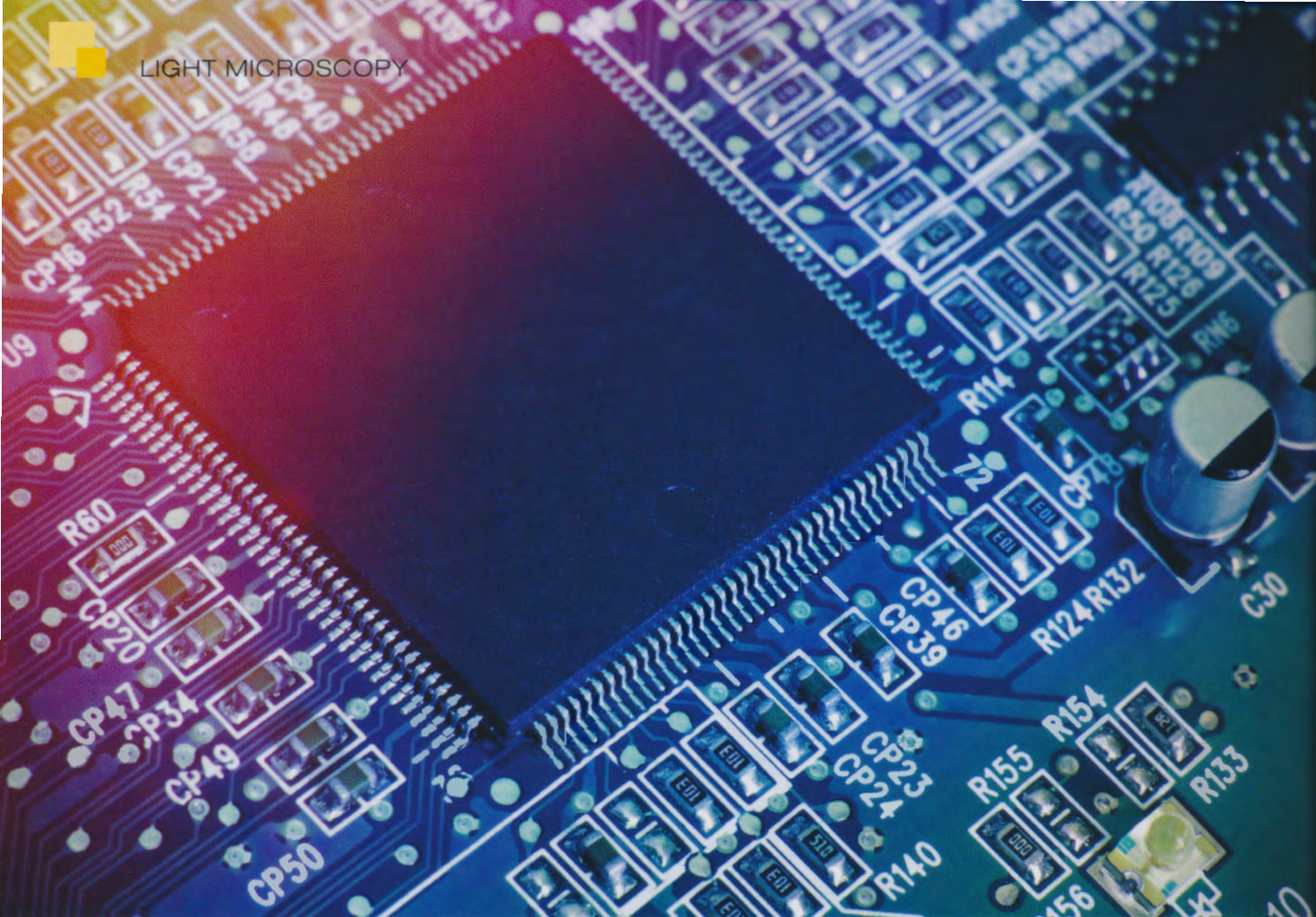




Piezo Drives in the Real-Time Autofocus System

High-Speed Microscopy for Quality Control

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A great number of large-surface objects must be examined during quality control for tiny details that can only be seen under a microscope. Because of the high degree of miniaturization, the need for microscopic test processes in the semiconductor and electronics production is significant. Other areas such as biotechnology or pharmacy, have similar requirements, for example, for screening samples in microwell plates. However, particularly when high resolution is necessary, conventional microscopy process cannot keep pace with the speed of the automation technology, that is usual today. Thanks to new high-throughput microscopy systems, that has now changed. Piezo actuators for driving your real-time autofocus systems play an important role.

The problem for both electronics and semiconductor manufacturing as well as biotechnology or pharmacy: For large samples such as wafers, printed circuit boards and microwell plates, high magnification microscopic image recording often takes too long, because up to several thousands of individual images must

be created and evaluated and the stage with the sample also has to be exactly positioned for each individual image. Then again, because high throughput is necessary for industrial quality assurance, many do without 100-percent testing and are satisfied with random inspection of just a few selected places (fig.1). Now,

the Fraunhofer Institute for Production Technology IPT has developed a new image-recording process that allows large-surface objects to be completely microscopied within seconds (fig. 2 and 3). For the first time ever, 100-percent microscopic tests are now possible in the industrial environment.

On-the-Fly Measuring For High Frame Rates

During image recording, the stage moves the object continuously at a constant velocity in contrast to the conventional "stop-and-go" method. This allows the sample to be digitized at high frame rates, which, depending on the camera, can be

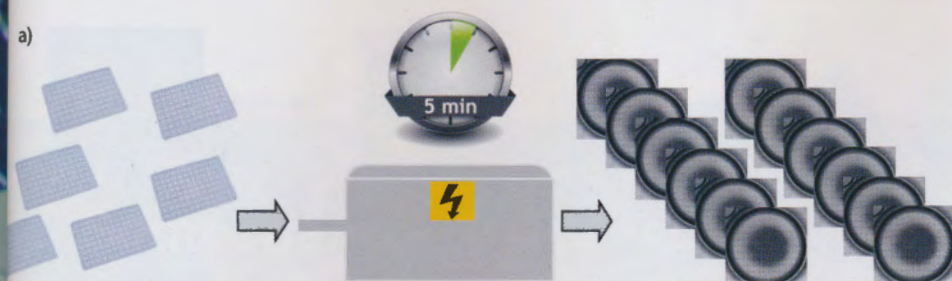
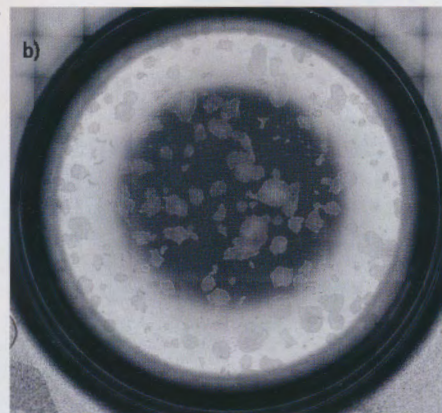


Fig. 1: The process of high-magnification microscopic image recording of wafers (a) or microwell plates (b) often took too long. That has now changed thanks to new high-speed microscopy. (Image: Fraunhofer IPT)



more than 100 fps. Because the object is illuminated by a flash, the image is also free of motion blur. The time-optimized scanning process is combined with real-time data handling and image-processing steps. Even CPU-intensive tasks such as the stitching processes run almost without any delay. Individual images can be merged seamlessly into the overall image even while measuring is in progress.

Of course, this is mainly due to the processing power of the system and the sophisticated software, but the hardware used also contributes significantly to this.

It is important to adjust the focus accordingly during continuous scanning. The surface topology considerably exceeds the depth of focus of a microscopic objective, irrespective of whether this is due to unevenness of injection-molded plastic microwell plates used in biotechnology or the various different heights of the components on the board, or tilting of the entire wafer during manufacturing of the electronics. It is only possible to focus sharply on the surface when the focus is adjusted in time. A real-time autofocus function is therefore necessary for micro-

scopic image recording; the focus must be adjusted dynamically in the direction of the optical axis with high precision.

Piezo Actuators and their Properties

Piezo-based drive systems take care of these tasks (fig. 4). With a travel range of approximately 500 μm , they are well-suited to autofocus applications and, when taking accuracy and particularly dynamics into account, they are far superior to stepper motors. In addition, piezo

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drives also have a wide range of further characteristics that benefit microscopy: Piezoelectric materials convert electrical energy directly into mechanical energy and vice versa. The motion that results when an electric voltage is applied to a piezoelectric material is important for positioning. Actuators based on this piezo effect can perform high-dynamics motion with subnanometer resolution and with scanning frequencies up to several hundred kilohertz. The motion is based on crystalline effects so there is no friction and no rotating parts; therefore, piezo actuators require practically no maintenance and are free of wear.

The PIFOC-Z drives from PI (Physik Instrumente) used by the Fraunhofer IPT in its high-speed microscopes, offer a very good solution for such applications. It is possible to make them very small and stiff. Therefore, their response times are short and, thanks to the stable guiding, precision positioning is possible even over comparatively large travel ranges up to 500 μm . The zero-play and high-precision flexure guide ensures high focus stability. Fine positioning is therefore possible in a range of less than a nanometer. Nevertheless, the requirements on accuracy in the application described



Fig.2: High-throughput microscopy systems: Large-surface objects can be microscopied within seconds. For the first time ever, 100-percent microscopic tests are now possible in the industrial environment. (Image: Fraunhofer IPT)



Fig.3: The basic design of the modular high-speed microscope (Image: Fraunhofer IPT).

here are fairly moderate for piezo systems, because it is only necessary to position more accurately than the depth of focus of the objective. However, the repeatability and settling time of less than 10 milliseconds are important. The piezo drive prevents the object from going out of focus at high scanning speeds. In conjunction with direct metrology, the piezo drives achieve the highest linearity at a maximum deviation of 0.06%. The capacitive sensors measure the mechanical part in motion directly and without physical contact.

Neither friction nor hysteresis interferes with the measurement. The position of the objective can be matched accurately to the individual image.

Easy Integration

For control, the IPT uses an E-709 digital controller with linearization algorithms, which can simply be connected to the overall system via an analog interface. The QuickLock adapter for the drives also allows easy integration. After the adapter is screwed into the revolving nosepiece, the drive is then fixed for the desired direction. Because the objective positioner itself does not have to be rotated, cabling is no longer an issue. A version with a 29-mm diameter threaded insert is available for applications that require a particularly large optical aperture. This opens up a wide range of completely new possibilities for microscopy under industrial conditions; Piezo drives have contributed to this.

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Fig.4: It is possible to make the PIFOC-Z drives very small and stiff. Response times are short and, thanks to excellent guiding, precision positioning is possible even over comparatively large travel ranges to 100 or even 400 μm . (Image: PI)

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