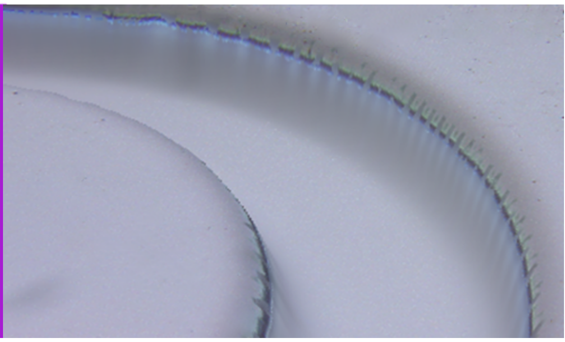
Application Note

Closed Channel Optical Metrology for Microfluidics Applications

Zeta Optical Profilers



Introduction

For microfluidics applications, precise flow characterization through micro-channels is a critical aspect of device manufacturing and quality assurance. These channels are typically fabricated on highly-reflective substrates, and often include multiple layers of transparent materials to achieve the desired device characteristics. Modeling used to design, analyze and improve the performance of these devices relies on measurements of the fabricated topologies. Laminar flow within the channel is highly affected by surface roughness and interlayer mating methodology, as well as the channel cross-sectional area. In order to ensure optimal device performance, the channel interior dimensions must be well-characterized, regardless of the number of transparent layers and any applied surface treatments.

Measuring Microfluidics Devices

The image in Figure 1 was generated using a Zeta-20 multi-mode optical profiler and shows a fully-open microfluidics channel. In this figure, the ZI vertical scanning interferometer mode was used to measure the dimensions of the channel, yielding an average depth of 60.6µm. The measured depth, as well as the uniformity of depth throughout the channel, are key contributors to the overall effectiveness of the device in providing uniform, laminar flow.

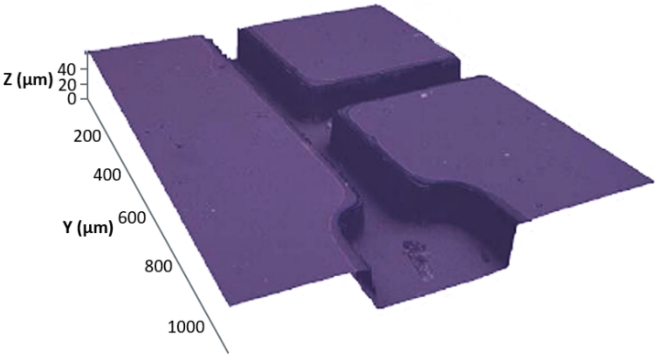


Figure 1. Zeta 3D height profile of a fully-open microfluidics channel measured with ZI vertical scanning interferometer, with an average measured depth of 60.6µm.

To accurately measure depth, the Zeta ZDot™ technology, illustrated in Figure 2, maximizes signal strength at each focal depth, which includes the top surface of the device, the surface height at all interfaces, and the bottom surface of the channel.

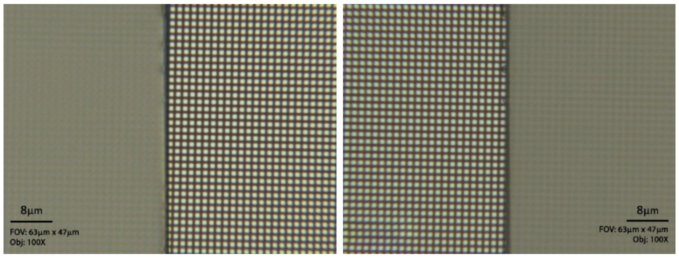


Figure 2. ZDot™ technology maximizes signal strength at multiple focal planes in order to provide accurate step height measurements. The left image shows the ZDot grid in focus at the top surface of the step (right side of image), and the right image shows the grid in focus at the bottom surface of the step (left side of image).

Once the channel has been defined in the manufacturing process, it is enclosed by affixing a transparent layer across the upper surface. Due to the installation of the transparent layer(s), tensile, shear, and/or compressive stresses may be induced at the interfaces that slightly alter the original channel dimensions.

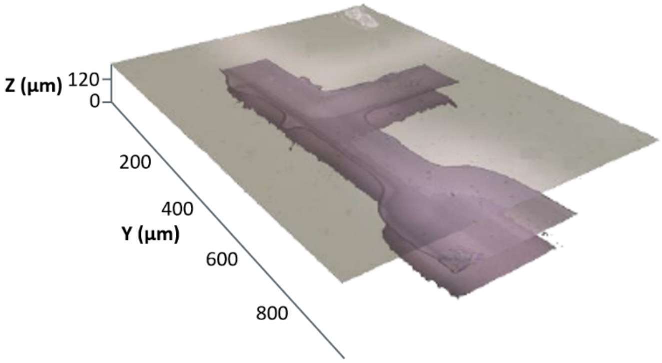


Figure 3. Zeta image of a similar microfluidics channel with a transparent cover plate, showing top, middle, and bottom surfaces. The cover plate thickness measured 93.4µm, and the channel depth measured 59.2µm.

Title image courtesy of IMTEK, Laboratory for MEMS Applications, Freiburg, Germany

Figure 3 shows a similar microfluidics device, but with a transparent cover plate enclosing the channel. The ZI scanning interferometer mode was also used to generate accurate step height measurements of the channel depth (59.2µm), and the cover plate thickness (93.4µm). Figure 4 shows another example of a closed channel device, with the measurements of both cover plate thickness (138.83µm) and channel depth (76.3µm).

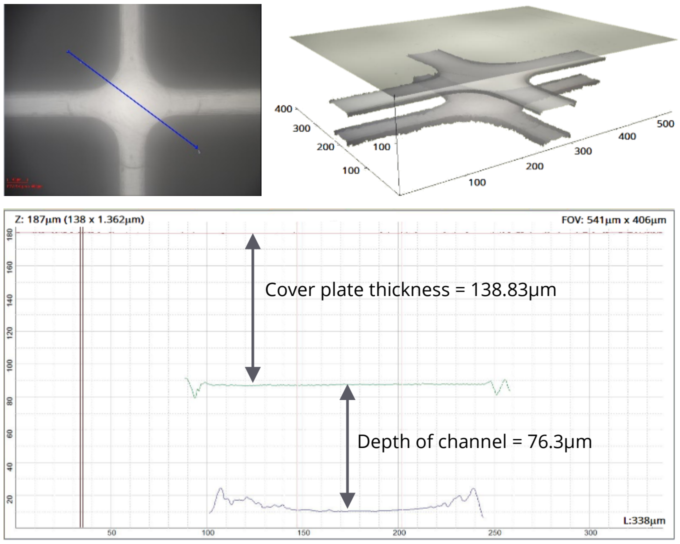


Figure 4. Zeta measurements of cover plate thickness and channel depth, showing the XY location of the measured Z profile across the channel (top left image, blue line), the Zeta image of the three closed channel surfaces (top right), and the measured Z profile showing cover plate thickness and channel depth (bottom).

Surface roughness of the interior channel surfaces affects the precise flow of fluid within that channel, and surface roughness at the device interface layers may induce material stresses that may alter the interior channel dimensions. The ability to quantify the surface roughness, therefore, is important in generating an accurate evaluation of device performance.

To measure nm-scale surface roughness, the Zeta-20 may be used in interference contrast imaging (ZIC) mode, or in shearing interferometry (ZSI) mode. For larger-scale surface roughness characterization, ZDot technology is used, where the system detects the vertical position of the surface of the sample for each lateral position, generating the height profile of the surface. The local variation of the height profile across the surface represents the roughness, as shown in Figure 5. The high sensitivity of ZDot technology allows measurements of transparent surfaces exhibiting very little optical contrast.

Due to the unique imaging capabilities of the Zeta-20 multi-mode optical profiler, surface characterization and dimensional measurements may be made for both open- and closed-channel microfluidic structures. These measurements may be performed quickly and non-destructively at any point in the fabrication process, for up to eight separate transparent surfaces simultaneously, even when the devices are manufactured on a highly reflective surface such as silicon. The automated measurement capability of the Zeta-20 enables measurement of devices, features and locations across the wafer, providing data on process uniformity and statistics on process variability to guide process development and assess quality control. The Zeta-20 can perform many different measurements, enabling the manufacturing process to be more tightly controlled and resulting in improved device fabrication.

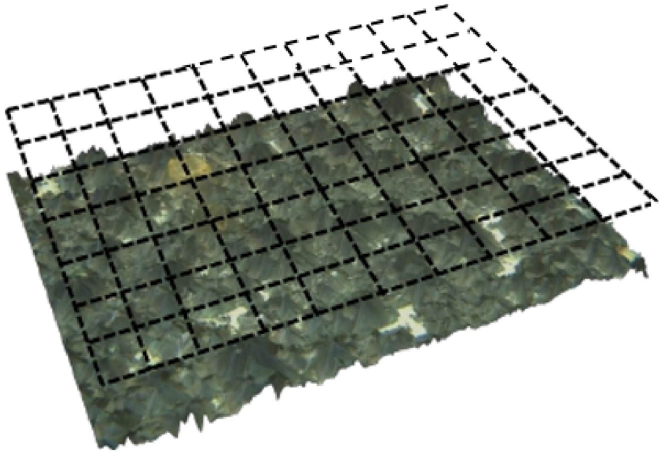


Figure 5. ZDot technology is used to measure the height profile across a surface, which generates the roughness measurement. The superimposed grid is added to illustrate the ZDot concept.

Summary

KLA Zeta optical profilers offer the optimal solution for both open- and closed-channel microfluidics device metrology. Capabilities include multi-surface 3D imaging and metrology, large Z range, large field of view (FOV), and material-independence. The Zeta tools utilize proprietary ZDot technology that includes unique transmissive and dark field illumination methods. Zeta optical profilers are also available with interference contrast imaging (ZIC) for characterizing nm-level surface roughness, shearing interferometry (ZSI) for sub-nm vertical resolution, and reflectometry (ZFT) for thin film thickness measurement.

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