Characterizing MEMS Devices Through Transparent Media

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Introduction

Optical profiling (white light interferometry) has long served as a standard technique for measuring surface topography of MEMS and optical MEMS devices. To date, most measurements have been made early in the manufacturing process, before the MEMS is packaged. Most devices, however, perform differently once encased in their final packages, which often include a nitrogen atmosphere, vacuum, or other special environments. A new method has been developed for testing MEMS devices through their transparent packaging, for rapid, accurate verification of actual device performance.

Measuring MEMS Through Glass

Optical profiling is a widely used technique for production measurement of MEMS roughness, step heights and topographic features. In an optical profiler, white light passes through a beam splitter, where part of the beam is directed to the sample and part to a reference surface (Figure 1). When the light reflected from these two surfaces recombines, a pattern of interference "fringes" forms. During a measurement, a series of these interference patterns is collected, from which the height of each point on the surface can be determined with resolution to 0.1nm.

Measuring a packaged MEMS device presents a challenge for optical profiling because the transparent glass/plastic packaging (referred to below as "cover glass") is introduced into only one arm of the interferometer. This can cause dispersions and aberrations that reduce fringe contrast or wash out the fringes completely. Decreased contrast may impede detection of the peak fringe intensity and thus may affect the reported heights. The effect becomes more dramatic as the thickness of the cover material increases.

An effective solution at low magnifications is to compensate for the cover glass by inserting a slide of the same material and thickness into the reference arm of the interferometer (Figure 2). Careful placement of the compensation slide is required to ensure crisp focus and maximum fringe contrast.

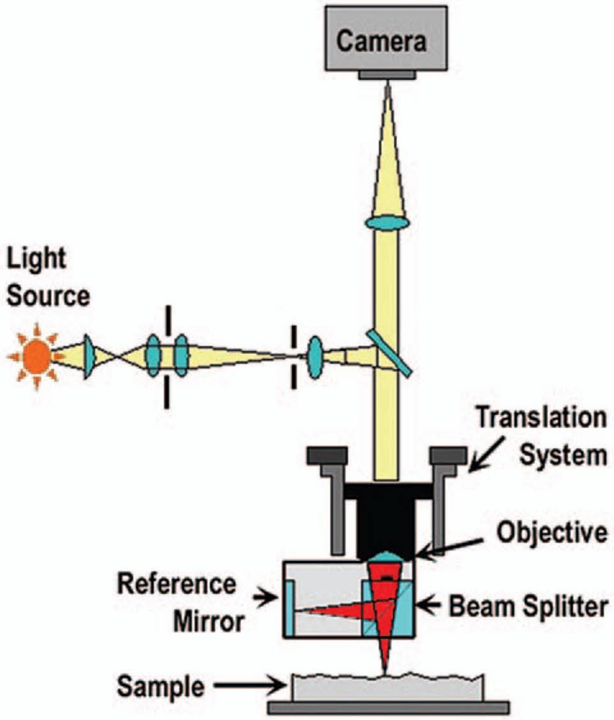

Figure 1. Schematic diagram of an optical profiler.

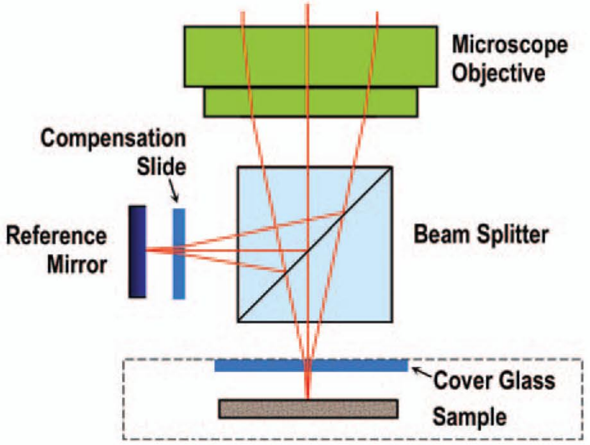

Figure 2. Compensation glass is added to objective for low-magnification, through-glass measurements.

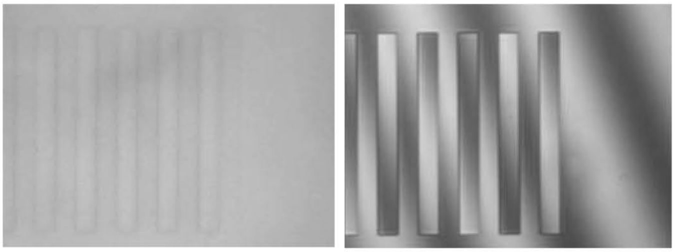

Figure 3. A compensation slide added to the reference arm (right) greatly improves fringe contrast over an uncompensated objective (left).

Figure 3 shows fringes on a sample without and with a compensation slide. The method has proven effective at magnifications up to 10X, compensating for transparent packaging up to 3mm thick.

High Magnification Measurements

For higher magnification measurements (20X and above) a Mirau objective is typically employed, because the design offers enough physical space for the interferometric elements while also remaining parfocal with other objectives. However, in the Mirau design there is no simple way to add a compensation slide.

To provide high magnification measurements through transparent packaging, Veeco has developed a long working distance, 20X Michelson objective, with ample physical space for the interferometric elements and compensation slide (Figure 4). A patent-pending illuminator greatly improves fringe contrast and reduces aberrations, as well as allowing for variability in the cover glass thickness up to approx. 0.1mm from the nominal value.

Figure 4. This specialized 20X objective is the first for high magnification, through-glass measurements.

Veeco has now developed through-glass solutions for effective magnifications from 1X to 40X. These objectives include a holder which allow the user to switch compensation slides to match different packaging—a fast, easy and much more cost-effective approach than permanently mounting compensation glass for each application.

Measurement Performance

One of the significant advantages of optical profiling is the repeatability of measurement data, from nanometer-scale roughness through millimeter-scale steps. To verify the repeatability of through-glass height measurements, a super-smooth silicon carbide (SiC) mirror and a calibrated 10µm step height were first measured with a standard 20X objective, then with a 20X through-glass objective compensated for 3mm of cover glass. The 1-sigma standard deviation of RMS roughness (Rq) over 30 measurements was found to be well within the error bars for the test. Similar excellent results were determined for the 10µm step. Both values are essentially equivalent to the performance of a standard interferometric objective. Repeatability of lateral dimensions was verified by measuring the spacing of a 20µm pitch grating, with and without cover glass. Here again, the 1-sigma standard deviation was within the error of the calibration procedure. These results are summarized in Table 1 below.

	SiC Mirror Rq	10µm Step Average	20µm Pitch Grating Line Width
Standard	0.0015nm	5.599nm	10.7nm
Through Glass	0.00297nm	5.395nm	6.1nm

Table 1. 20X objective performance through 3mm cover glass.

MEMS manufacturers depend upon reliable, proven metrology methods to ensure high yields and excellent device performance. Optical profiling, the technique of choice for critical MEMS process and quality control, is now able to measure devices throughout the manufacturing process, from wafer to final test. Packaged MEMS devices can now be accurately characterized through their transparent packaging, for the most accurate analysis of actual device performance.

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