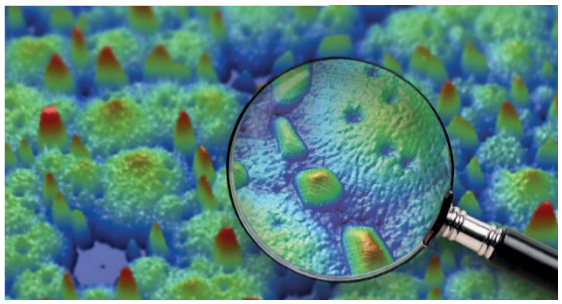
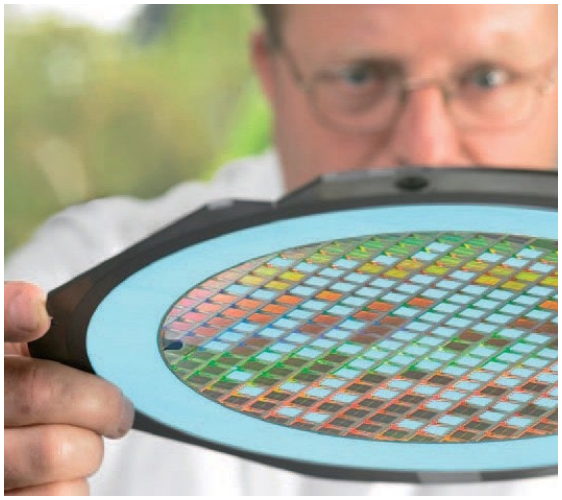


TECHNICAL NOTE

Profilometry: Surface Topography Characterization



Profilometry provides height information from the millimeter scale down to the nanometer scale. It is crucial for monitoring dimensions of fabricated surface (micro)structures, like gratings, steps and holes. In addition, surface profile analysis plays an important role in determining how a surface interacts with its environment. Surface roughness, for example, influences wear, corrosion, wetting behavior and visual appearance. At Eurofins EAG a range of techniques is available for measuring surface structures at various dimensions.



The profilometry techniques can roughly be divided into contact and non-contact methods. Contact methods usually involve scanning a probe across the surface; non-contact methods are generally based on optical measurements. Three of the most commonly used techniques are presented here. All three techniques can measure height variations down to 1 nm, but they differ in height range, and in lateral range and resolution. In this respect the techniques are complementary to each other as can be seen in the Characteristics table. Which technique is most suitable depends on the (optical) surface properties, the application of the surface and on the lateral and vertical resolution required.

Stylus Profiler

With a Stylus profiler, measurements are made by moving the sample beneath a diamond-tipped stylus, with a tip radius of typically a few micrometers. The vertical movement of the stylus is registered electromechanically. Height variations on almost any surface can be measured by scanning individual lines.

Optical Profiler

Optical profilometry or white light interferometry is based on interference of light reflected from a sample surface and from a reference mirror. The interference fringe pattern, projected via a microscope objective onto a digital camera, is used to construct a 3D map of the surface. Height variations can be measured very accurately as long as the surface is sufficiently reflective.

Atomic Force Microscopy

In atomic force microscopy (AFM) a cantilever ending in a very sharp tip, typically made of Si or Si_3N_4 with a radius of 5 to 10 nm, is scanned across a sample surface.
The vertical motion of the cantilever is monitored with a laser beam that is reflected by the cantilever. A 3D map is obtained by scanning the surface line by line.

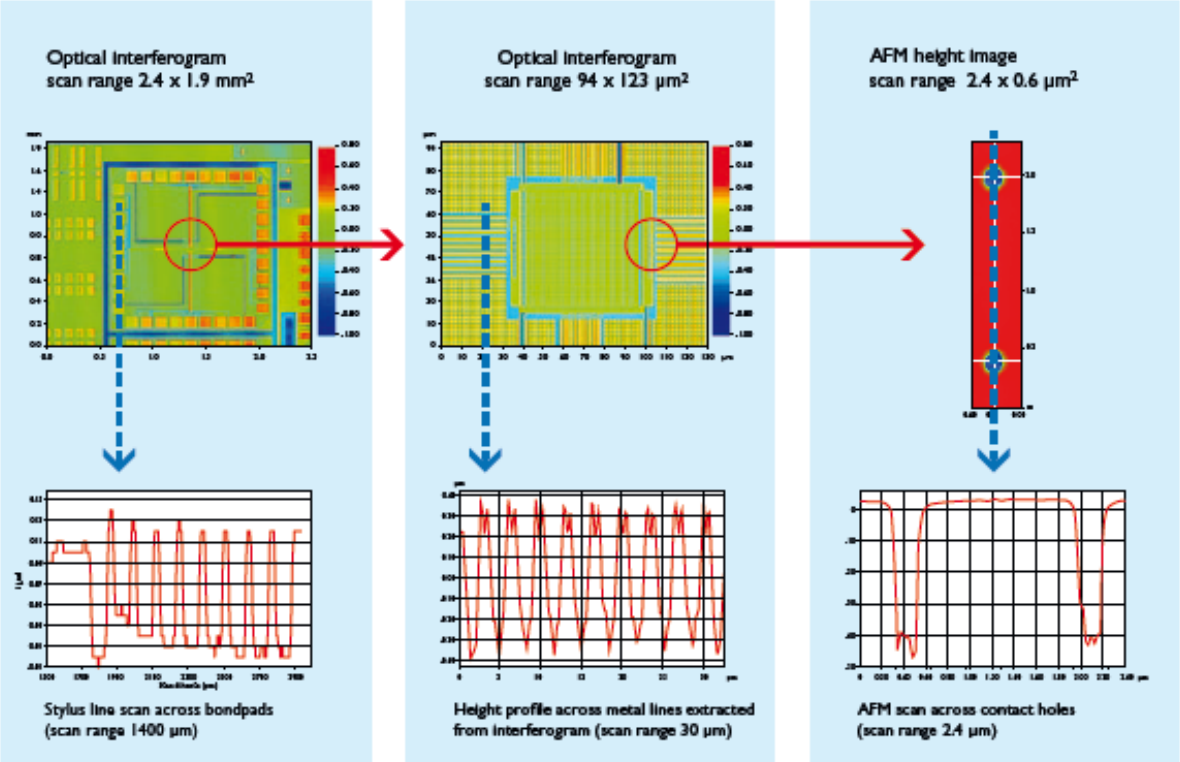


Fig. 1: Example of a mounted chip where the three different surface profile techniques were used to characterize specific parts of the device on a scale ranging from mm to nm.

The measurements can be performed on any surface in air, as well as in liquids. Besides height information it also offers the possibility to study mechanical, magnetic and electrical properties of materials.

Example

In figure 1 an example is shown, where the three different techniques were used to characterize specific surface parts on the same sample. The sample consists of a fully processed IC device. With the Stylus profiler the step height of the bondpads, which are used to make electrical connects to the package, is determined. On a smaller scale, the height of the metal lines that connect the bondpads with the components of the IC is measured using the optical profiler. Finally, AFM was used to determine the depth of the contact holes in the components themselves.

All this information is crucial for the final step in which the IC device is mounted in a package.

Applications

- Calibration of ion sputter velocities
- Layer thickness analysis
- Crack / scratch propagation on flat (glass) surfaces
- Defect analysis in metals, crystals and ceramics surfaces
- Visualizing particles ranging from a few nm to a few microns.
- Pitch, step height and width analysis of resist profiles
- Topographical information of bio-molecules (such as DNA) on a surface submerged in liquid (figure 2)
- Roughness after mechanical (grinding and polishing) or chemical (etching) surface treatment
- Grain size after heat treatment (of e.g. metals)
- Flatness and shape of optical components
- Surface area of catalysts

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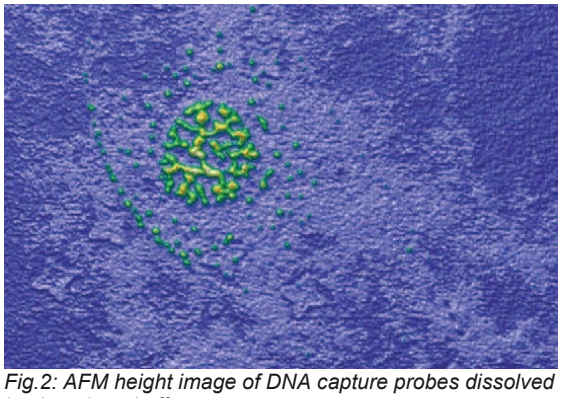

Fig.2: AFM height image of DNA capture probes dissolved in phosphate buffer

Characteristics

	Stylus profiler	Interferometer	AFM
Maximum vertical range	1000 µm	10000 µm	10 µm
Vertical resolution	1 nm	0.2 nm	0.1 nm
Maximum lateral range	55 mm	2-100 mm	0.1 mm
Lateral resolution	2 µm (depends on tip radius)	0.5 µm (depends on microscope objective)	5 nm (depends on tip radius)
Maximum sample dimensions	20 cm (diameter) 5 cm (height)	30 cm (diameter) 30 cm (height)	20 cm (diameter) 1.5 cm (height)