Accurate Profile Reproduction of the Finest Structures Thanks to Piezo Technology and Confocal Technology

Optical 3D Surface Measuring Technology for Industry and Research

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For surface inspections that are indispensable in many of today's industries, the trend is heading toward smaller and smaller structures that must be reproduced or resolved accurately at nanometer level. Optical measurement processes as contact-free and destruction-free analysis and test methods are chosen for many applications because they can be applied to almost all materials and are also suitable for sensitive samples. Highly precise, confocal reproduction principles can present the sample topography and roughness structures not only qualitatively, but also correspondingly quantitatively using matching tactile measurement methods that are described in many industry standards. Piezo-based positioning systems are making considerable contributions in this field.

Fig. 1 Here is the new product “µsurf expert” which will be launched in spring 2014 (Image: NanoFocus)

NanoFocus AG, located in Oberhausen, Germany, has been considered for many years as a pioneer in optical-confocal 3D surface measuring technology. Different product lines cover various areas of application, from fast inline production inspection to flexible, customer-specific solutions and even high-precision µsurf systems (Fig. 1).

Fig. 2 The optical 3D surface inspection is ideal both for the lab as well as demanding industrial use, e.g. for checking paint appearance in the automotive industry (Image: NanoFocus)

For rapid wide-area measurements these µsurf systems work with vertical resolutions up to 1 nm, laterally up to 300 nm. This means they are suitable both for the lab as well as for demanding industrial use (Fig. 2), such as three-dimensional surface measurements in medical technology, the semiconductor industry, forensics, electronics, the automobile industry, materials management and the steel industry.

The measurement principle works reliably on both transparent and metallic surfaces and on rough or polished surfaces. Furthermore, layer thicknesses of partially transparent surfaces can be analyzed using special algorithms.

Extremely Low-Scatter and Robust Signaling

The core of each of these µsurf systems is the integrated confocal-optical filter unit that is combined with a highly precise and fast focusing module.

The patented multi-pinhole disc (MPD) is used as an optical filter of reflected light rays (Fig. 3) and distinguishes itself through extremely low scatter light intensity as well as robust signaling with a high light yield. The objective focuses light from a high-performance LED source through the multi-pinhole disc onto the surface. Only the portion of the light that is reflected from one point of the surface and which lies precisely in the focal distance of the objective can pass the point openings of the MPD. In contrast, light that is reflected by a sample area that is not within the focal plane of the objective, is blocked. By rotating the MPD, the entire sample surface can be quickly and completely scanned.

By moving the objective vertical to the sample surface, all contour lines of the sample are focused one after the other. The CCD camera used stores the brightness values of the visual field for each objective position. Points with maximum brightness are located on one contour line. Each confocal image is a horizontal cross-section through the surface topography of the sample. The 3D structure of the sample can be determined from the total number of images at different height intervals, this is called the image stack. This stack consists of an average 200 to 400 individual images that are recorded in a few seconds and are converted by the measurement software into a 3D topography representation (Fig. 4), accurate to within a few nanometers.

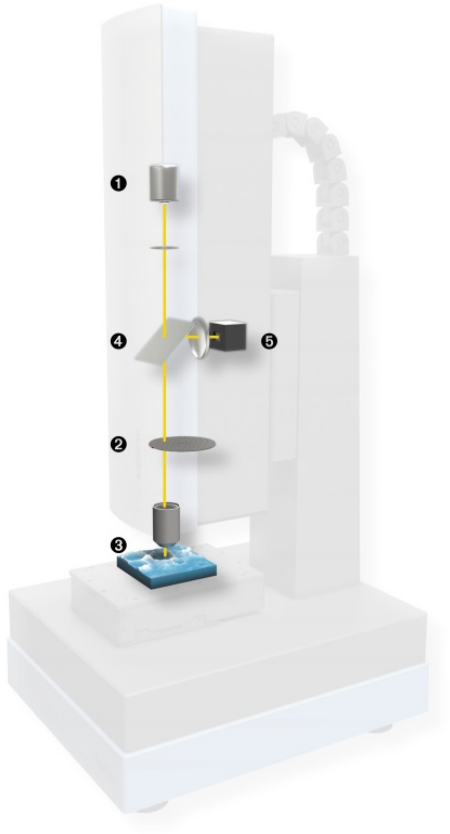

Fig. 3 LED light source (1), multi-pinhole disc (2), sample surface (3), mirror (4) and CCD camera (5) (Image: NanoFocus)

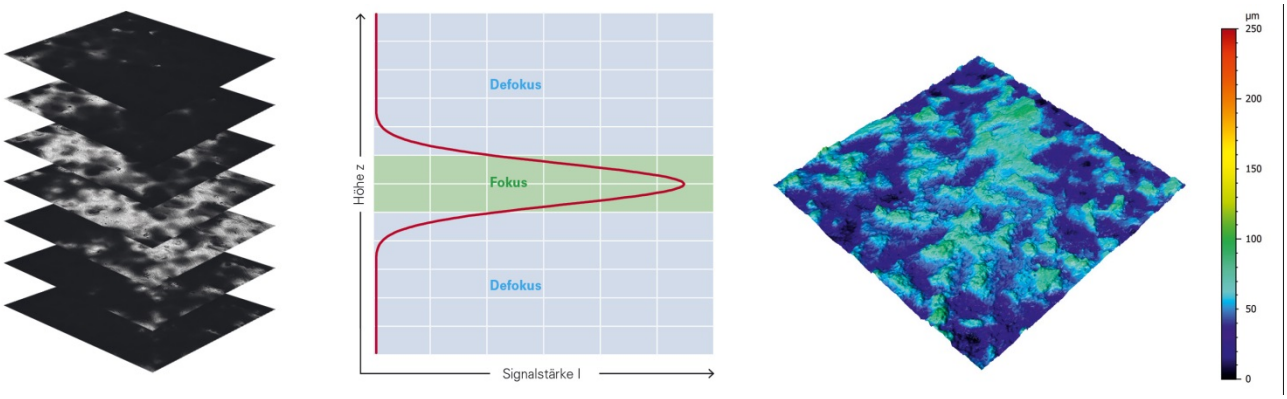

Fig. 4 200 to 400 individual 2D images are converted into a 3D image by the measurement software. (Image: NanoFocus)

Piezo Positioning System for the Objective

In order to achieve such a high measurement resolution, the objective must be moved in the direction of the z axis with great precision. “This is almost impossible using conventional motor drives,” explains Dr. Georg Wiora (Image 5), responsible for strategic development and innovation management at NanoFocus. “The positioning system for our objective is therefore based on piezo actuators. They work free of wear and friction with zero play and they are suitable for high recording frequencies due to their dynamics.” Zero play and highly precise flexure guides together ensure high focus stability.

This is how travel of up to 500 µm is achieved in the described application; the position accuracy of the kinematics thus lies in the nanometer range.

Fig. 5 Dr. Georg Wiora, head of strategic development and innovation management at NanoFocus (Image: NanoFocus)

The piezo-based, single-axis positioning system (Fig. 5) used in the µsurf system originates from the comprehensive product portfolio of Physik Instrumente (PI). It was adapted to precisely meet the application requirements, was able to be easily integrated into the objective holder thanks to its compact dimensions and moves the objective at a constant speed.

The measurement is performed on the fly. That is why the core requirement of the positioning system is a high velocity constancy in the nanometer range. This is the only way absolutely accurate (down to a few nanometers) roughness measurements can be taken that are compatible with tactile processes and meet the requirements of the corresponding industrial norms. Repeatability is just as important when positioning the objective, so as to prevent a height offset when assessing the stack of individual images.

Fig. 6 The piezo-based single-axis positioning system was adapted to precisely meet the company's application requirements. It fits easily into the objectiveholder due to its compact dimensions (Image: PI)

High-Resolution Measuring Process and Application-Specific Controller

Repeatability and linearity in highly dynamic and high-resolution positioning systems are inconceivable without the use of measurement processes with the highest possible resolution. Position accuracies of just a few nanometers or lower require precise position measurement methods that are able to detect motion in this range.

In the described application, capacitive sensors ensure this highly precise actual value recording. The high sensor bandwidth also allows closed-loop control in dynamic applications. The capacitive sensors are generally suitable for measurement ranges up to 1000 µm, for resolutions down to 0.01 nm. The repeatability and absolute positioning accuracy of the objective are therefore guaranteed.

A controller with an integrated piezo amplifier analyzes the sensor data and controls the positioning system's piezo actuator. The compact customized electronics can be integrated into the NanoFocus control system seamlessly, both in terms of hardware dimensions as well as electrical interfaces. “In this area, too, Physik Instrumente (PI) has proven to be a competent partner that has contributed decisively to our success,” explains Dr. Wiora. Piezo-based positioning systems have therefore shown once again that they can drive technology.

About NanoFocus

As early as 1994, NanoFocus AG has been developing, producing and selling high-precision optical 3D measuring systems and software to measure industrial surfaces. Its innovative systems make it possible to measure 3D topography extremely quickly, contact free and easily with resolutions in the micro- and nanometer range.

The product families µsurf, µscan and µsprint offer reliable and repeatable measurement accuracy for different areas of application. This ideal and intuitive software is available for measurement, analysis and control. It delivers industry standard-compliant results, comprehensive measurement reports and the option to automate measurement sequences.

With high measurement and analysis speeds, the systems are ideal both for the test lab as well as for production-related use and inline control. Typical areas of application include medical technology, the semiconductor industry, forensics, electronics and the automobile industry, materials science and the steel industry.

About Physik Instrumente (PI)

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and fifteen sales and service offices abroad, the privately managed company operates globally.

Over 850 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

The required piezoceramic elements are manufactured by its subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications as well as parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.

Author

Dipl.-Physiker Gernot Hamann, Head of Key Account Management at PI (Physik Instrumente)