WEAR TESTING GLASS
WITH ACOUSTIC EMISSIONS MONITORING

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INTRO

Acoustic emission (AE) is the high-frequency elastic waves that travel through a dense medium because of dynamic processes occurring in the material[i]. It is usually generated when a material is subjected to external stress and rapidly release energy in the form of transient stress waves, causing localized small surface displacements. AE technique is widely used in inspection, quality control, system feedback, process monitoring and others.

IMPORTANCE OF ACOUSTIC EMISSION MONITORING DURING WEAR

AE has been commonly used as an additional component for scratch test. The AE generated during scratch test can be related to the failures taking place at different critical loads, e.g. crack formation, propagation, as well as buckling, spallation and complete delamination of hard coatings, allowing users to detect premature adhesive/cohesive failures of the coating/substrate system in real-life applications. During wear tests, the constant rubbing process of the counterface against the test sample creates a series of events, such as deformation, cracking, abrasion, phase transformation and material removal. These rapid stress-releasing events are the sources of AE. A quantifiable and reliable measurement of AE can provide more insight in the wear failure mechanism.

MEASUREMENT OBJECTIVE

The wear behavior of three types of glass (Regular glass, Galaxy S3 glass and Sapphire coated glass) is compared in a controlled and monitored manner using the Nanovea Tribometer equipped with an AE detector. In this study, we would like to show the application of AE detection during wear and its correlation with the evolution of coefficient of friction (COF).

Fig. 1: Pin on test sample.

MEASUREMENT PRINCIPLE

TRIBOMETER PRINCIPLE

The sample is mounted on a rotating stage, while a known force is applied on a pin, or ball, in contact with the sample surface to create the wear. The pin-on-disk test is generally used as a comparative test to study the tribological properties of the materials. The COF and AE is recorded in situ. The volume lost allows calculating the wear rate of the material. Since the action performed on all samples is identical, the wear rate can be used as a quantitative comparative value for wear resistance.

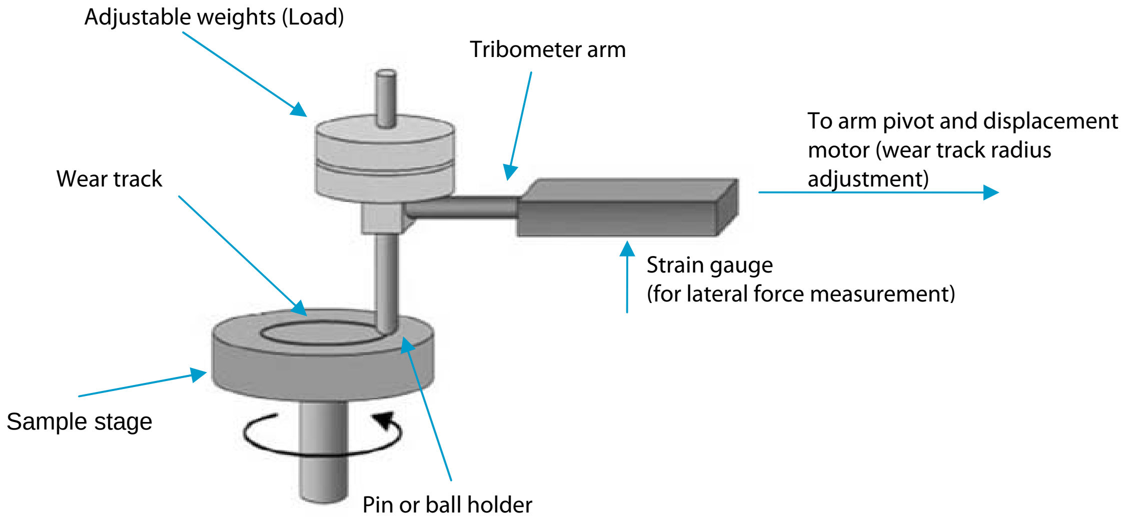


Fig. 2: Schematic of the pin-on-disk test.

TEST PROCEDURE

WEAR TEST

Nanovea Tribometer equipped with an AE detector was applied to evaluate the tribological behavior, e.g. coefficient of friction, COF, and wear resistance. An Al_2O_3 ball tip (6 mm dia.) was applied against the tested glasses. The COF and AE was recorded in situ. The test parameters are summarized in Table 2. The wear track morphology was examined using optical microscope.

Test parameters	Value
Normal force	1 N
Rotational speed	30 rpm
Duration of test	20 min
Wear track radius	5 mm

Table 2: Test parameters of the pin-on-disk measurement.

RESULTS AND DISCUSSION

The pin-on-disk wear tests were conducted on the Regular glass, S3 lens and Sapphire coating samples. The COF and AE were recorded *in situ* during the wear tests as shown in Fig. 3 and Fig. 4. Fig. 5 compares the wear tracks after the tests.

As shown in Fig. 3, the Regular glass exhibits high COF of above 0.7 in the first 100 s wear test. In comparison, S3 lens shows a low COF of ~0.1 in the first 20 s, followed by an increase of COF to ~0.55 until ~200 s. Sapphire coating maintains a low COF of ~0.1 in the first 200 s. Such a trend in the evolution of COFs at the beginning of the wear tests shows a strong correlation with the evolution of AE in Fig. 4. High peaks of AE signals are recorded in the first 100 s of the wear test on Regular glass, corresponding to the high value of COF in this period. S3 lens starts to generate AE at ~20 s, while Sapphire coating shows no AE under the constant rubbing movement against the Al_2O_3 ball at a low COF in the first 200 s of the wear test.

The AE signal is indicative of the change at the sliding surface and possible wear failures of the test sample. In this particular study, we observes signs of wear scar formation as the AE detector records high signals. As more AE spikes get detected, the localized wear scars grow longer and wider, eventually leading to the formation of a complete wear ring. Such a wear ring occurs quickly on the Regular glass, but it is not observed on the Sapphire coating in the first 200s wear process.

The COF of Regular glass and S3 lens progressively decreases and reaches a constant value of ~0.35 and ~0.25, respectively, which indicates the establishment of a stable sliding contact; in comparison, Sapphire coating shows a substantial increase of COF to ~0.8 after 200s wear test. This corresponds to the evolution of AE in Fig. 4 – Signals of AE starts to be detected at ~200 s, and high AE spikes occurs from ~300 to 500 s, indicating initiation and propagation of wear scars during this period. Relatively high AE throughout the rest of the wear test of Sapphire coating compared to the other two test samples is in agreement with its high COF. The higher COF and AE of Sapphire coating after run-in period is possibly related to the counterface Al_2O_3 ball used in this study, which possesses similar composition and serves as a self-mated couple.

Fig. 5 displays the wear tracks of the test glass samples under 200x microscope. Severe wear took place on the Regular glass surface. A lot of debris was formed and ground in the wear track, which acted as abrasive media and accelerated the wear process. S3 lens exhibits a track of mild wear with traces of shallow scratches, which demonstrates its substantially enhanced wear resistance compared to Regular glass. Sapphire coating shows a relatively narrow wear track and improves the wear resistance of the glass substrate.

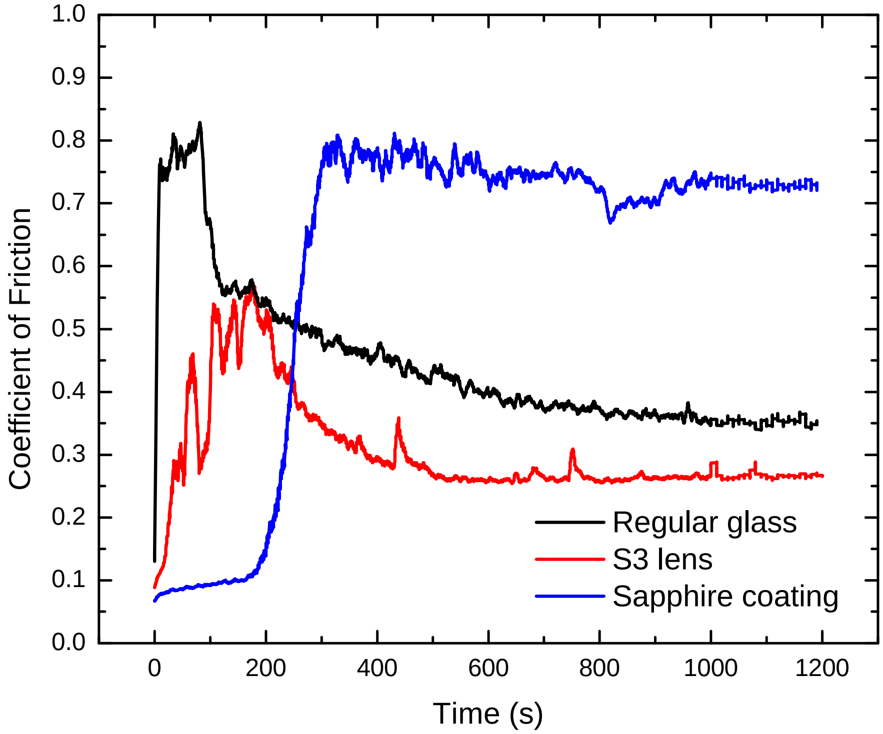


Fig. 3: Coefficient of friction during pin-on-disk tests.

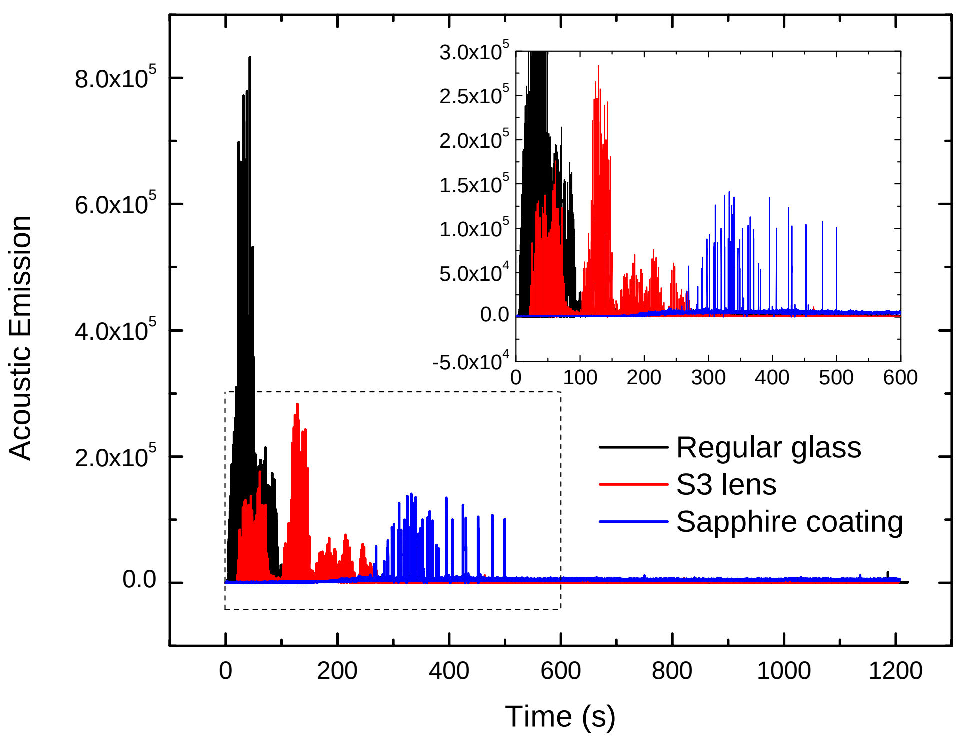
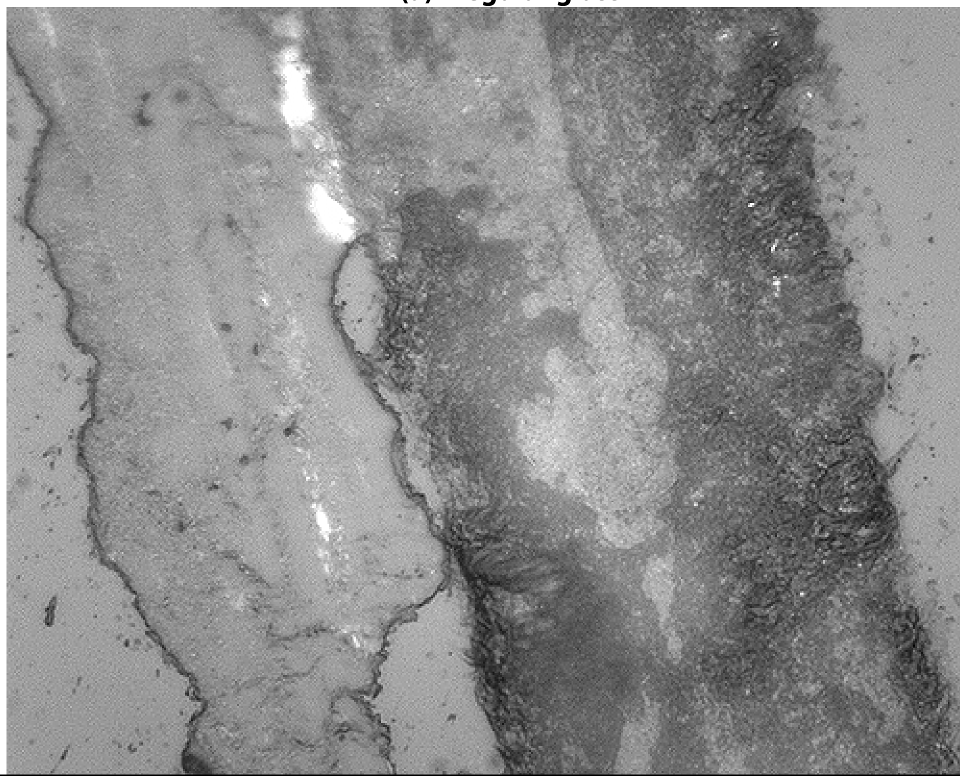
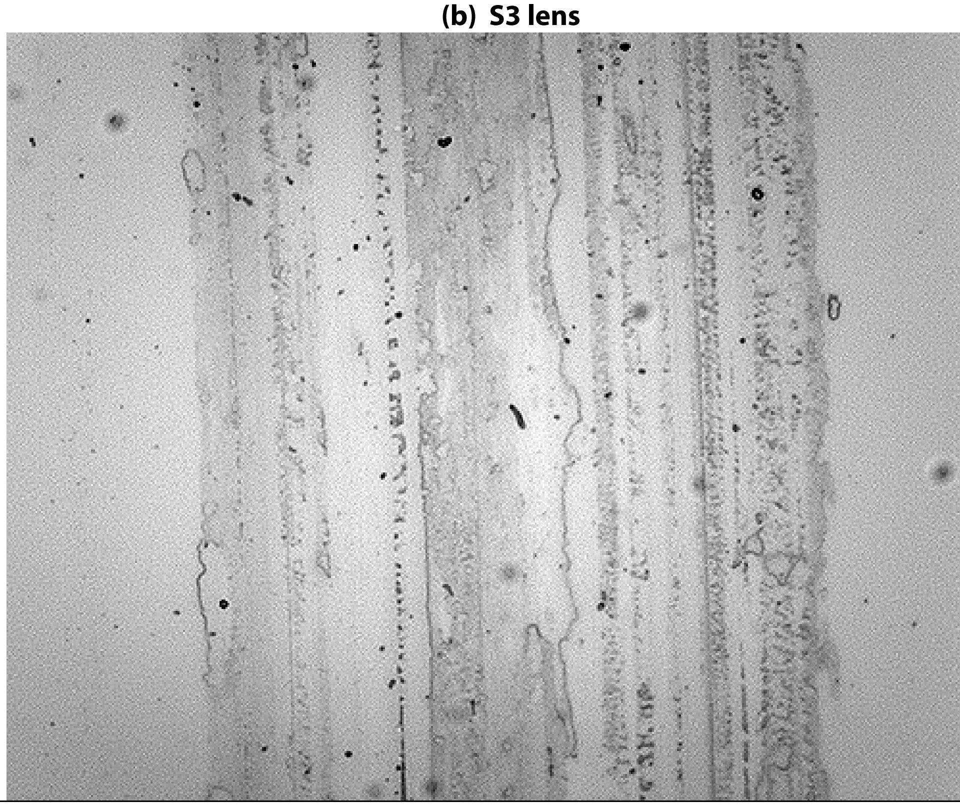


Fig. 4: Evolution of Acoustic Emission during pin-on-disk tests.

(a) Regular glass



(b) S3 lens



(c) Sapphire coating

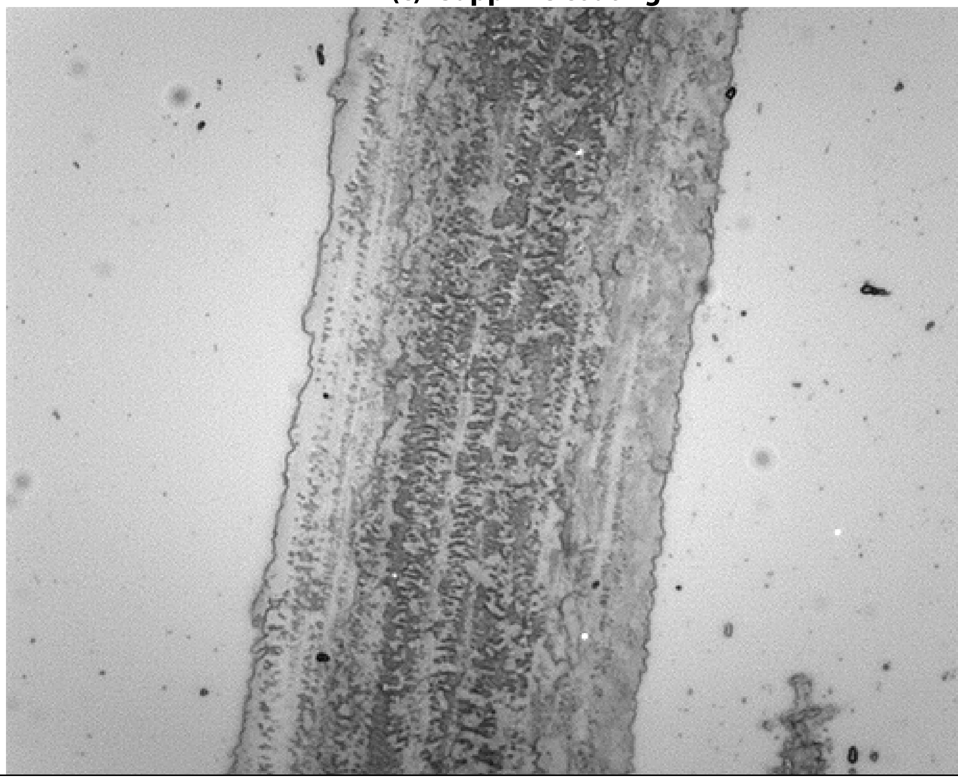


Fig. 5: Wear tracks after the pin-on-disk tests (200x).

CONCLUSION

In this application, we show that Nanovea Tribometer is a superior tool for evaluation and quality control of commercial glass. Acoustic Emission (AE) sensor can detect initiation and propagation of the wear scar and is a useful additional component to the tribometer. The capacity of in-situ AE and COF measurement allows users to correlate different stages of wear process with the evolution of AE and COF, which is critical in improving fundamental understanding of the wear mechanism and tribological characteristics of various materials.

Based on the comprehensive tribological analysis on the glass samples in this study, we show that Galaxy S3 lens and Sapphire coating possess enhanced wear resistance compared with the regular glass sample. This assessment allows us to evaluate and select the best candidate to fulfill the needs for targeted applications.

The 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. Optional 3D non-contact profiler is available for high resolution 3D imaging of scratch and wear track in addition to other surface measurements such as roughness. Learn More about Nanovea Tribometer and Lab Services

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[i] Liptai, R. G., Harris, D. O., Tatro, C. A. (1972) Acoustic Emission, Special Technical Publication 505, Ed. American Society for Testing and Materials, Philadelphia, PA, USA, 1972.