ADVANCED APPLICATIONS FOR STYLUS PROFILOMETERS

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INTRODUCTION

Stylus profilers are the most commonly used surface measuring instruments due to their rugged design, ease of use, and excellent value. Different configurations of stylus systems are available to fit a variety of budget, space and performance targets. The most common uses for these systems have been in measuring steps, particularly for films in the semiconductor industry, as well as in machine shops to examine precision metal surfaces. Configurations range from manual systems, where an operator drives to the measurement sites for single-line profilers, to automated gantry based systems, where multiple sites can be programmed for measurement with minimal operator intervention.

Stylus profilometry has been serving industry for more than 50 years, but innovation continues in these metrology instruments, driven by increasing customer requirements to measure smaller features, faster, and in a greater variety of applications. Newer applications include micro structures, 3D profiling of micro-shapes of optics and other precision surfaces, determination of cutting surface angles and sharpness, among many others. In addition to new applications, the systems have to perform to tighter specifications even on traditional applications, such as semiconductor step measurements. All of these factors are driving newer, more capable generations of products, while maintaining cost targets and the ability to deploy in most any environment.

ENVIRONMENTAL INSENSITIVITY

Low-cost stylus profilers are traditionally on smaller, less stable platforms, resulting in a higher degree of susceptibility to environmental noise than their more expensive counterparts. However, other systems, such as precision microscopes and white-light optical profilers, have developed extremely rigid but low-cost platforms to allow precision measurements by those instruments. For Veeco, moving the Dektak 150 model stylus profiler to the same base as its Wyko line of optical profilers, which have a very high stiffness to weight ratio, allows low-cost stylus profilers to be deployed to measure finer features in noisier environments, such as industrial clean rooms with noisy air handlers and other industrial process equipment.

Data from the UCLA NRF lab below illustrate results from different systems in the same overall environment. To determine how well the stylus profiler operates in a noisy environment, a 1mm scan is taken on an optically flat surface, such as a silicon carbide mirror, and two items are analyzed to identify the stability of the measurement. The overall shape of the scan can be determined by analyzing the topographical difference of the highest point of the dataset to the lowest (Peak to Valley), the higher the Peak to Valley, the more shape the scan has, this is an indication of low frequency noise disturbing the system. The other analysis, Ra, is of the profile height deviations from the mean the scan is broken into 10 segments and Ra is analyzed and averaged over the entire dataset, consistently high Ra values indicates high frequencies from the environment is disturbing the stability of the measurement. Many applications require measured Ra of less than 10Å in order to achieve consistent repeatable results. Such results are easily achieved on the D150 product while other stylus systems cannot reach those levels.

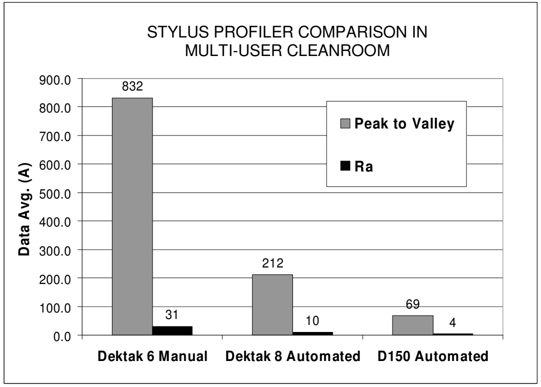


FIGURE 1)Several different stylus profilers were compared in an extreme environment. The Dektak 6M was very susceptible to the environmental noise and could not repeatably measure 1µm steps. The Dektak 150 was the

best at controlling both the high and low frequencies, resulting in the best measurement quality and allowing for angstrom-level repeatability on a 1µm step.

IMPROVING AUTOMATION

Implementation of new, smarter, higher performance motors allows for enhanced performance in a compact package, so that long travel and high precision can be achieved without increasing cost. Previous stylus profiler offerings by Veeco and other vendors achieved only +/- 5µm stage repeatability. The latest profiler, the D150, achieves +/- 1µm. Such x-y automated stages can repeatedly find precision measurement sites using feature recognition wizards. This is key to applications where not only repeatability but reproducibility of measurements are critical.

The example below is a rendering of a structure on a 4-inch semiconductor wafer. Two fiducials or alignment points were identified in opposing corners and 16 features, rendered below, were automatically located, measured and analyzed using dynamic step detection software that can be monitored with real-time databases.

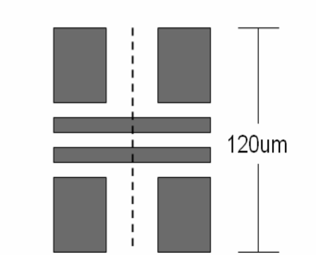
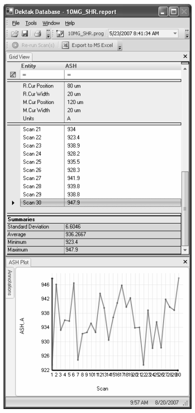


FIGURE 2) 10µm wide by 2µm step automatically located and measured on 4" wafers.



Entity	ASH
=	=
R.Cur Position	80 um
R.Cur Width	20 um
M.Cur Position	120 um
M.Cur Width	20 um
Units	A
Scan 21	934
Scan 22	923.4
Scan 23	938.9
Scan 24	928.2
Scan 25	935.5
Scan 26	928.3
Scan 27	941.9
Scan 28	939.8
Scan 29	938.8
Scan 30	947.9

Summaries	
Standard Deviation	6.6046
Average	936.2667
Minimum	923.4
Maximum	947.9

FIGURE 3) User-configurable database with real-time plotting monitors measurements as they are taken.

The newer motors also have the added benefit of enabling higher resolution stylus 3D mapping. This is enabling applications in the solar/photovoltaic industry where optical profiling is held back due to multiple layering of thin films, and AFM may not be cost effective. This next example illustrates this feature. Stylus profilers render 3D maps of surfaces by incrementing the y-axis in between taking scans in the x-axis. As the y-axis increment decreases, higher resolution is achieved and smaller features can be mapped. Typically, stylus profilers can step in 3 to 5µm increments. The D150 can step in micron increments and it is even possible to step in submicron increments. This enables stylus profilers to image surfaces that were previously out of their range of resolution.

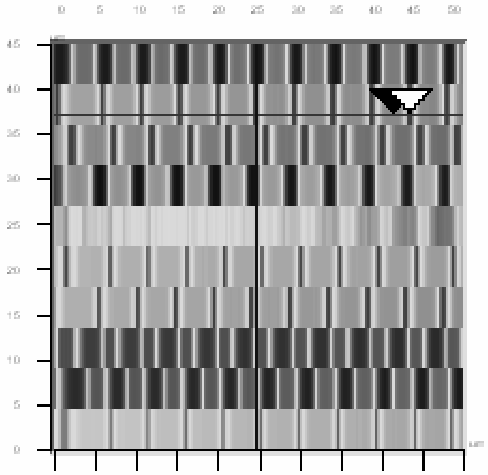


FIGURE 4) 50µm square area imaged with 5µm y-axis spacing.

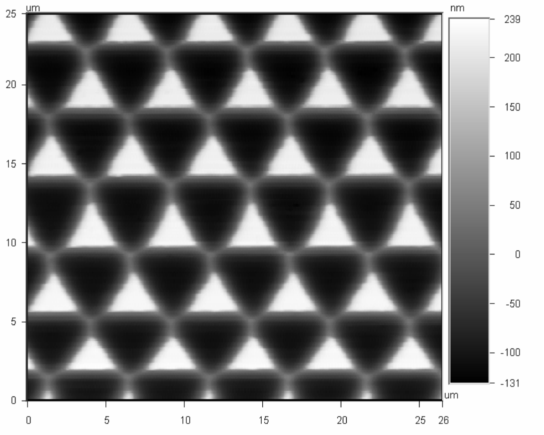


FIGURE 5) 25µm square area imaged with submicron scan spacing, the base of the triangles are 2.5µm.

MEASURING MICRO FORMS

The next generation of stylus profilers have new calibration routines that can extend accurate stylus metrology to microforms. Stylus profiling instruments commonly use a pivoted horizontal arm with a perpendicular stylus tip at the end. The stylus moves up and down along an arc, not straight up and down. The result is a horizontal shift, the run of the angle is elongated while the stylus is rising, and shrinks while descending (see Figure 6). Using a well known sample or an angle standard, it is possible to calibrate your profiler to better than 1% symmetry. For accurate angles the profiler must be calibrated vertically and horizontally, with this done and the symmetry calibrated, +/- 0.1deg of accuracy can be achieved from 1 to 60 degrees. This is ideal for measuring blades, sharps, microlenses and gratings where symmetry is crucial. Vision, the 3D analysis package for Dektak, has built-in features, such as curvature removal for in-depth surface analysis, line-width analysis for critical dimensioning and multi-region analysis for considering different regions in the same dataset individually, as well as many other analyses. Therefore, Vision is not limited to just displaying the entire map, the software allows the user to manipulate it to acquire more information about the sample.

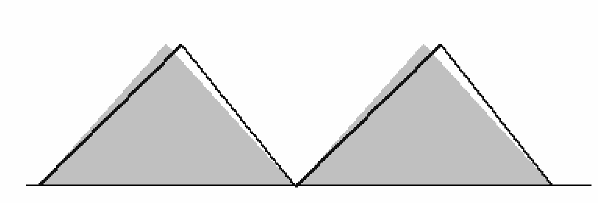


FIGURE 6) Gray area is actual surface, dark line is skewed measurement without correction.

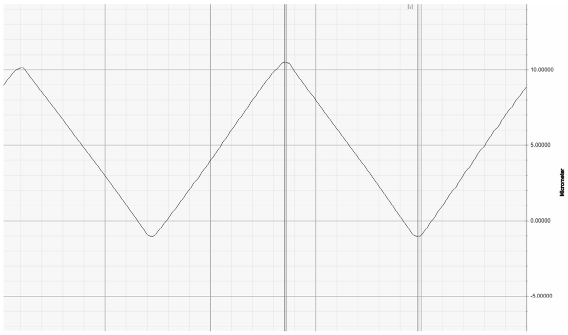


FIGURE 7) 90 degree symmetrical grating.

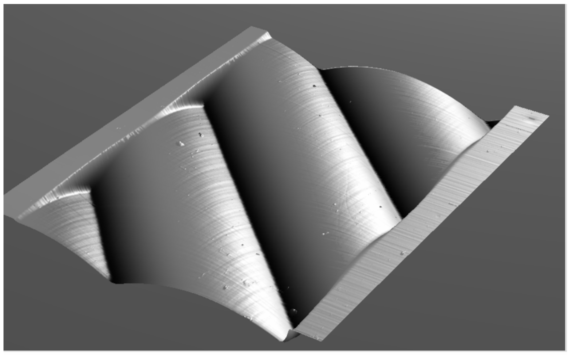


FIGURE 8) Microlens array

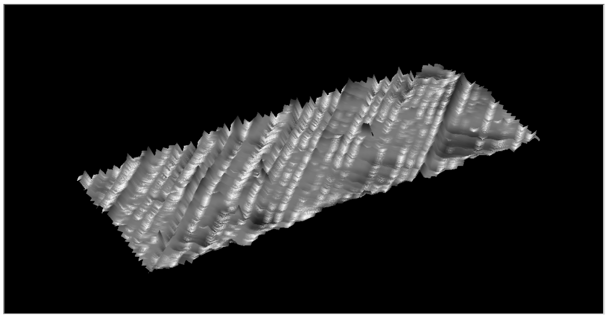


FIGURE 9) Surface roughness on peak of lens array in previous figure. A subregion of the peak with curvature removal displays the machine marks used to make the mold.

CONCLUSION

Stylus profiling technology has been in wide use for decades. Stylus profilers continue to be the metrology systems of choice for step heights, thin films, and other large shape characterization. However, innovative hardware enhancements and advanced software capabilities have continued to make large strides in fitting stylus techniques to challenging and emerging applications. Coupled with convergent software platforms, stylus users can now also confidently measure microshapes and other traditionally difficult sample features without incurring the costs of more expensive technologies.

REFERENCES

[1] J.Fruhaut, B.Hannemann, K.Lohr. Measurement of Form Profiles of Microstructures Using Stylus instrµments. Meas. Sci. Technol. **9** No 3 (March 1998) 293-296

[2] “Filtering of Surface Profiles,” Section 1, *Terms Related to Surface Texture,* ASME B46.1, American Society of Mechanical Engineers: New York, 2002