GOLD COATING TRIBOLOGY ON QUARTZ CRYSTAL SUBSTRATE

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INTRO

The Quartz Crystal Microbalance (QCM) is a piezoelectric device composed of a thin plate of quartz and two electrodes affixed to each side of the plate. It is an extremely sensitive mass sensor capable of making precise measurements of very small mass in the nanogram range. QCMs are widely applied in research and industrial instruments, such as thermogravimetry, sorption/desorption systems, and surface property instruments to detect and monitor the change of mass, adsorption, density and corrosion, etc.

IMPORTANCE OF RELIABLE WEAR EVALUATION FOR QCM

The QCM works based on the piezoelectric properties of the quartz crystal. It measures the mass change on the surface down to 0.1 nanogram during material deposition by detecting variations in the resonance frequency of the crystal. Due to the extreme sensitive and accurate characteristics of the QCM, it is critical to ensure that the two electrodes on both sides of the quartz plate possess good wear resistance. Any mass loss on the metal electrodes caused by wear can lead to significant error in the measurement. Therefore, reliable and accurate wear evaluation is important for quality control and R&D of QCMs.

MEASUREMENT OBJECTIVE

In this application, we investigated the wear behaviors of a QCM sample to showcase the capacity of Nanovea Tribometer in performing accurate evaluation of the tribological properties of very delicate samples.

Fig. 1: Linear wear test on the QCM sample.

TEST PROCEDURE

The coefficient of friction, COF, and the wear resistance of a QCM sample was evaluated by Nanovea Tribometer using linear reciprocating Wear Module. A SiN ball (6 mm diameter) was used as the counter material. The test parameters are summarized in Table 1. The wear rate, K, was evaluated using the formula $K=V/(F \times s)$, where V is the worn volume, F is the normal load, and s is the sliding distance. Wear track 3D profiles were measured by the Nanovea Optical Profilometer, and the wear track morphology was examined using optical microscope.

Sample description	Quartz Crystal Microbalance
Normal force	2 N
Amplitude	2.5 mm
Speed	60 cycles/min
Duration of test	1, 2, 3, 5, 20, 30 min

Table 1: Test parameters of the wear measurements.

RESULTS AND DISCUSSION

The evolution of COF during the wear test of the QCM sample is plotted in Fig. 2. The QCM sample exhibits a progressively increasing COF from ~0.1 to ~0.5 in the first two minutes. It gradually decreases to ~0.4 in the third minute, and then gradually increases to above 0.6 in the following wear test.

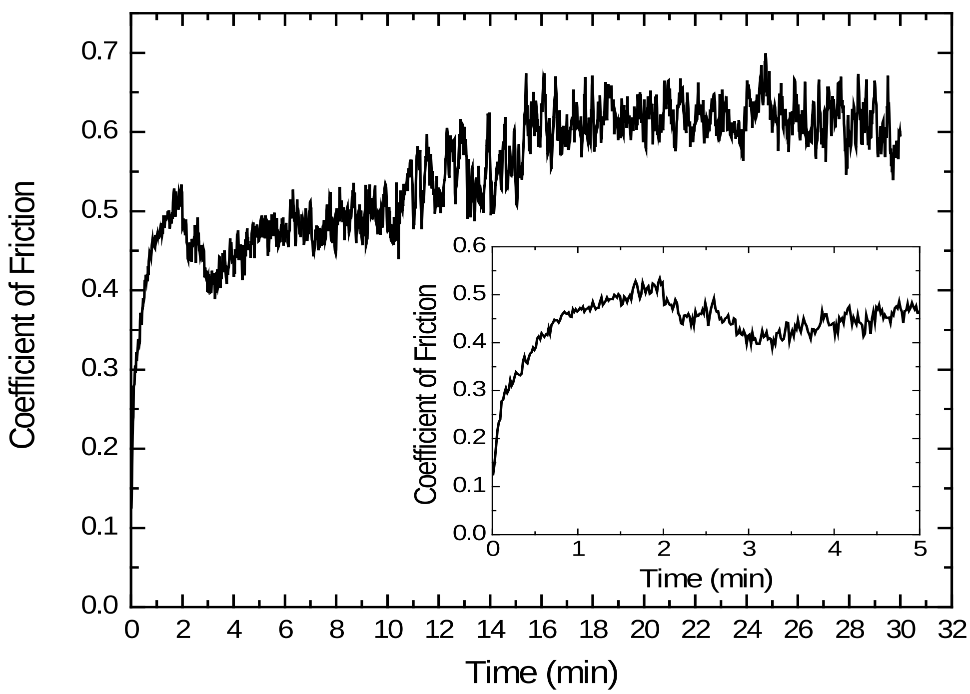


Fig. 2: Evolution of COF of the QCM sample.

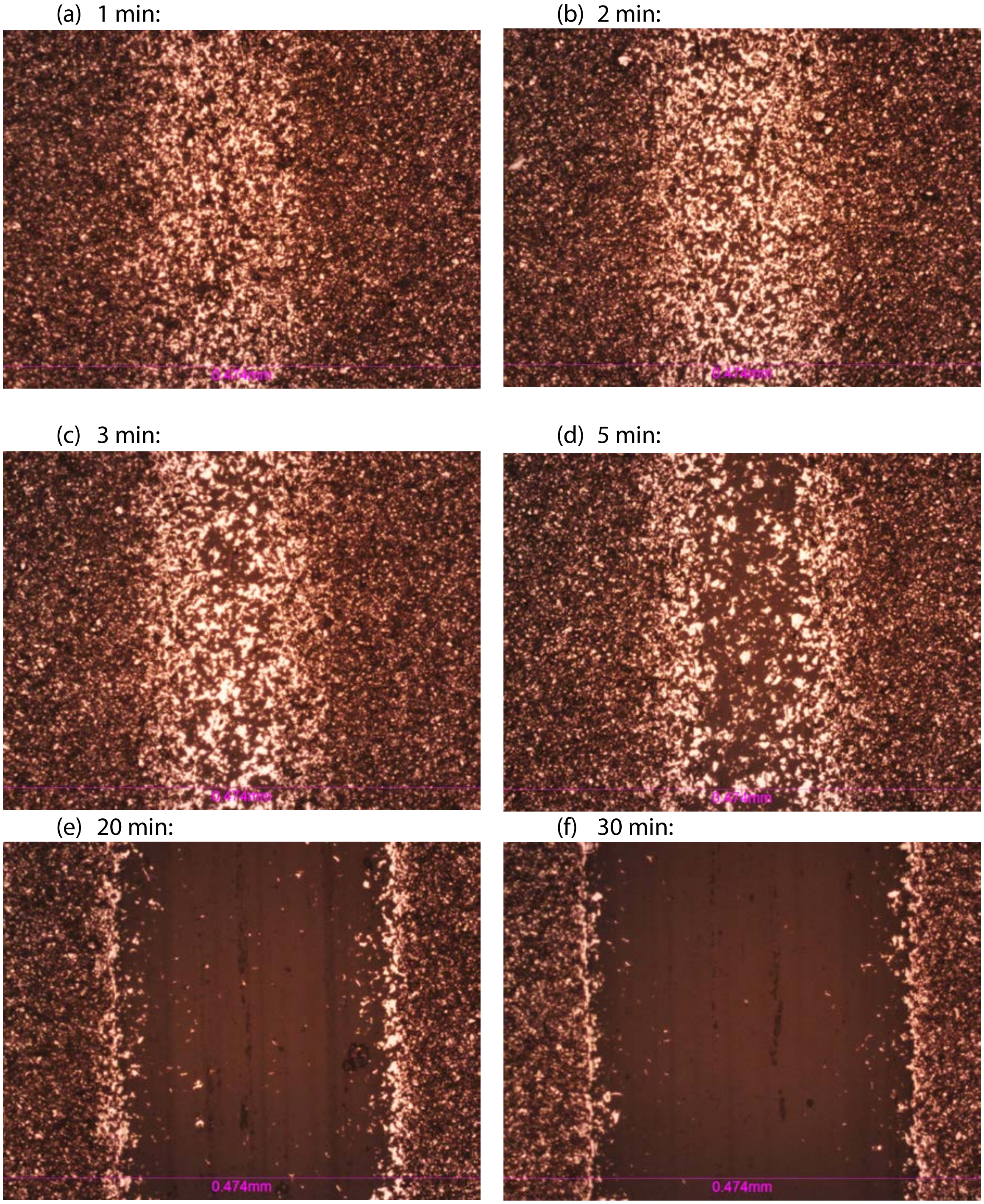


Fig. 1: Evolution of the tracks under optical microscope.

Fig. 3 shows the development of the QCM wear tracks under the optical microscope after 1, 2, 3, 5, 20 and 30 min wear tests. The wear track evaluation is in agreement with the observation of COF evolution: The gold coating on the QCM sample has a rough surface finish, which results in a higher COF of ~0.5 in the first two minutes' run-in period. This is followed by slight decrease of COF in the third minute, during which the surface asperities are worn and flattened, creating a relatively smooth wear track with lower friction. However, as the wear test continues, the gold coating progressively wears out and the quartz substrate is exposed. This results in increased COF above 0.6.

Fig. 4 compares the 3D wear tracks of the QCM sample after 3, 20 and 30 min wear tests. The wear volume and wear rate calculated from the wear track profiles are summarized Table 2. The gold coating has a wear rate of 2.26×10^{-5} mm^3/N m, as calculated using the wear track after 3 min wear test in which the wear is restricted in the gold coating. When the quartz substrate is reached, the more wear resistant quartz reduced the wear rate to $\sim 1.5 \times 10^{-5}$ mm^3/N m.

This study not only investigate the wear resistance of different layers of the QCM sample, but also demonstrates the importance of surface finish of the gold coating to its wear resistance. Smoother surface finish can reduce friction and enhance wear resistance.

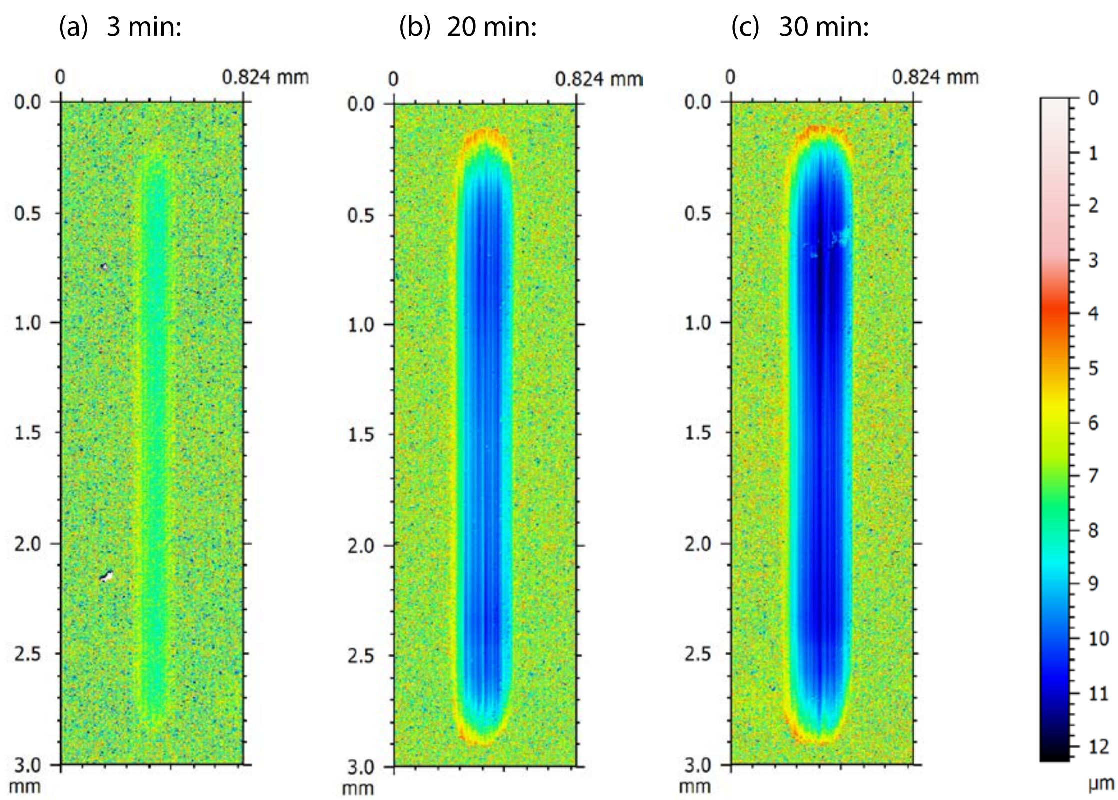


Fig. 4: False color view of the wear tracks.

	Volume (μm^3)	Wear rate (mm^3/N m)
3 min	4.1E+05	2.26E-05
20 min	1.8E+06	1.52E-05
30 min	2.8E+06	1.56E-05

Table 2: Result summary of wear track analysis.

CONCLUSION

In this study, we showcased the capacity of Nanovea Tribometer in performing accurate evaluation of the coefficient of friction and wear rate of the Quartz Crystal Microbalance (QCM) in a controlled and monitored manner. The surface finish and homogeneity of the QCM sample plays an important role in the wear behavior. Smooth surface enhances wear resistance by reducing friction.

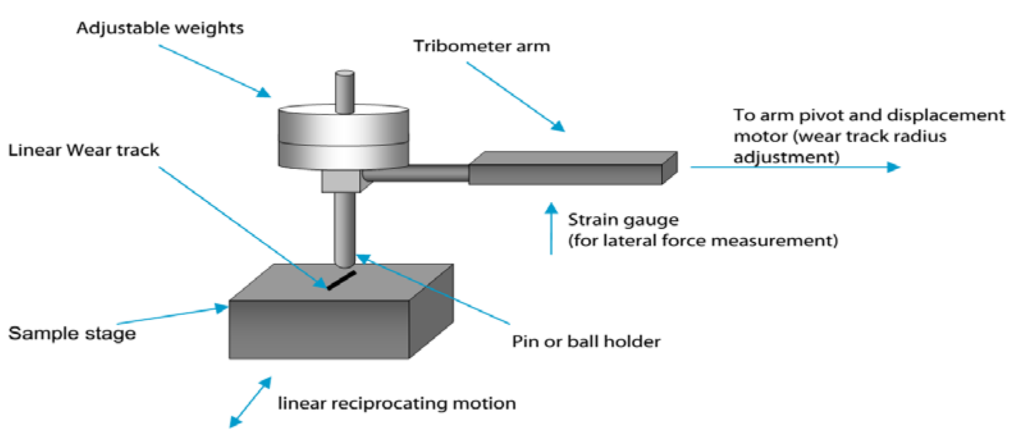
Nanovea Tribometer offers precise and repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional high temperature wear, lubrication and tribo-corrosion modules available in one pre-integrated system. Nanovea's unmatched range is an ideal solution for determining 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

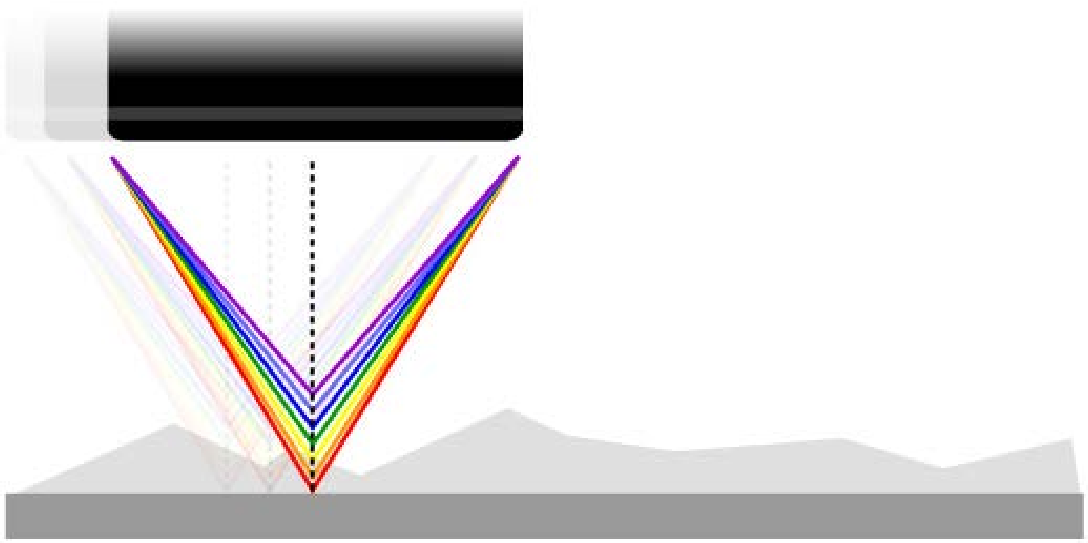
RECIPROCATING WEAR PRINCIPLE

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.