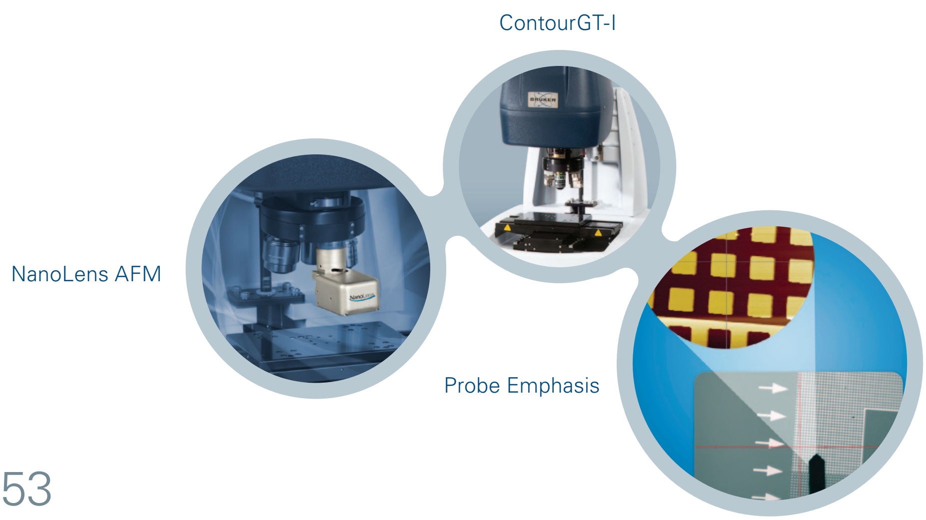

Application Note #553

Integrated Optical and AFM Metrology: Bruker 3D Optical Microscopes and NanoLens AFM

Surface metrology and characterization is ever more critical for overall product performance in wide ranging applications across the semi-conductor, LED, data storage, medical and automotive industries. 3D optical microscopes are among the fastest and most accurate imaging systems on the market today, and are employed in these industries for rapid and precise process monitoring, product development, and research. However, there are instances where they have performance limitations and the benefits of scanning probe/atomic force microscopy provide a clear advantage. A few examples include thin film metrology applications that require very high lateral resolution, such as defect review, that require a contact method to mitigate dissimilar materials offsets. To address such applications, Bruker has introduced an atomic force microscope (AFM) module that mounts directly to a 3D optical microscope to provide unprecedented flexibility for surface metrology. This application note provides an overview of basic system operation and an application example for the NanoLens™ AFM on a ContourGT 3D optical microscope.

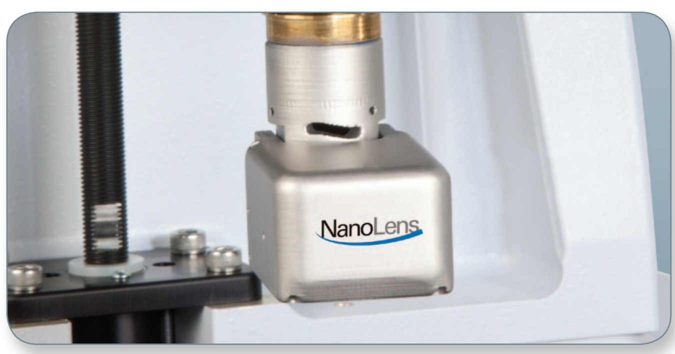

Figure 1. NanoLens AFM Module installed on a bench-top ContourGT-I 3D Optical Microscope.

NanoLens AFM

The NanoLens AFM consists of an electronics control box and an AFM scan head that can be mounted to a Bruker 3D optical microscope turret or single objective adapter. The electronics control box is connected to the scan head via a HDMI cable connector and also to the microscope computer via USB connection. The scan head holds a micro fabricated silicon chip with integral cantilever probe that contacts the surface during measurement. The sharp probe tip is automatically brought into close proximity and then in contact with the sample surface and held there by means of a force-based feedback loop. The probe is then scanned in a raster fashion across the measurement surface. The measurement feedback is performed via beam defection where a laser beam centroid is reflected from the cantilever probe onto a position sensing photo-detector (PSD). By monitoring the position change on the PSD, along with the X and Y scan position, a very high-resolution 3D surface map is created.

Basic AFM Module Operation

NanoLens has two main imaging modes. The first is the static or contact imaging mode. In this mode the probe is brought into contact with the surface at a known pressure so the cantilever deflects a prescribed amount and then is rastered across the surface. The deviations from the nominal pressure deflection create the image mapping of the surface under test. The second mode is the dynamic imaging mode, which is used on softer or more fragile surfaces to minimize the possibility of surface damage or deformation. In the dynamic mode, the NanoLens AFM cantilever is oscillated normal to the surface near the resonance frequency of the probe (typically near 150kHz) to eliminate shear force to the sample and minimize contact force. In both imaging modes, a force-based feedback loop is used to control the contact of the probe to the surface under test (see Figure 2).

The ease of implementation of the NanoLens provides a powerful compliment to Bruker's 3D optical microscope capabilities. The NanoLens AFM can be easily co-aligned to the other objectives on the microscope system for fastest high-resolution inspection of an area of interest. No special sample preparation is needed to measure a wide range of surface topography and properties. Additionally, there is a built-in 8x objective lens (up to16x when viewed through Bruker 3D optical microscope zoom optics) that allows the user to view the sample-cantilever interaction via the 3D microscope camera to easily identify the measurement region. The NanoLens AFM provides an automated approach over a 5mm range, with a maximum scan range on samples of up to 22µm with angstrom resolution. The maximum X/Y scan range is 70µm, though this can be zoomed to a much higher resolution inspection to highlight much smaller regions of interest as well.

A precision, quick-release adapter for turret mounting allows for fastest cantilever exchange with micron-level position reproducibility. This reproducibility is facilitated by a cantilever groove design (shown in Figure 3) that provides a kinematic mounting interface, eliminating the need for laser alignment.

Applications Example: Defect Inspection

The NanoLens AFM provides excellent surface information with sub-nanometer height resolution and typically less than 10nm lateral resolution. These capabilities provide a significant extension of the reach of 3D optical microscopes to "1000x" capability and beyond. The following example shows how this powerful combination of 3D optical microscope speed and the flexibility of the co-aligned NanoLens AFM can be used for both identification and high-resolution detailed inspection.

Figure 3. Top view of cantilever chip seated in kinematic mounting interface.

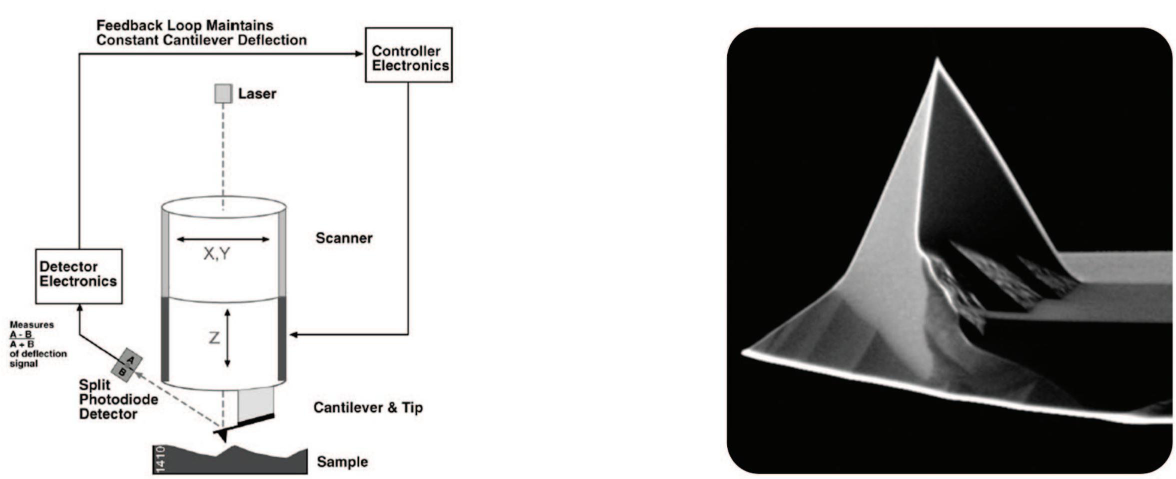

Figure 2. AFM Schematic with feedback loop and typical cantilever geometry.

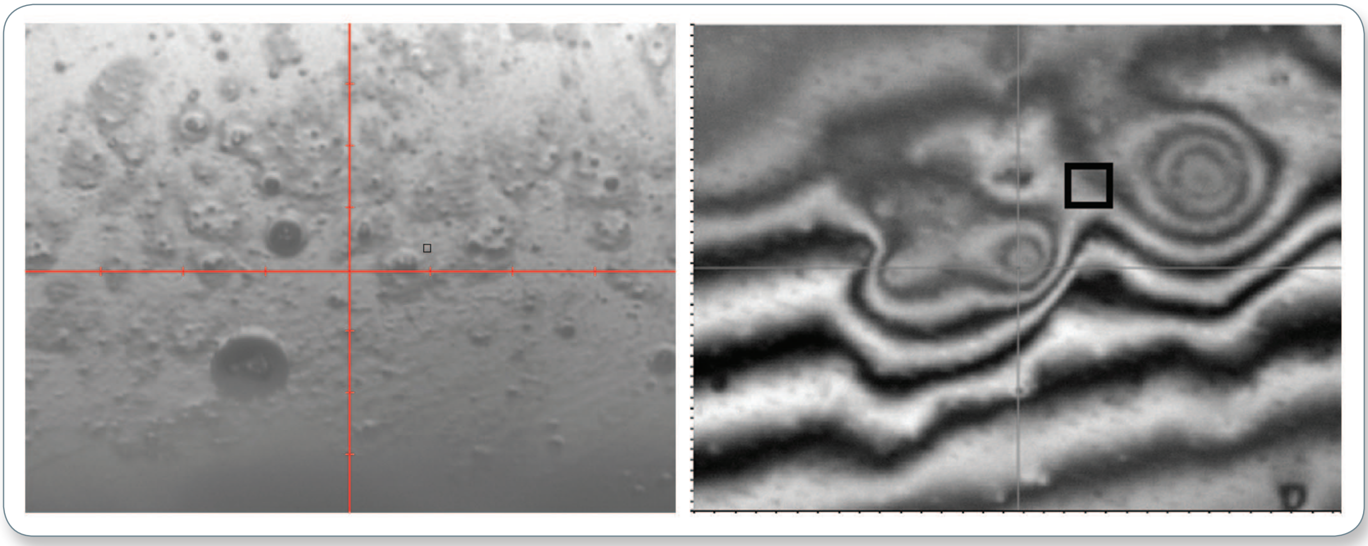

Figure 4. Intensity image of CD ROM surface with contaminants shown at 16X magnification through integrated 8X optics and 2X FOV modifier lens (top). 50X interferometric objective intensity image near same site (bottom). Note hint of surface pits.

Figure 4 shows images of a surface area on a CD ROM disk, with a small black square indicating a candidate area for high-resolution NanoLens AFM inspection.

Upon identification of such a region of interest, 3D surface measurements at that location are straightforward with the combination Bruker 3D microscope and NanoLens AFM toolset. For example, optical inspection at 50x magnification may be of interest for such an area. An example 3D microscope image of the area on the CD ROM surface pictured in Figure 4 is shown in Figure 5.

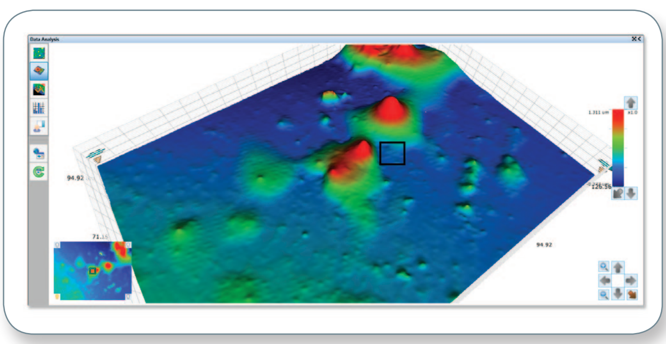

Figure 5. 3D representation from 50x objective inspection on CD ROM surface. The black square represents area of interest for extended NanoLens AFM inspection.

3D Microscope and AFM Combined System Advantage

Once optical measurement is made at a particular area of interest, the full benefit of the NanoLens AFM can be realized. The turret-mounted NanoLens can be moved into position (it is co-aligned with the other objectives available on the 3D optical microscope head) and a direct measurement can be made on the region of interest, without moving the sample. Figure 6 details the NanoLens AFM in the process of image acquisition. The scanning of the cantilever can be observed while the image is produced for the square area depicted previously. A progress bar is shown directly in Vision64™ software to let the user know what portion of the measurement is complete.

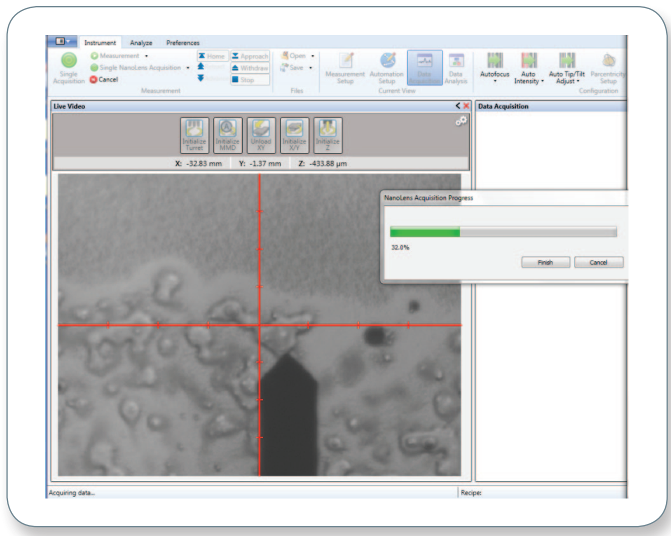

Figure 6. NanoLens AFM inspection of area of interest in progress.

The image in Figure 7 was produced via dynamic force measurement with the NanoLens AFM. The data bits in the CD surface are shown clearly, as well as some non-uniformity on the surface at small scales (in this case on the order of 10µm square area of interest). These small scale variations in topography are less than 500nm wide, even 100nm in some cases. These features are easily imaged using the NanoLens AFM. An additional NanoLens advantage when measuring samples for inspection applications is the ability of phase imaging to differentiate between contamination and surface defects. Where organics or polymers are present on the surface, variations in material that are nearly invisible in the topography scan, show up with high contrast in the phase images. Additionally, steep surface topography with small absolute height levels is resolved quickly and easily. The NanoLens

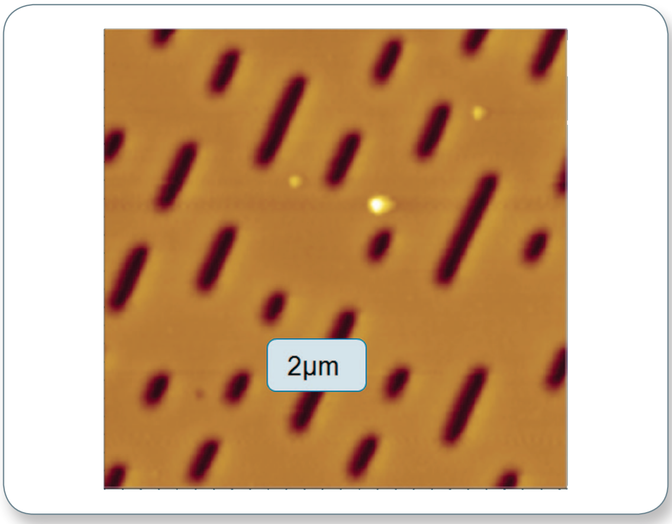

Figure 7. High-resolution NanoLens AFM image of CD surface, including data bits.

AFM can also be applied to resolve inaccuracies in optical system measurements that may occur due to narrow line width spacing, dissimilar materials, or the presence of thin films on the sample. Reverting to optical system functionality is easily accomplished via a turret move, and a correlation function can easily be applied directly in Vision64 software based on the NanoLens AFM data.

Conclusion

The NanoLens AFM integrated with Bruker 3D optical microscopes provides a significant extension of metrology capabilities. The addition of this "1000x" lens extends lateral resolution, eliminates dissimilar material and thin film issues, and provides immediate capability for co-aligned (parcentric) operation of optical and AFM technologies.

This co-location of complementary technologies provides efficiency and direct impact on time to data and a data benefit for critical inspection applications in a range of industries. Combining the two systems not only increases and enhances metrology capabilities, but also drastically improves the overall efficiency of the measurements. The end result is a single, simple-to-use system providing superior accuracy and resolution for today's research and manufacturing environments.

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