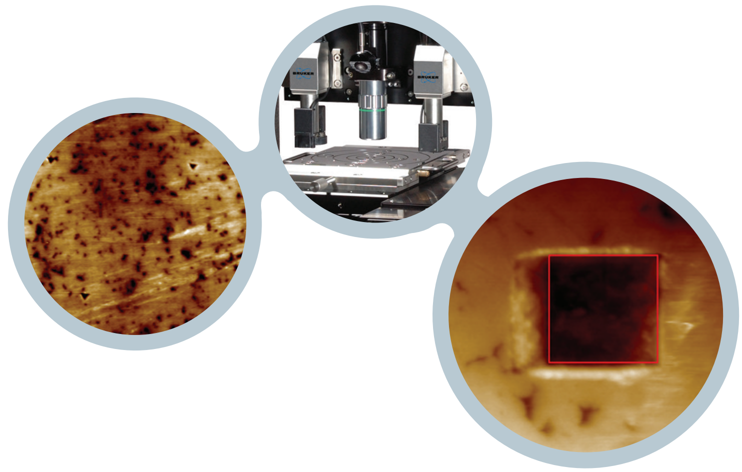

Application Note #1535

Investigating Wear and Nanomechanics of Thin Hard Coatings on Steel

Hard coatings are often used on the surfaces of steel components to increase their service life. These tribological coatings prevent wear between contacting parts, such as the surfaces of tools or the contacting surfaces of gear teeth. Since the mechanical properties of a coating can be greatly influenced by deposition parameters, coating reliability is often a concern. Significant substrate effect may occur for a hard coating on a soft substrate. Bruker's Hysitron TI Series nanomechanical test instruments can precisely monitor the hardness, reduced modulus, and wear depth in thin hard coatings on steel.

Testing and Methodology

A Hysitron TI Series nanomechanical test instrument was used to investigate mechanical properties of three 2 µm thick nitride coatings on steel substrates. The as-deposited coatings had rough surfaces, so all samples were mechanically polished to bright reflective surfaces. In-situ imaging was used to verify that the roughness was below 5 nm RMS after polishing.

Nanoindentation tests with a diamond Berkovich indenter probe were performed to measure hardness and modulus of the three coatings. In-situ SPM imaging was used for precise placement of indents as well as pre- and post-test analyses of sample topography. The indentation tests were performed at several different loads to measure the mechanical properties as a function of depth to ensure that no substrate effects were seen.

ScanningWear™ testing is a feature enabling research into wear resistance of coatings and films at the nanoscale. ScanningWear tests were performed using a Cube Corner probe. The probe was raster-scanned on the sample surface with a 400 µN normal scanning force in a 2x2 µm area. Twenty wear passes were performed on each sample and the wear tracks were analyzed with in-situ SPM imaging.

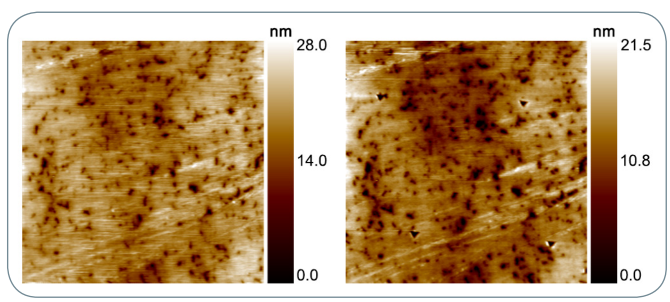

Figure 1. In-situ SPM image of polished nitride hard coating showing pre-test (left) and post-test (right). Image scan size was 20 µm.

Results

A representative 20 µm, 2D topographical in-situ SPM image obtained on Sample 2 is shown in Figure 1. Similar images obtained on all samples were used to determine surface roughness and identify ideal locations for nanoindentation tests. Roughness of three samples after polishing is listed in Table 1. Hardness, reduced modulus, and wear depth are included in the same table.

	Hardness (GPa)	Modulus (GPa)	Wear Depth (nm)	Roughness (nm)
Sample 1	30.65	437.41	60.567	2.00
Sample 2	35.62	412.78	23.0735	2.60
Sample 3	29.93	344.64	67.397	4.77

Table 1. Hardness, reduced modulus, wear depth, and roughness on the polished surfaces of Sample 1, Sample 2, and Sample 3.

A general rule of thumb when testing a thin coating is to test only the first 10% of the coating thickness to avoid substrate effect on measurements. Because these coatings were approximately 2 µm, our tests were kept below 200 nm. Figure 2 shows the hardness and reduced modulus for three hard coating samples at different depths, from 10 nm to 90 nm. As there are no trends in the hardness or modulus with changing depth, the results represent the coating properties without substrate effect. The average value for hardness and reduced modulus is shown in Figure 3. The results show that, of the three coatings, Sample 2 has the highest hardness and Sample 1 has the highest modulus.

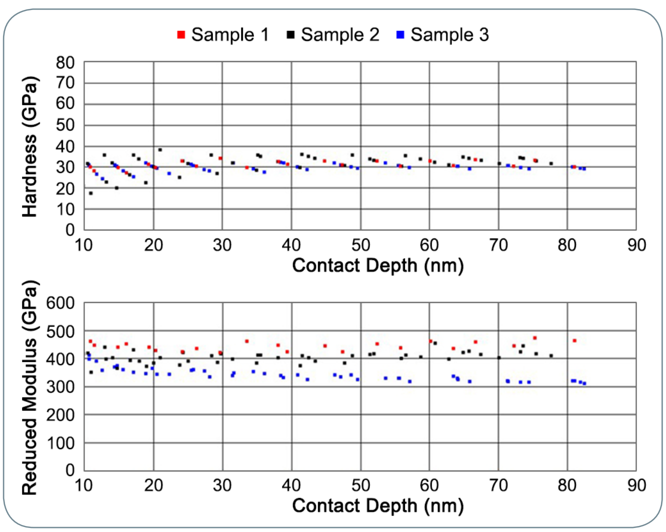

Figure 2. Hardness and reduced modulus of hard coatings as a function of indentation depth.

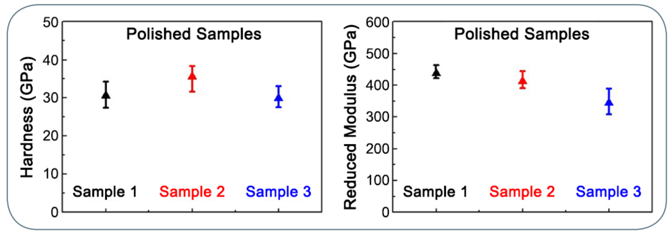

Figure 3. The average value of hardness and reduced modulus from indents on Sample 1, Sample 2, and Sample 3.

Figure 4 shows the in-situ SPM images and the measured wear of the three coatings after ScanningWear tests. The squares are the wear area, and the difference between mean height outside and inside each wear area is the wear depth. The wear depth on Sample 2 was measured as 23.07 nm, which is significantly smaller than the other two samples. Lower wear depth on Sample 2 indicates that Sample 2 has the best wear resistance. The hardness of Sample 2 was also higher, indicating there may be a correlation between hardness and wear resistance. There was no measured correlation between wear resistance and modulus. Large amounts of pile-up around Sample 3 indicate the wear mechanism may have been different from the other two samples.

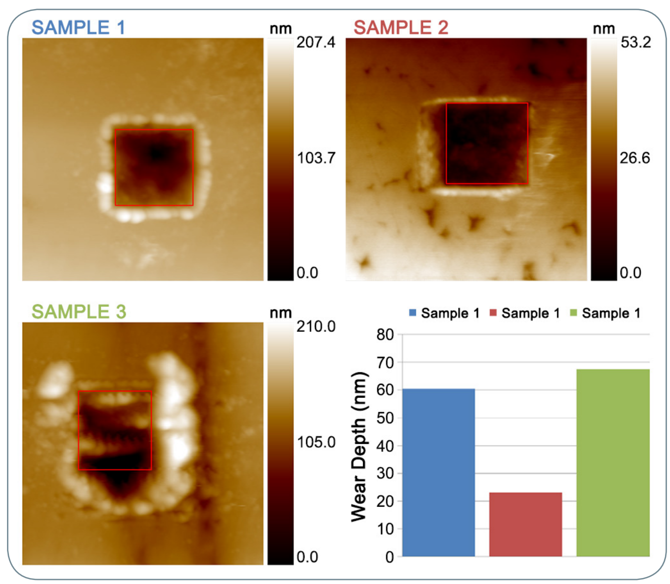

Figure 4. 6x6 µm topographical in-situ images of the surfaces of Sample 1, Sample 2, and Sample 3 after wear tests on 2x2 µm areas at 400 µN with 20 passes. The chart shows the resulting wear depth for each sample.

Conclusions

A Hysitron TI Series nanoindenter was used to successfully measure hardness, reduced modulus, and wear depth for thin, super-hard coatings on steel samples. In-situ imaging was very important for verifying the roughness of the samples as well as test placement and post-test analysis. Significant substrate effects may occur for a hard coating on a soft substrate. The ability to quickly and automatically obtain mechanical properties as a function of depth allowed verification that substrate effects were minimal. The sensitivity of Bruker's proprietary transducer allowed tests to be easily performed below 200 nm, all the way down to 10 nm in depth. All tests can be fully automated and can be easily applied in process control, as well as in R&D. The ability to characterize wear properties of ultra-thin films and the capability to understand sliding single asperity contact interactions in conventional engineered systems is critical for designing components with an enhanced service life.

Authors

Ude D. Hangen, Ph.D. (ude.hangen@bruker.com)
Bruker

Bruker Nano Surfaces and Metrology Division
Minneapolis, MN · USA
+1.952.835.6366
productinfo@bruker.com

www.bruker.com/nanomechanical-testing