

Smart Microscope

Classical light microscopes can be extended to a 3D surface measuring device with considerably improved usefulness.

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Microscopes are of great importance not only in research or for documentation, but also to monitor products or analyze surfaces. In many laboratories optical microscopes are part of the standard equipment. However, most surfaces cannot be mapped in all detail using two dimensions only. Therefore the three-dimensional analysis of surfaces has become a more and more important tool in recent years.

Highly accurate 3D measurements with a resolution in the nanometer range have gained much importance in the microscopy sector recently. Typical fields of application are the characterization of surfaces with different roughness (wafer structures, mirrors, glass, metals), the determination of step heights and the precise measurement of curved surfaces, for example micro lenses. Many institutions are therefore considering to purchase a 3D surface measurement device. But first of all the question needs to be answered, whether an already present microscope can be extended to a 3D measuring device.

The answer is simple: for most microscopes by well known producers this is possible, if the following conditions are satisfied:

- The microscope has been designed for an infinite distance of the intermediate picture.

ADVANTAGES OF THE MICROSCOPE EXTENSION

- No new device technology needed, therefore short training period.
- A new workstation for the 3D measurement device is not required.
- Conventional 2D procedure is maintained, but supported by the 3D measurement.
- Many components, that are already present (lighting, tube, lens revolver, z-actuator, xy-measuring table) provide the basis for the extension and result in a very economical solution.
- A complete 3D analysis of surfaces is feasible.



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By means of an adapter it is possible to fix the interference objective which is needed for three-dimensional imaging.

The extended microscope allows for scanning surfaces in three dimensions with high resolution.

- A reflected light bright-field illumination is present.
- A video camera connection is present.
- The mounting dimensions of the tube allow for a change of lens.

GBS mbH in Ilmenau¹⁾ has already successfully extended microscopes manufactured by Zeiss, Nikon, Leica, Olympus or Mikroskoptechnik Rathenow (Fig. 1). The basic principle is hereby given by white light interferometry – a well established method to capture topographies in the lower nanometer range in three dimensions. In contrast to interferometry with monochromatic light white light interferometry uses broadband light

with a coherence length of about 2 μm . For the measurement it is necessary to scan through this region of coherence and to take a picture every 70 – 80 nm. For monochromatic light – in most cases a laser – the coherence length is in the order of kilometers, making it impossible to scan this large region.

The interference contrast becomes smaller when the path difference approaches the coherence length. Moving the object with a well defined step width through the reference plane and recording an interference picture at every step yields a stack of pictures from which the intensity can be obtained for every pixel.

The measurement points are captured and processed in parallel allowing the height information to be obtained on a large surface within seconds. The very efficient calculation of the measurement data is a special feature of the so-called smartWLI solution of GBS mbH. Moving the complex 3D calculation to the graphics card reduces

1) www.gbs-ilmenau.de

2) MountainsMap® Imaging Topography is a product of Digital Surf, www.digital-surf.com

the evaluation time for one million measurement points from 30 seconds to less than one second.

Smartly extended

Thanks to the SmartWLI-microscope from GBS mbH conventional microscopes are turned into a 3D surface measurement device. This contains the following hardware components: a PC-controlled positioning system accurate to nanometers based on the piezo effect, a high quality interference lens, a fast and highly sensitive CCD-camera with modern GigE interface, optionally an electrical *xy*-table for large surface measurement via stitching and a PC with i5-processor, MS Windows, 4 GB RAM, NVIDIA GPU for fast processing of the measurement data, TFT monitor, keyboard and mouse.

For retrofitting the microscope piezo actuators by piezosystem jena GmbH are used. These are so-called MIPOS-lens-actuators, that allow for a computer controlled scanning regime of up to 500 μm in *z*-direction. Typically interference lenses with a magnification from 2.5 to 100 are used.

The smartWLI software provides the basis for generating three dimensional measurement data. It can be handled intuitively and allows for quick analysis and nanometer precision. The calculated 3D data are directly transferred to the widely used analysis package MountainsMap® Imaging Topography, which provides extensive evaluation methods: visualization in 2D or 3D, roughness measurement, step height measurement, particle analysis and report function.²⁾

Thanks to the high computing performance of the GPU unit the three-dimensional data can be calculated already during the scan. This allows scanning large vertical regions without having limited PC-CPU performance or memory consumption as was the case previously.

The parameters that can be obtained for the smartWLI-microscope are:

- vertical scan range: < 400 μm
- lateral scan range: 480 x 360 μm^2 when using a 10 x lens
- vertical resolution: 0.1 nm
- lateral resolution: max. 650 nm
- scan velocity 3.6 to 16 $\mu\text{m}/\text{s}$
- calculation time : < 1 s for 1 million measurement points.

Rough Tool

A microscope, that has been extended to a 3D measuring device is now capable to take a very close look on the nanometer scale at a diamond fitted grinding tool for example (Fig. 2). The goal of this measurement is to determine the form, surface and volume of the diamond. Here another feature of the smartWLI-microscope technique is used: the automatic “stitching”, i. e. the combination of many 2D measurement fields and picture stacks to create a 3D image of a large surface. In combination with an electrical *xy*-table large sections of the surface can be scanned.

For the grinding tool 3 x 3 regions where measured with a 10 x Miraulens. The large measuring speed of the smartWLI-solution also makes it possible to scan larger regions with more than a hundred measuring fields in just a few minutes.



Fig. 1 Most microscopes of well known suppliers can in principle be extended without many complications. The interference lens is one of the central elements of the extension. A table that moves the sample in *xy*-direction allows scanning large regions of a structured surface in a very short time span.

In conclusion the smartWLI-microscope by GBS mbH provides a complete extension for optical microscopes. Experienced engineers upgrade the microscope and train the operating staff. Normally this modification does not result in any restrictions for the microscopes. Even the microscopy software, that is already present, can still be used.

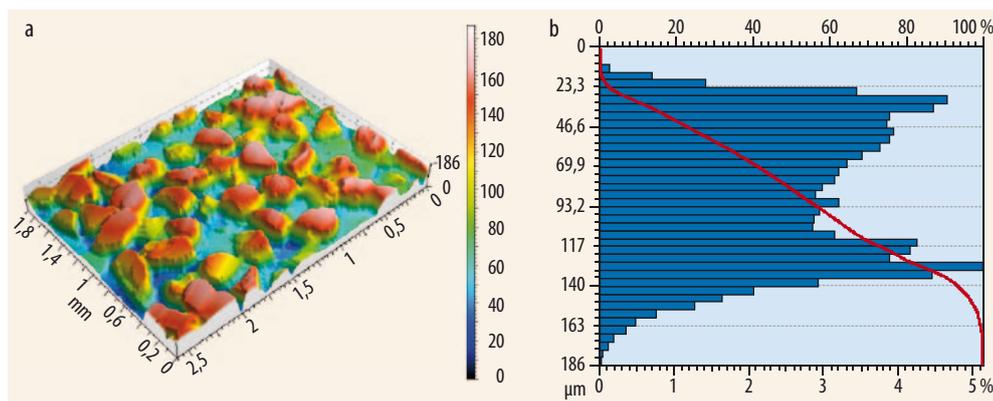


Fig. 2 3D surface of a diamond-coated tool (a). The Abbot curve (red) and the histogram (blue) describe the material distribution as a function of the vertical height of the structures of the object (b). The Abbot curve provides a quantitative measure of how much material is sticking out and whether the surface is free of errors.