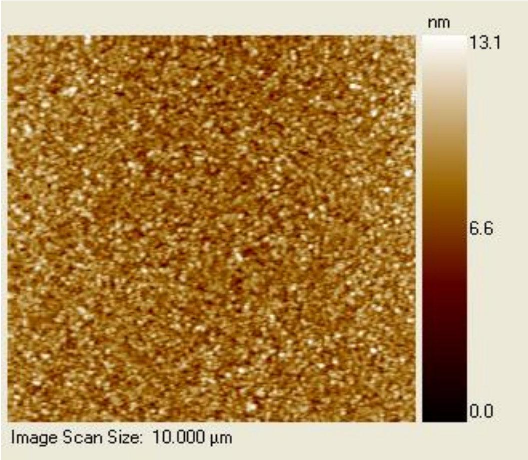
Surface Roughness and Morphological Analysis Through Scanning Probe Microscopy

Surfaces play a critical role in numerous material applications. In many cases, surfaces are the very first place to show signs of failure or breakdown. Examples of surface changes may include detachment of coating particles, cracks caused by fatigue, grinding damage due to friction, and phase separation appearing on the surface. Therefore, observing and monitoring surface morphology are of practical significance in industries so as to prevent catastrophic breakdowns and interruptions by detecting signs of failure at its early stages. Controlling surface roughness is also very important in applications such as precision position controls, semiconductors, and manufacturing. One good example is with combustion engines. The engine cylinder surface requires a certain surface roughness in order to hold lubricants in between the parts under compression while not too rough to induce metal-metal contact. It is evident that characterizing surface roughness and surface features is essential for quality control, work condition monitoring, failure analysis, and design improvement.

Surface roughness is usually characterized by several parameters such as average surface roughness (Sa), root mean squared, RMS, surface roughness (Sq), maximum peak height (Sp), maximum valley depth (Sv) and Peak-to-Valley Height (Sz). According to ASME B46.1, Sa is the arithmetic average of the absolute values of surface height deviations from the defined mean surface. Sq is the root mean square average of the surface height deviation from the defined mean surface. Sa and Sq are the most often used parameters to characterize the surface roughness based on the same measurement results of surface peaks and valleys. However, the Sq is influenced more by isolated large peaks or valleys.

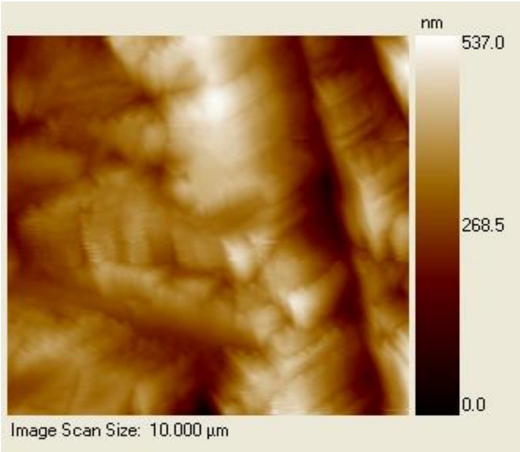
Surface roughness may be measured by either contact methods or non-contact methods. For the contact methods, a component of the measurement instrument contacts the surface during the measurement. Such methods include mechanical stylus profilometry and scanning probe microscopy. Contact methods can provide high resolution measurements in both vertical and lateral directions. However, a sharp stylus tip may cause unwanted damage to a soft sample surface. Then a non-contact method may be used instead of contact method. The non-contact methods are based on optical profilometry techniques such as interferometry, confocal microscopy, and chromatic aberration. A major advantage of the non-contact methods is the ability to rapidly produce three-dimensional measurements without contact to potentially damage or alter the surfaces. Nonetheless, if the surface has varying optical properties, is transparent or has extremely low reflectivity, optical profilometry may lead to inaccurate results. It is understandable that the contact and non-contact methods for surface roughness and topography analysis are complementary and could be selected to suit the application’s needs.

Presented here are two surface roughness and morphological analyses: one for a coating on a wafer substrate and one for a stainless steel sample puck. Both surfaces were scanned through *in-situ* scanning probe microscopy on a Hysitron TriboIndenter system. Both images have a scan size of 10 × 10 µm. The statistical results of the surface roughness were obtained using the software for SPM image processing, Gwyddion. The Sa, Sq and Sz roughness parameters of each surface were given in the corresponding tables. It can be seen that the coated wafer surface is very smooth and uniform, and the steel puck has a higher surface roughness with large peaks and valleys as a machined surface would have.



Sa (nm)	Sq (nm)	Sz (nm)
1.05	1.32	13.01

Figure 1. Surface roughness analysis and morphology for a coated wafer surface.



Sa (nm)	Sq (nm)	Sz (nm)
64.20	80.46	537.47

Figure 2. Surface roughness analysis and morphology for a stainless steel puck surface.