INSPECTION OF TITANIUM NITRIDE COATINGS BY TRIBOMETER

Prepared by

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INTRO

Hard composite ceramic coatings deposited by PVD/CVD process are widely used in a variety of machine tooling applications, such as razor blades, metal cutting, injection molding and sawing, in order to improve the work efficiency and service lifetime of the metal components. In particular, transition metal nitrides, such as titanium nitride (TiN), TiSiN and TiCN possess superior hardness, chemical stability and wear resistance. They become the best protective coatings under extreme working conditions in aggressive environments.

IMPORTANCE OF RELIABLE WEAR EVALUATION FOR PROTECTIVE COATINGS

Wear of the tools in service creates loss of dimensions and functionality of the tools. It has significant influence on the tool life, as well as the surface integrity and dimension accuracy of the finished products. The tribo-mechanical properties of the protective ceramic coatings can substantially enhance the service performance and lifespan of the machine tools. Reliable and accurate quality control of such protective coatings becomes vital to ensure quality performance of the tools.

MEASUREMENT OBJECTIVE

In this application, we demonstrates the process for evaluating the quality of the protective TiN coating samples using Nanovea Tribometer.

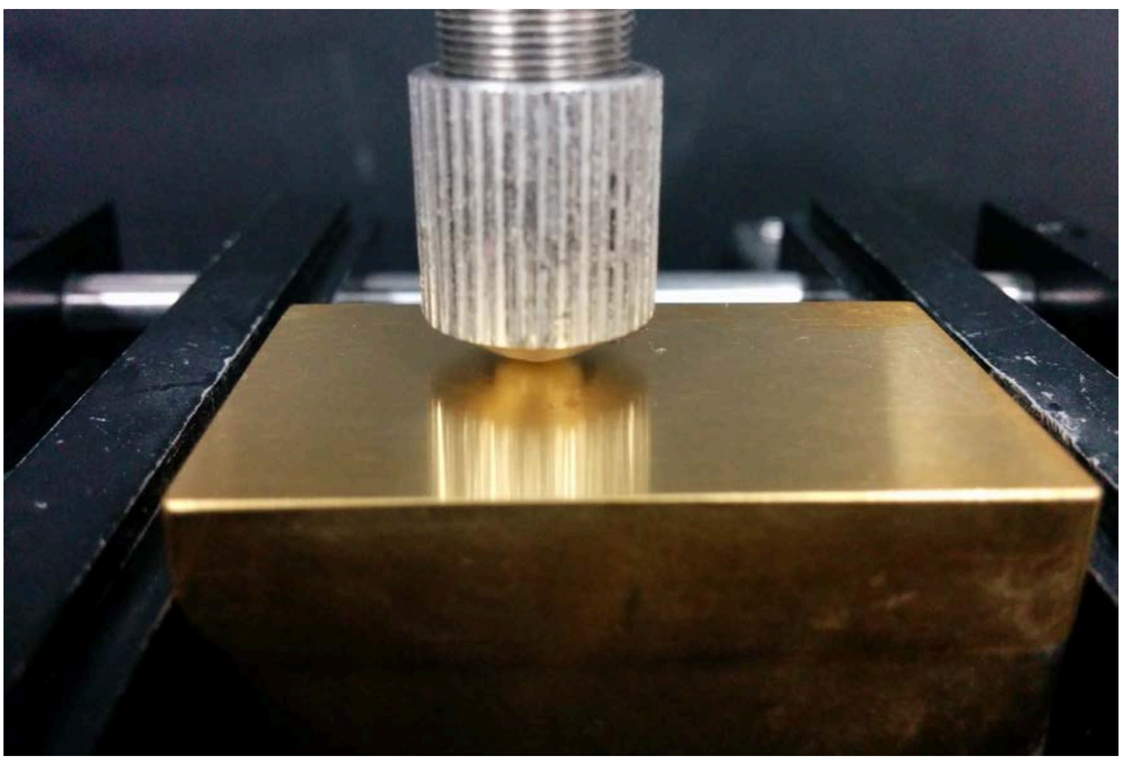


Fig. 1: Linear wear test on the TiN coating sample.

TEST PROCEDURE

The coefficient of friction, COF, and the wear resistance of a batch of Titanium Nitride (TiN) coating samples were evaluated by Nanovea Tribometer using linear reciprocating wear module. An Al_2O_3 ball (6 mm diameter) was used as the counter material. The test parameters are summarized in Table 1. Wear track 3D profiles were measured by the Nanovea Optical Profilometer, and the wear track morphology was examined using optical microscope.

Sample description	Titanium Nitride Coatings
Normal force	10 N
Amplitude	8 mm
Speed	200 cycles/min
Duration of test	5 min

Table 1: Test parameters of the wear measurements.

RESULTS AND DISCUSSION

The evolution of the COF during the wear tests of the TiN samples is plotted in Fig. 2. The TiN Samples 1, 2 and 3 exhibit a progressively increasing COF from ~0.1 to ~0.5 during the first 600 cycle run-in period. It then gets relatively constant at ~0.5 in the following wear test. In comparison, Sample 4 shows a higher COF of ~0.2 during the run-in period of 400 cycles. Violent fluctuation of the COF takes place as the coating is damaged and the metal substrate is exposed.

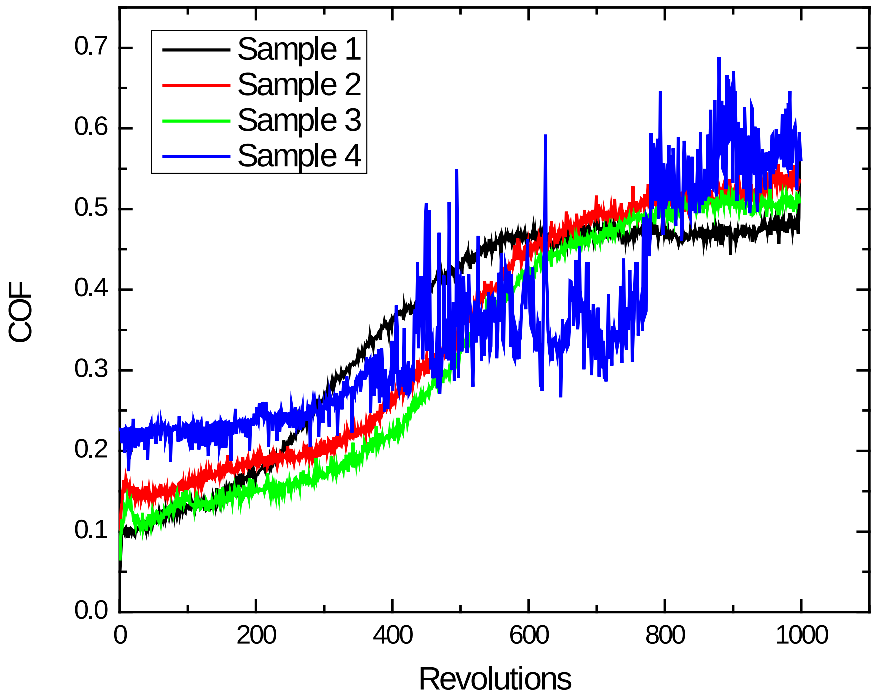


Fig. 2: Evolution of COF of the TiN samples.

Fig. 3 shows the wear tracks of the TiN coatings under the optical microscope after the wear tests. The wear track evaluation is in agreement with the observation of COF evolution: The TiN coating has a rough surface finish with directional parallel texture created during machining of the metal substrate. For Samples 1, 2 and 3, the surface asperities were worn out and flattened during the wear tests across the surface texture, creating a relatively smooth and shallow wear track. The TiN coatings did not failed and they still played a protective role during the wear test. However, the TiN coating of Sample 4 wore out quickly during the wear test and left the steel substrate exposed and unprotected. It resulted in a substantially accelerated wear process which generated a deep wear track on the surface.

Fig. 4 compares the false color view of the wear tracks of the TiN coating Sample 1 (Pass sample) and Sample 4 (Fail sample) after the 5-min wear tests, which can provide more insight in the wear failure mechanism. The wear is restricted in the TiN coating for Sample 1 and it creates a shallow wear track on its surface. The wear process, however, forms a significantly larger wear track on Sample 4 due to the failure of the TiN coating.

Fig. 5 compares the wear scars of the Al_2O_3 balls after the tests under the optical microscope. Samples 1, 2 and 3 exhibit similar mild wear scar morphology. In comparison, the ball against Sample 4 has a much larger wear scar showing metal and coating debris attached to it.

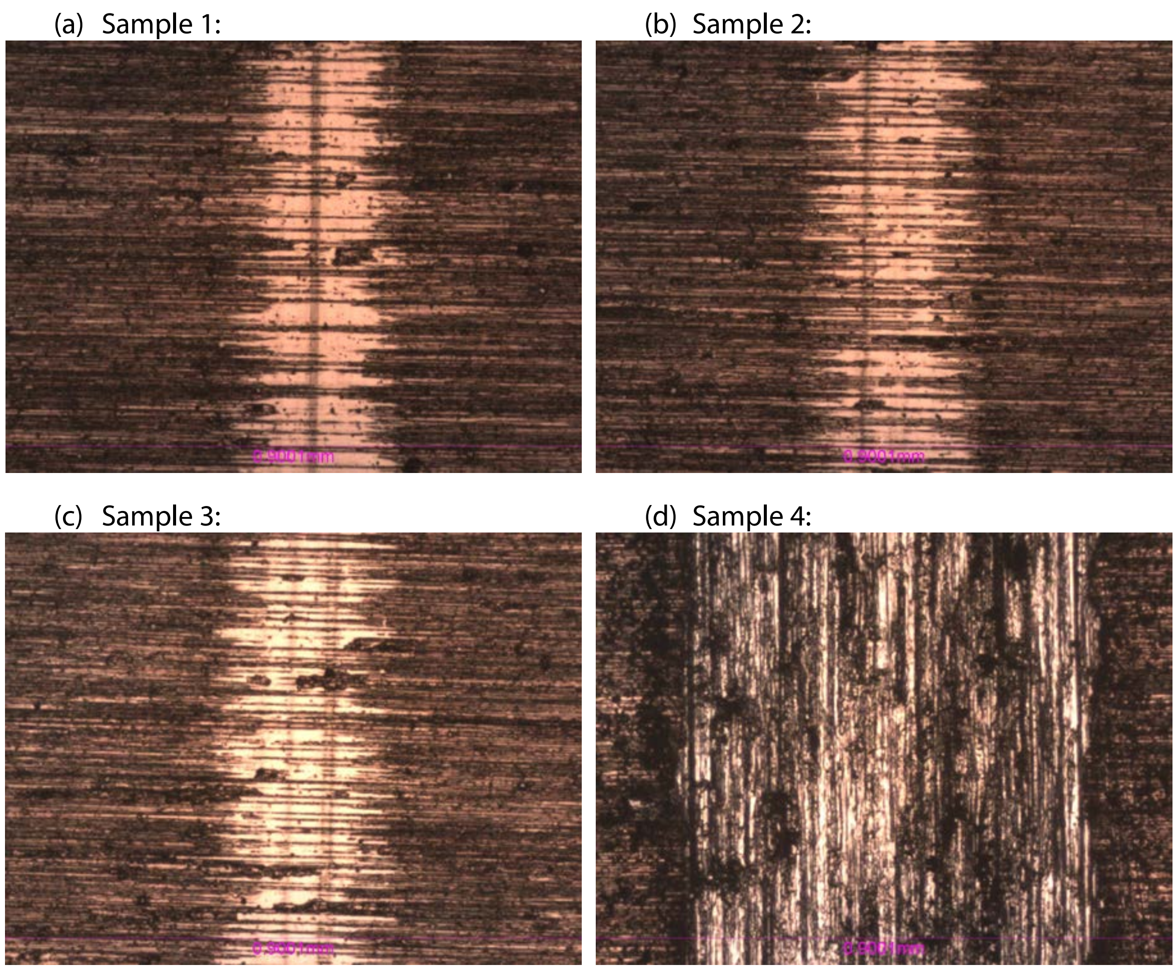


Fig. 3: The wear tracks under the optical microscope.

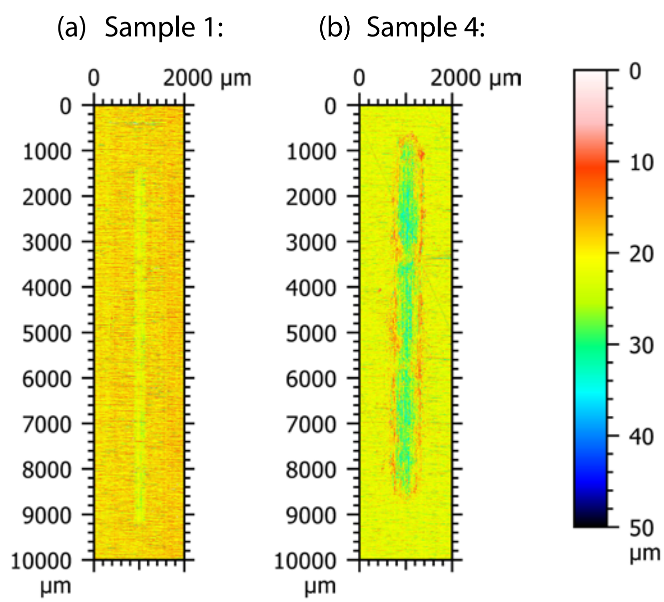


Fig. 4: False color view of the wear tracks.

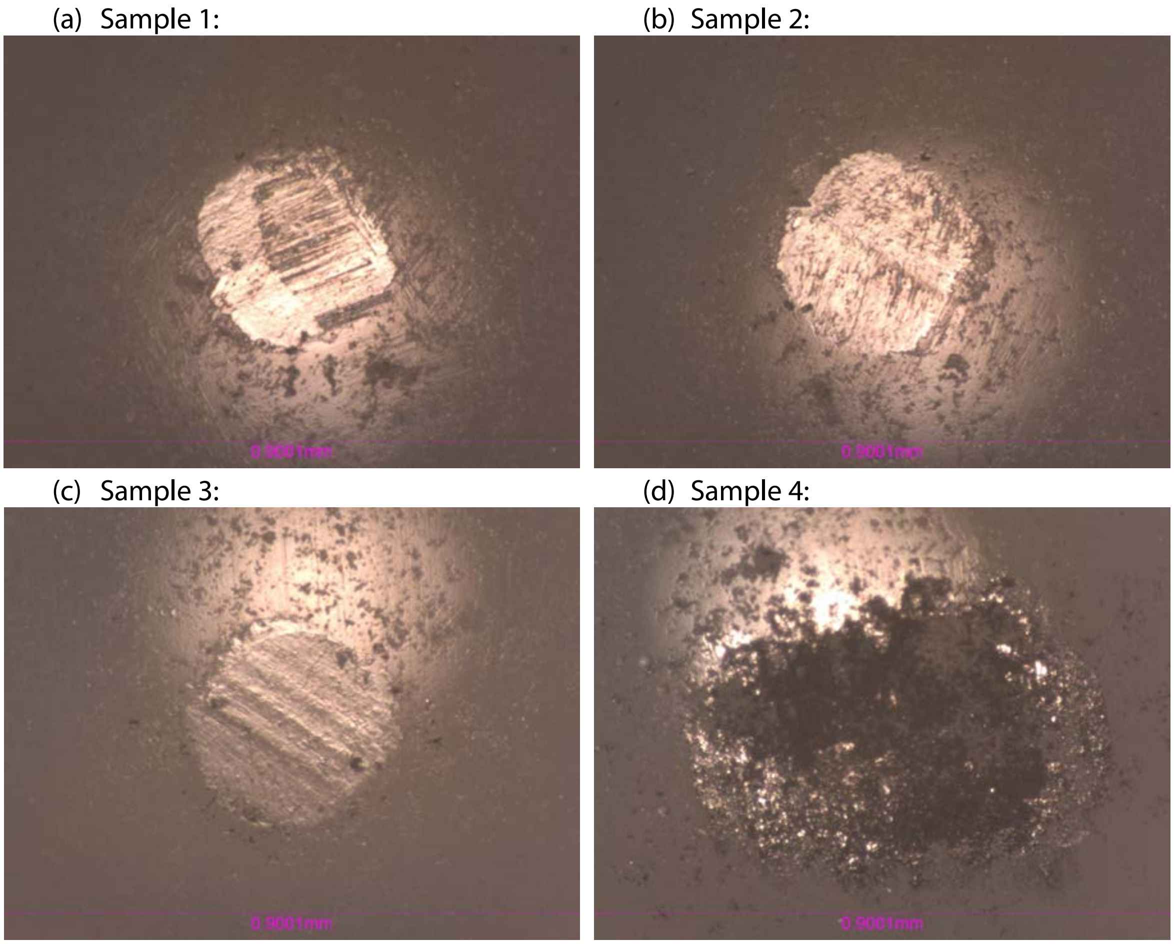


Fig. 5: The wear scars on the balls against the TiN coatings under the optical microscope.

CONCLUSION

In this study, we showcased the capacity of Nanovea Tribometer in performing fast and accurate inspection of the protective TiN coatings in a controlled and monitored manner. Quality coating enhances wear resistance of the metal substrate and tremendously extends its service lifetime. This study demonstrates an easy and reliable method to evaluate and inspect the quality of the protective coating. By setting up a standard test procedure and conditions, the user can quickly find out the defective coatings during the quality control process.

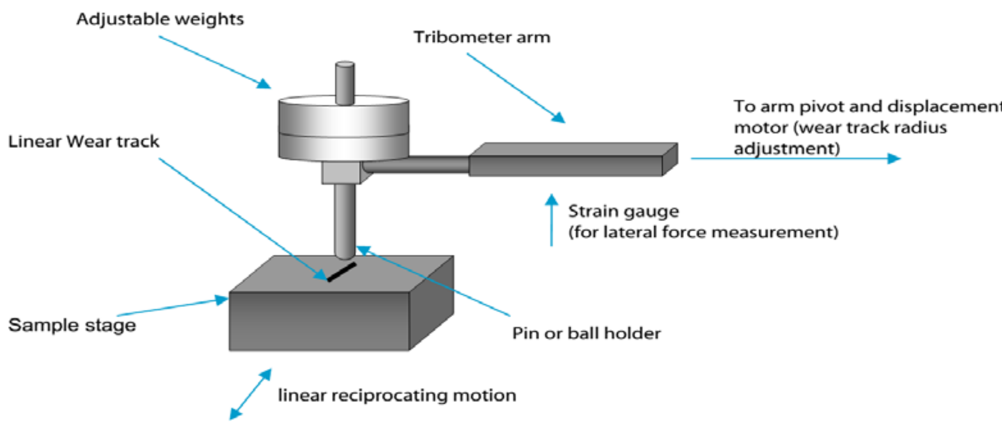
Nanovea Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for determining the full range of tribological properties of thin or thick, soft or hard coatings, films and substrates.

Learn More about the Nanovea Tribometer, Nanovea Profilometer and Lab Service

APPENDIX: MEASUREMENT PRINCIPLE

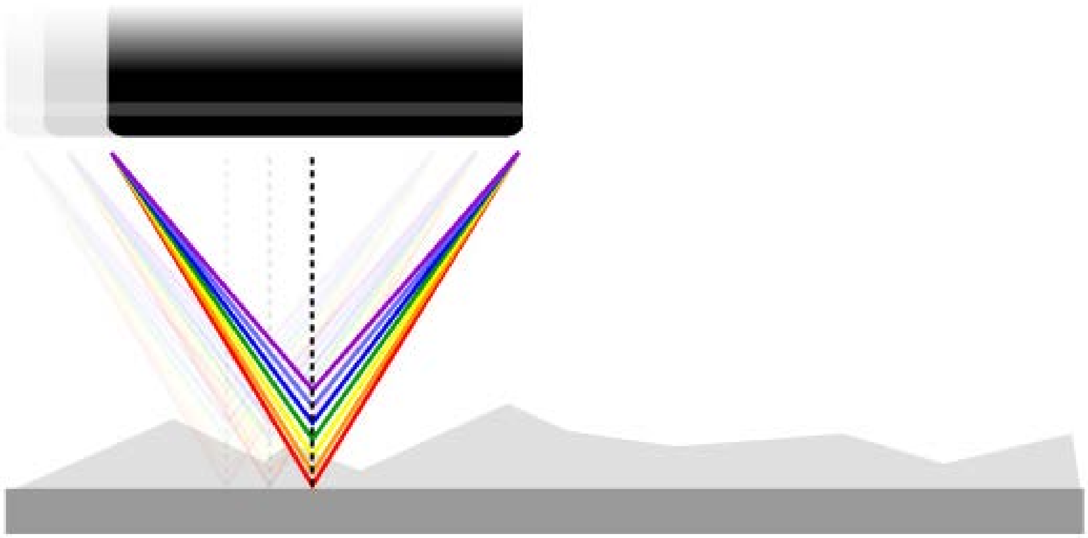
RECIPROCATING WEAR PRINCIPLE

A flat or a sphere shaped indenter is loaded on the test sample with a precisely known force. The indenter (a pin or a ball) is mounted on a stiff lever, designed as a frictionless force transducer. As the plate slides in a linear reciprocating motion, the resulting frictional forces between the pin and the plate are measured using a strain gage sensor on the arm. Wear rate values for both the pin and sample may also be calculated from the volume of material lost during a specific friction run. This simple method facilitates the determination and study of friction and wear behavior of almost every solid state material combination, with varying time, contact pressure, velocity, temperature, humidity, lubrication, etc.



3D NON-CONTACT PROFILOMETER PRINCIPLE

The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



Unlike the errors caused by probe contact or the manipulative Interferometry technique, White light Axial Chromatism technology measures height directly from the detection of the wavelength that hits the surface of the sample in focus. It is a direct measurement with no mathematical software manipulation. This provides unmatched accuracy on the surface measured because a data point is either measured accurately without software interpretation or not at all. The software completes the unmeasured point but the user is fully aware of it and can have confidence that there are no hidden artifacts created by software guessing. Nanovea optical pens have zero influence from sample reflectivity or absorption. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent/opaque, specular/diffusive or polished/rough.