NANOVEA
A Better Measure.

HUMIDITY EFFECT ON DLC COATING TRIBOLOGY

Prepared by

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INTRO

Diamond-like coatings (DLC) possess substantially enhanced tribological properties, namely excellent wear resistance and very low coefficient of friction (COF). The DLC can be deposited on different materials such as metals, metal alloys, glass and ceramic, and impart some of the useful characteristics of diamond. Its favorable tribo-mechanical properties makes it an attractive candidate as protective coatings in various industrial applications, such as razor blades, metal cutting tools, bearings, motorcycle engines and medical implants.

IMPORTANCE OF WEAR EVALUATION OF DLC IN HUMIDITY

The DLC coating exhibits very low COF against steel ball (below 0.1) under high vacuum and dry condition[1 2]. However, it has also been reported that the DLC is very sensitive to the change of environmental conditions, particularly the relative humidity (RH)[3]. The environment with a high humidity and oxygen concentration may lead to significant increase of the COF[4]. In order to simulate the realistic environmental conditions of the DLC coating for tribological applications, reliable wear evaluation in a controlled and monitored humidity is in need. It allows users to properly compare the wear behaviors of the DLC coatings exposed to different humidity and to select the best candidate for the targeted application.

MEASUREMENT OBJECTIVE

In this study, we showcased that the Nanovea Tribometer equipped with a humidity controller is an ideal tool for investigating the wear behavior of the DLC coatings exposed to different humidity.

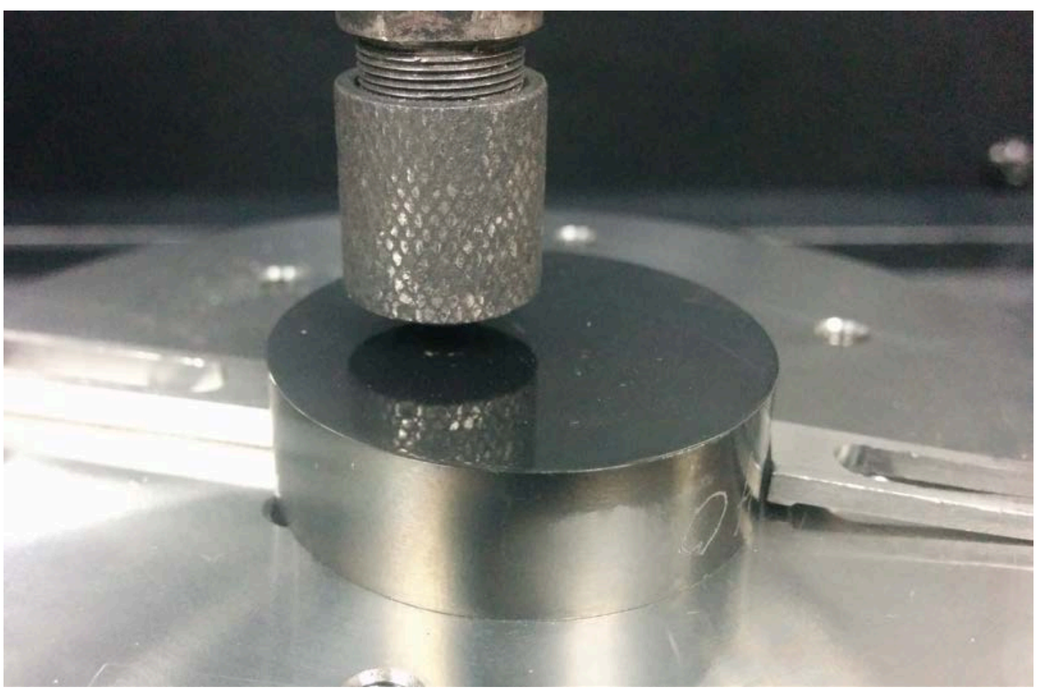


Fig. 1: SiN ball sliding against the DLC sample.

TEST PROCEDURE

The DLC coatings were deposited on stainless steel SS304 substrate. The coefficient of friction, COF, and the wear resistance of the DLC coating were evaluated by Nanovea Tribometer. A SiN ball was used as the counter material. The test parameters are summarized in Table 1. A humidity controller attached to the tribo-chamber precisely controlled the relative humidity (RH) value in the range of ±1%. The wear tracks on the DLC coating and the wear scars of the SiN ball were examined using the optical microscope after the tests.

Please note that the SiN ball as a counter material was used as an example in this study. Any solid material can be applied to simulate the performance of different material coupling under actual application conditions, such as in liquid or lubricant.

Test parameters	Value
Ball material	SiN
Ball diameter	6 mm
Normal force	2 N
Rotational speed	200 RPM
Duration of test	15 min
Wear track radius	3 mm
Lubricant	None
Atmosphere	Air
Temperature	24°C (room)
Humidity	10%, 30%, 50%, 70% and 90%

Table 1: Test parameters of the wear measurements.

RESULTS AND DISCUSSION

The DLC coating is known for the very low friction and superior wear resistance, making it a good candidates for a wide variety of tribological applications. Fig. 2 compares the evolution of COF of the DLC coating in different RH during the wear tests. Humidity dependence of the friction behavior can be observed for the DLC coating. In the relatively dry condition of 10% RH, the DLC coating shows a very low COF of ~0.05 throughout the wear test. As the RH value increases to 30%, the DLC coating exhibits a constant COF of ~0.1 during the test. When the RH rises above the value of 50%, the initial run-in regime of the COF is observed in the first 2000 revolutions. The DLC coating shows a maximum COF of ~0.20, ~0.26 and ~0.33 in RH values of 50, 70 and 90 %, respectively. Following the run-in period, the COF of the DLC coating maintains a constant value of ~0.11, 0.13 and 0.20, respectively, in the atmosphere with RH values of 50, 70 and 90%.

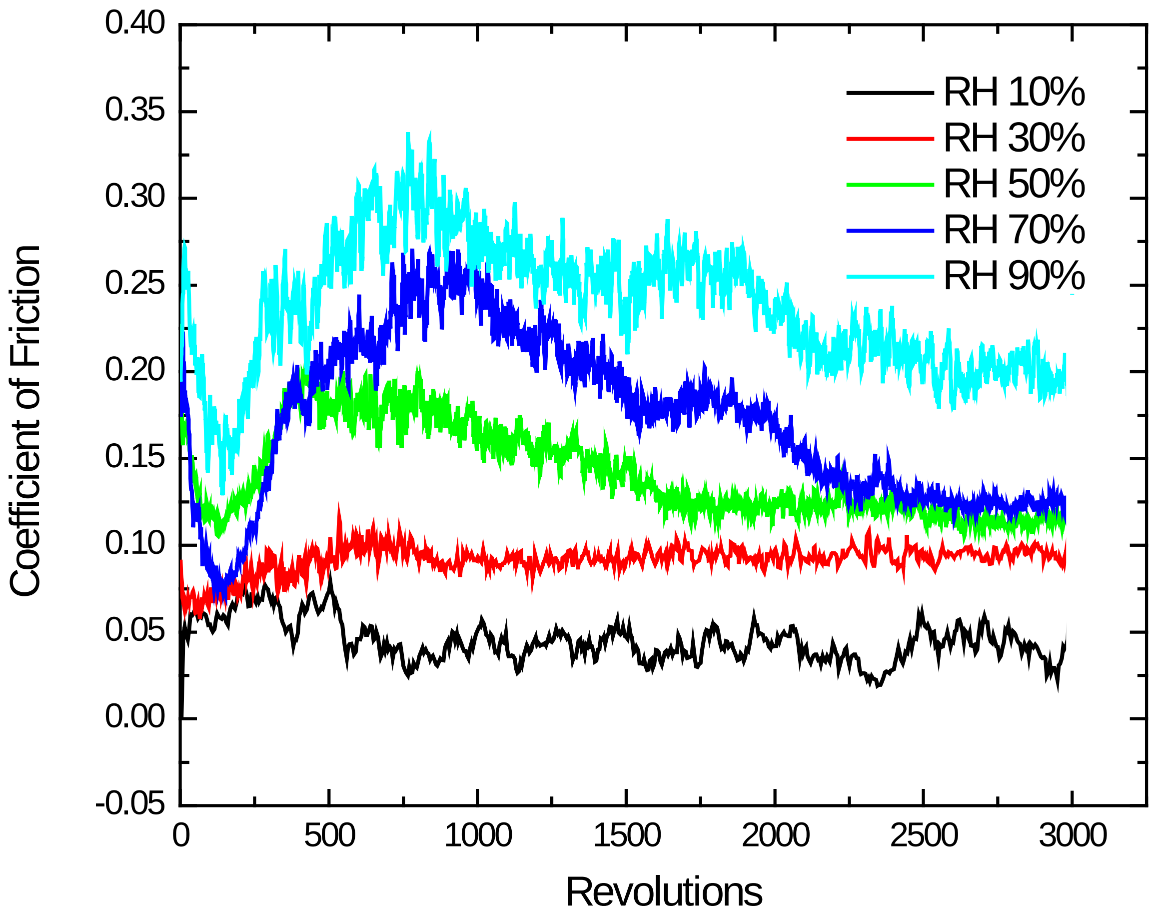
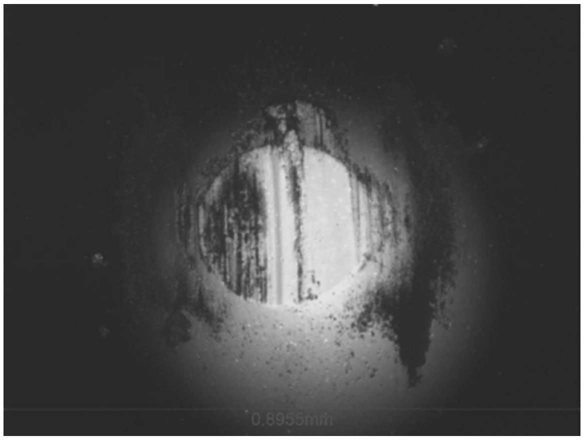


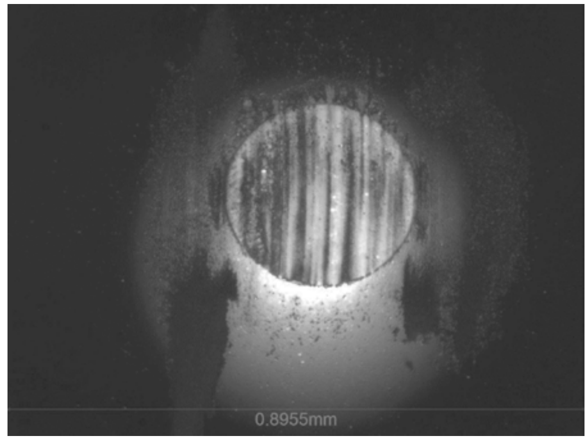
Fig. 2: Evolution of COF during the wear tests.

Fig. 3 and Fig. 4 compare the wear scars of the SiN ball and the wear tracks on the DLC coating after the wear tests, respectively. It can be observed that the diameter of the wear scar was smaller when the DLC coating was exposed to an environment with low humidity. Transfer DLC layer accumulates and forms on the SiN ball surface during the repetitive sliding progress at the contact surface. At this stage, the DLC coating slides against its own transfer layer, which is known to act as an efficient lubricant to facilitate the relative motion and restrain further mass loss caused by shear deformation. Such a transfer film can be observe in the wear scar of the SiN ball in the environment of low RH values (e.g. 10% and 30%), resulting in decelerated wear process on the ball. This is also reflected on the wear track morphology on the DLC coating as shown in Fig. 4. The DLC coating exhibits a smaller wear track in the dry environment, due to the formation of the metastable DLC transfer film at the contact interface which significantly reduces the friction and wear rate.

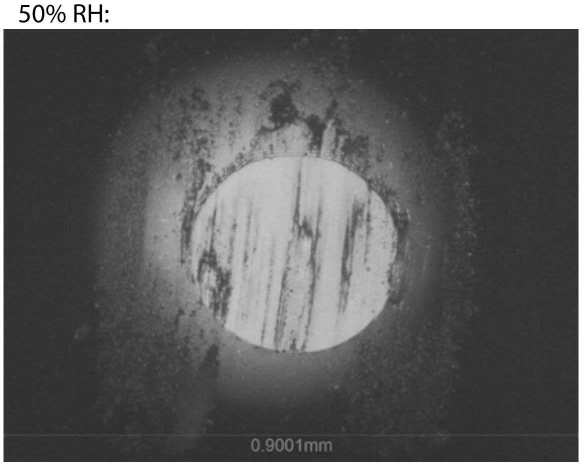
10% RH:



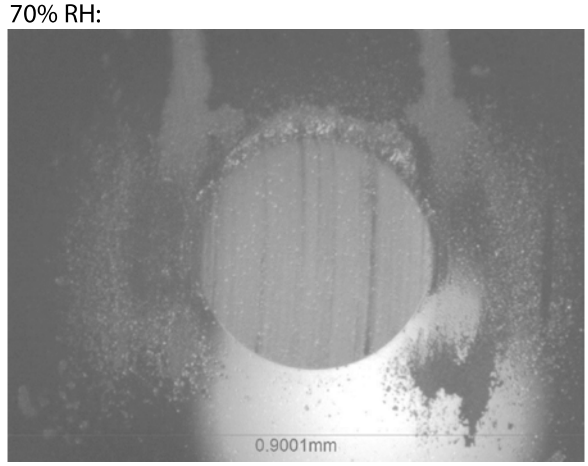
30% RH:



50% RH:



70% RH:



90% RH:

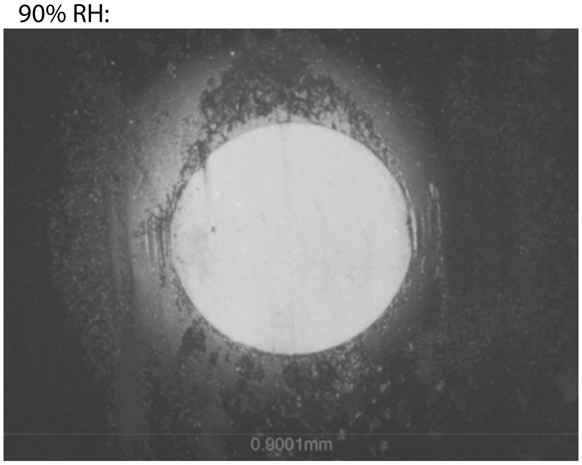
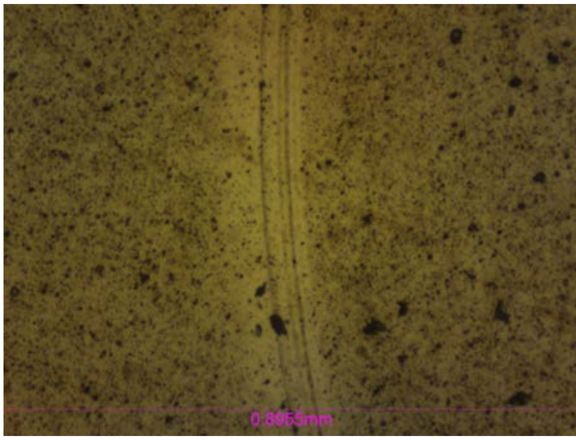
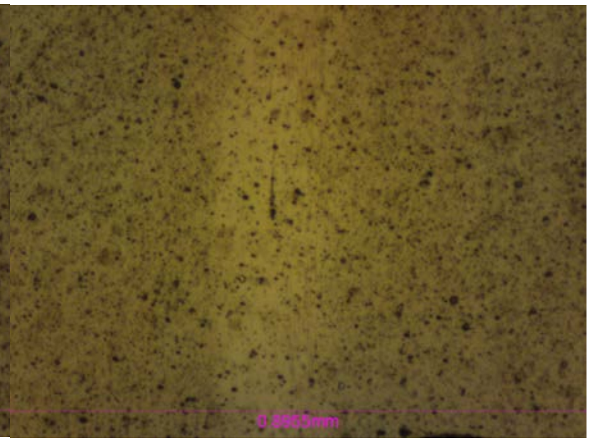


Fig. 3: Wear scars of the SiN ball after the tests.

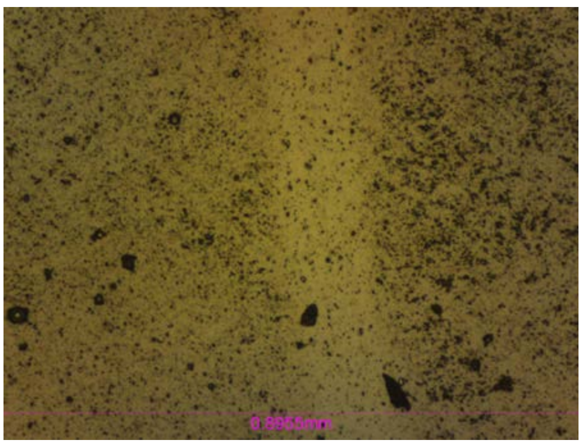
10% RH:



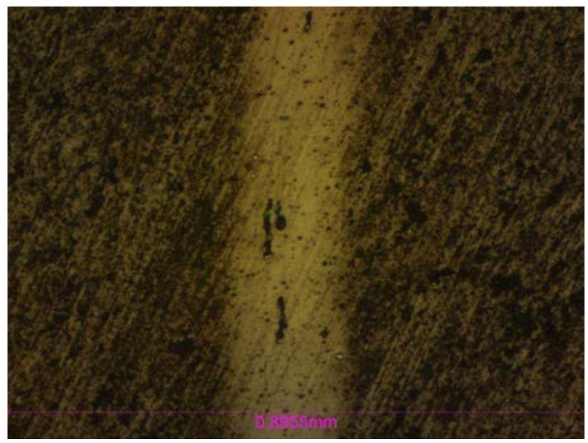
30% RH:



50% RH:



70% RH:



90% RH:

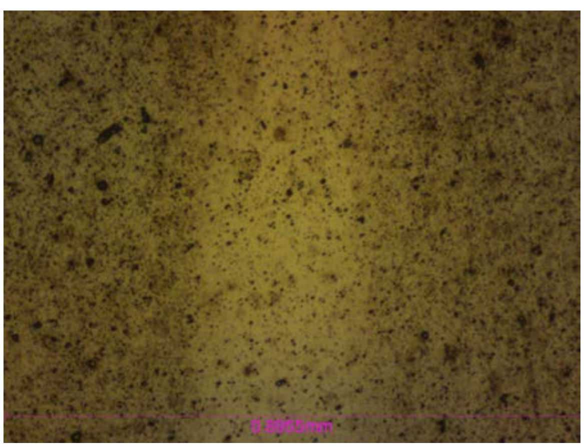


Fig. 4: Wear tracks of the DLC coating under the microscope.

CONCLUSION

Humidity plays a vital role in the tribological service performance of the DLC coating. The DLC coating possesses significantly enhanced wear resistance and superior low friction in the dry condition, thanks to the formation of a stable graphitic layer transferred onto the sliding counterpart (a SiN ball in this study). The DLC coating slides against its own transfer layer, which acts as an efficient lubricant to facilitate the relative motion and restrain further mass loss caused by shear deformation. As the humidity rises up, such a film is not observed on the SiN ball, leading increased wear rate on the SiN ball and the DLC coating.

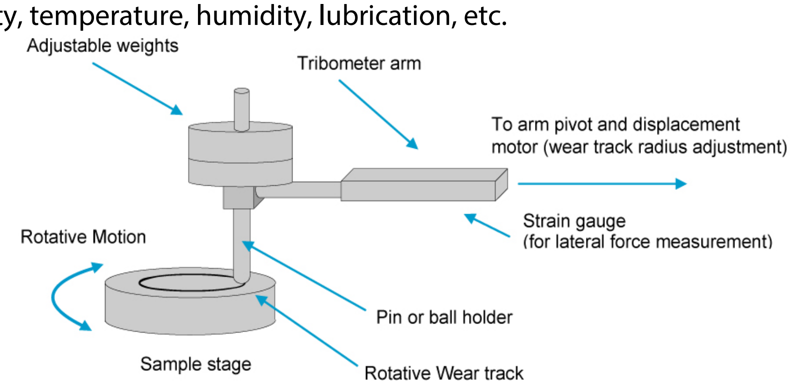
The Nanovea Tribometer offers repeatable wear and friction testing using ISO and ASTM compliant rotative and linear modes, with optional Humidity modules available in one pre-integrated system. It allows users to simulate work environment of different humidity, providing users an ideal tool to quantitatively assess the tribological behaviors of materials under different work conditions.

Learn More about the Nanovea Tribometer and Lab Service

APPENDIX: MEASUREMENT PRINCIPLE

PIN-ON-DISC 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 rotational 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.



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