T3 Review
Automated Wear Testing

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INTRODUCTION

Wear is a process of removal and deformation of material on a surface as a result of mechanical action of the opposite surface[i]. Wear has a complex nature with different mechanisms involved, such as adhesive wear, abrasive wear, surface fatigue, fretting wear, erosive wear and many others. In order to measure the wear rate within a specified time period in a controlled and repeatable manner, several standard test methods for different types of wear have been developed by the ASTM International Committee G-2.

Sliding wear behaviors of materials are usually measured under the linear reciprocating and rotative (pin on disk) wear test setups described in ASTM G133[ii] and ASTM G99[iii] standards. The wear rate can be calculated based on the loss of material during wear in terms of volume or weight. Conventional wear tests require either measuring the wear track profile using an additional profilometer after the test to calculate the wear volume, or weighing the sample before and after the wear test to determine the weight change. These two measurements become very challenging when the wear process takes place in a sub-micron scale, where both weight and volume losses are difficult to measure. Moreover, only one wear rate can be obtained at the end of the conventional wear test. For materials with varied mechanical properties at different depth from the surface, e.g. thin films, oxide layers, the wear rate can change substantially under different number of cycles.

Therefore, an automated tribometer with the capacity of monitoring wear evolution under a low loading condition is in need. Nanovea developed T3 – an automatic nano wear tester using linear reciprocating setup compliant with ASTM G133 for wear rate study. It applies a constant normal load on a diamond stylus as the counterpart material using a high precision piezo load cell during the wear test, and record the change of wear track depth in situ with a high resolution capacitor depth sensor. Such a fully automatic tribometer with nanometer range and controlled load and depth is available at a competitive price in the $20K range, making it an ideal tool for Quality Control of materials with delicate surface or thin films.

MEASUREMENT OBJECTIVE

In this application, the Nanovea T3 Tribometer is used to measure the wear rate of three different coatings, in order to showcase the simplicity and reliability this breakthrough tribometer.

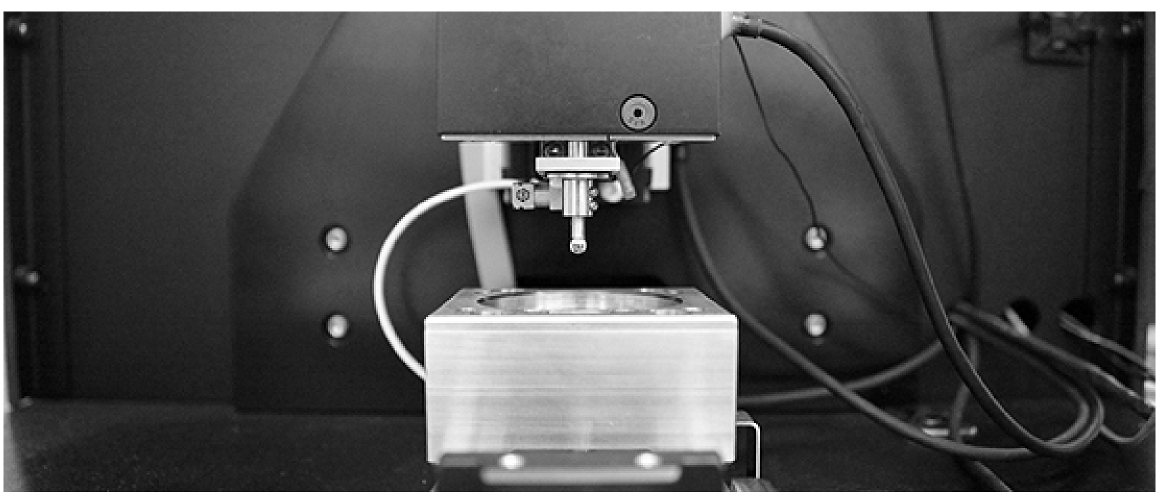

Fig. 1: Sample holder inside T3

TEST CONDITIONS & PROCEDURE

The evolution of the wear track depth of three coatings during the tests was evaluated by Nanovea T3 Tribometer equipped with a diamond conical spherical tip (100 μm radius). The test coatings were deposited on silicon wafer and have smooth surface finish. As shown in Fig. 2, the T3 system has a clean and simple user interface for test condition setup displayed on a touchscreen. The drop-down menu allows selection of the applied load, ball radius, wear track length and number of cycles, and Y and Z position control allows finding the intended test location on the coating. The test begins after the "START" bottom is clicked. The following procedure will be performed:

1) Automatically engage the indenter to find the sample surface.
2) Perform the linear reciprocating wear test using the test parameters given by the user and monitor the depth change during the tests.
3) Conduct automated calculation of the wear rate.

The wear rate is calculated based on the penetration depth and tip radius of the diamond stylus for the test. The test conditions are shown on the touchscreen of the T3 system as displayed in Fig. 2.

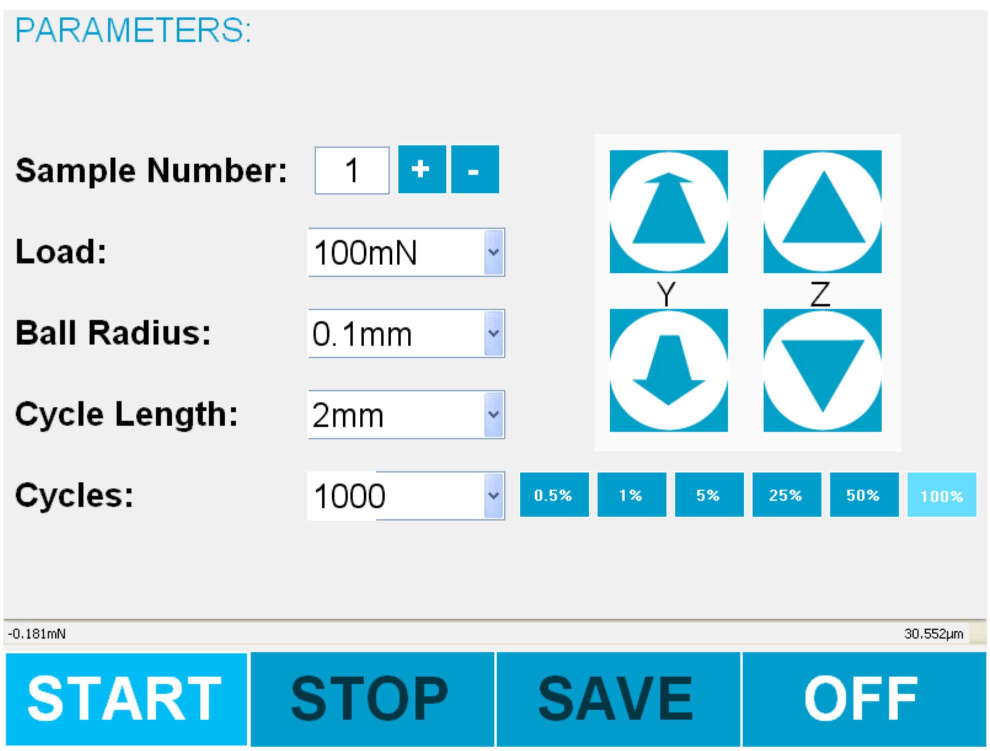

Fig. 2: User interface for test parameter input.

RESULTS AND DISCUSSION

The evolution of the wear track depth during the test is monitored and compared in situ. Fig. 3 shows the change of depth of the wear track every 200 cycles during the wear test of Coating 3 displayed on the touch screen as an example. The average depth of the test coatings were automatically calculated as shown in Fig. 4. It can be observed that all three coatings have a relatively higher penetration speed in the first half period of the wear test, followed by slowing down of the wear process. It is interesting that the coatings exhibit such a slowdown trend after different number of cycles during the wear test. Coating 1 slows down at 400 cycles, compared to 600 and 200 cycles, respectively, for Coating 2 and Coating 3. As a result, Coating 2 only exhibits substantially higher wear rate after 600 cycles wear test; however, at ~200 cycles, the wear depth values of the three test samples are comparable. This demonstrates the importance of monitoring the wear evolution at different number of cycles, which provides a more complete picture of the wear behaviors of different samples. Fig. 5 compares the final wear rates of the three coatings, which can be used as a number to quickly determine and compare the coating's quality in Quality Control.

Fig. 3: Change of the wear track depth every 200 cycles during the wear test for Coating 3.

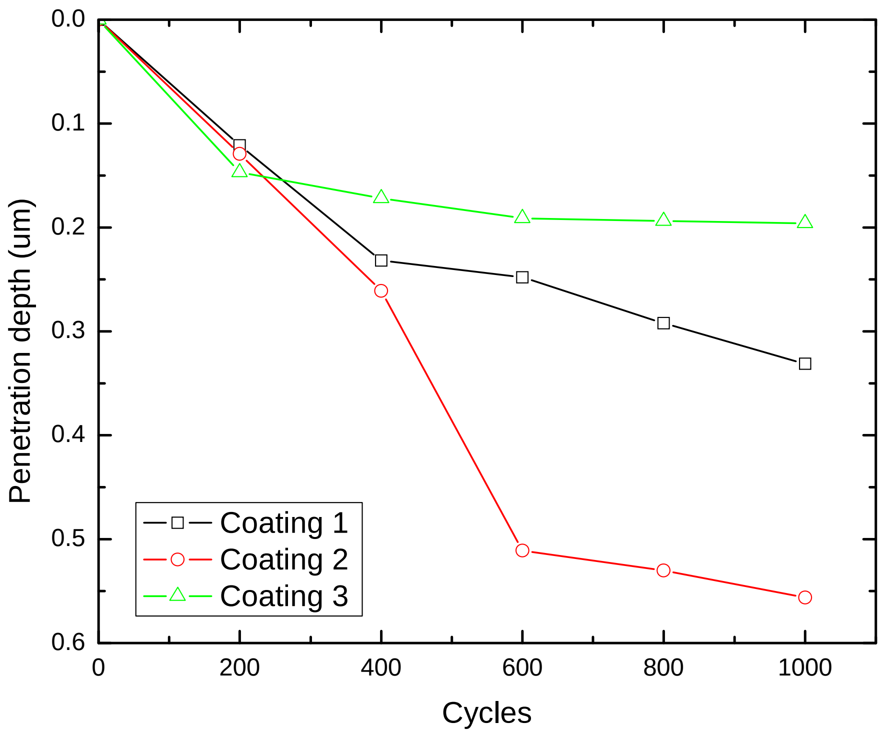

Fig. 4: Evolution of the average wear track depth of the test coatings.

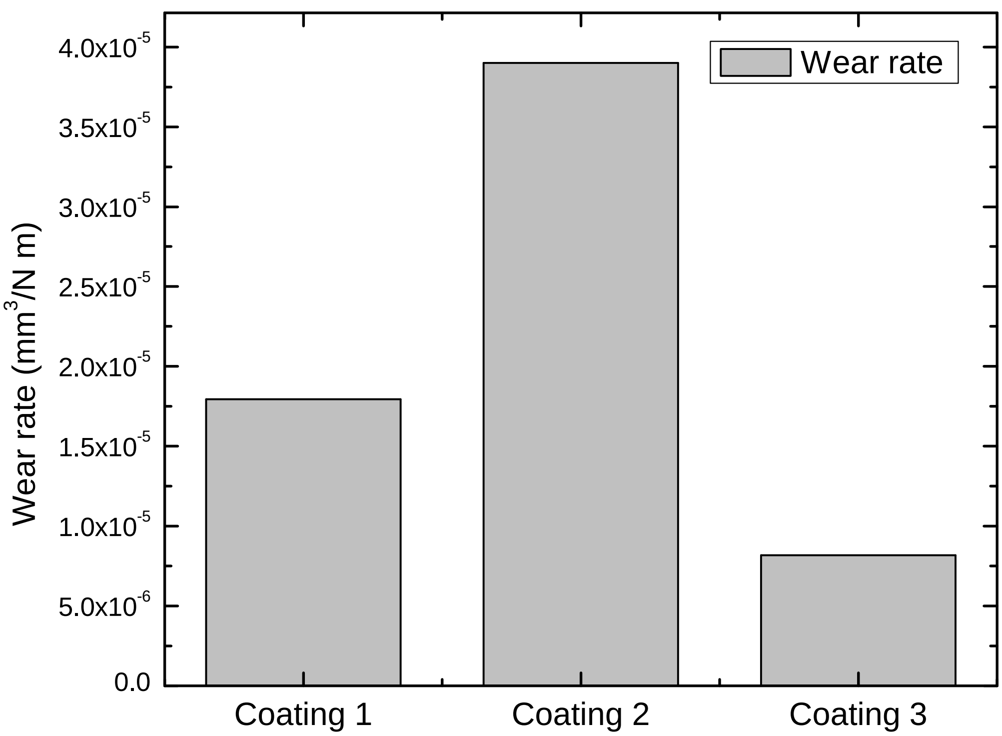

Fig. 5: Comparison of final wear rate of the three coatings.

CONCLUSION

In this study, we showcased the capacity of Nanovea T3 Tribometer in measuring the wear rate of thin films following the ASTM G133 standard. The simple experimental setup and full automation of this system make it accessible to average users without comprehensive instrument training. It is designed to price in the $20K market in order to bring high-end measurement technology to the broader market. The combination of competitive price and fully-automated high-precision measurement makes T3 system an ideal tool for quality control.

The Nanovea T3 system maintains a competitive price of $20K, making fully automated wear rate measurement available and affordable to the broader market such as smaller R&D units and quality control lines. Its fully automated and user-friendly test procedure provides simple and direct result presentation. Compared to conventional tribometers, T3 directly determines the wear rate based on the penetration depth of the diamond stylus and does not require wear track profile scan using an extra profilometer. The precision measurement of the wear track depth enables wear rate measurement of very thin films in a hundred nanometer scale, which can be hardly achieved using regular profilometer techniques. Nanovea also provides a load cell with the capacity of 4 N for the wear test under higher loads.

To learn more about Nanovea T3 Tribometer or Lab Services.

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[i] **Rabinowicz, E. (1995). Friction and Wear of Materials. New York, John Wiley and Sons.**
[ii] **ASTM G133 - 05(2010). Standard Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear.**
[iii] **ASTM G99 - 05(2010). Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus.**