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Identifying Cohesive Failure of Screen Protectors
with Acoustic Emission

Prepared by
Frank Liu

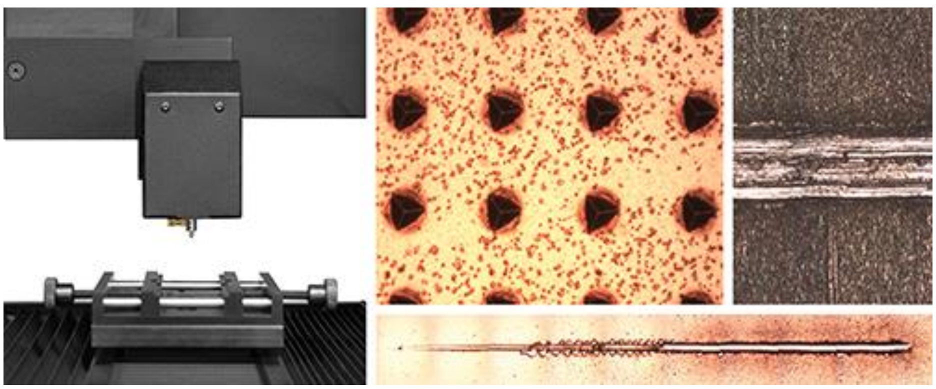
6 Morgan, Ste156, Irvine CA 92618 · P: 949.461.9292 · F: 949.461.9232 · nanovea.com

INTRO

In today's age of information, handheld electronic devices are extremely common amongst consumers. These portable multifunctional devices, however, can be quite expensive. To protect the fragile components, such as the glass interface, screen protectors can be used. How effective are the screen protectors? Using Nanovea's Mechanical Tester's Micro Module with an acoustic emission attachment, we can clearly identify critical loads at which the screen protector fails.

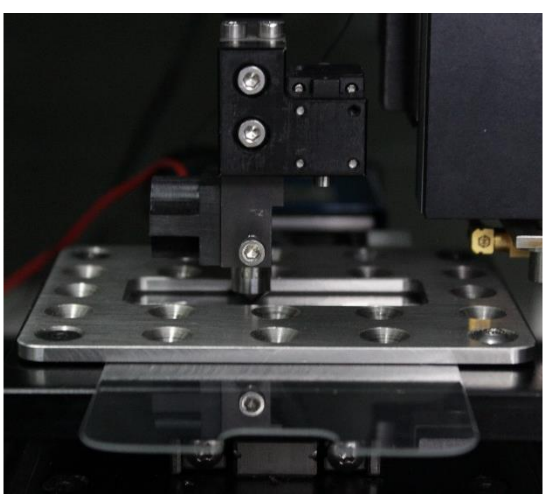
IMPORTANCE OF ACOUSTIC EMISSIONS FOR SCRATCH TESTING

Acoustic emission is a powerful technique that detects physical changes occurring in the material. This includes fracturing, deformation, and cracking. When combined with scratch testing, it can be used to find critical loads where cohesive failure, such as cracking, chipping, or fractures, or adhesive failures, such as a delamination, occurs. Since some of these failures occur below the surface, they may not be observable with a microscope, but acoustic emission is able to detect the underlying changes.



MEASUREMENT OBJECTIVE

Two different commercial screen protectors were tested using Nanovea's Mechanical Tester's Micro Module. 3 scratch tests were conducted per sample with the following parameters listed in Table 1. The normal force, friction force, true depth, and acoustic emission were closely monitored in-situ. By using acoustic emission and optical microscopy, the critical loads at which the samples failed are identified.



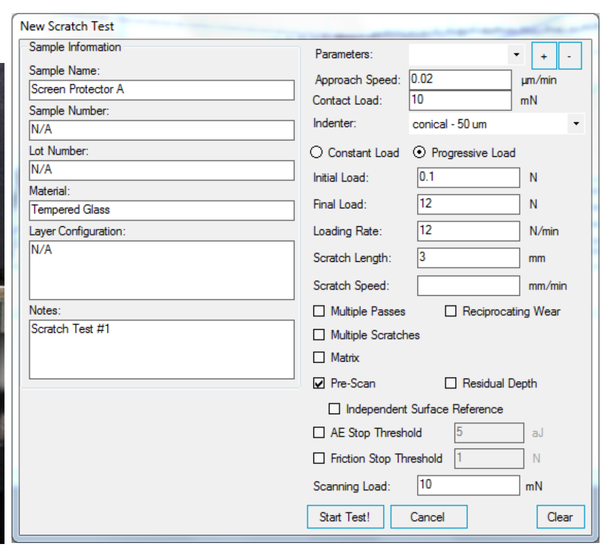


Figure 1: Picture of test setup (left) and scratch test parameters (right)

TEST CONDITIONS AND PROCEDURE

Table 1: Test Parameters for Scratch Testing on Screen Protectors

Test Parameters	All Samples
Load type	Progressive
Initial Load (N)	0.1
Final Load (N)	12
Loading rate (N/min)	12
Scratch Length (mm)	3
Scratching speed (mm/min)	3
Indenter geometry	120° Conical
Indenter material (tip)	Diamond
Indenter tip radius (μm)	50

RESULTS

Table 2: Summary of Results

	Critical Load #1	Critical Load #2
Screen Protector A	2.918 ± 0.249	10.40 ± 0.78
Screen Protector B	5.404 ± 1.026	8.721 ± 0.633

From scratch tests conducted, two critical loads were identified using both optical microscopy and acoustic emissions. Critical load #1 is defined by signs of radial cracking seen under the microscope. This is the point where consistent cracking at the surface of the glass is observed. Critical load #2 is defined by the first large change in acoustic emission. This is the point where the glass begins to consistently fracture.

Since the fracturing causes substantial damage to the surface of the sample, it is very difficult to accurately identify critical loads from imaging techniques after the scratch test is completed. Luckily the acoustic emission was able to clearly define the point at which the critical loads were reached. The full results from the tests can be seen below.

Screen Protector A

Table 3: Critical Loads from Scratch Testing on Screen Protector A

	Critical Load #1	Critical Load #2
1	2.614	10.53
2	3.223	11.277
3	2.918	9.379
Average	**2.918**	**10.40**
Standard Deviation	**0.249**	**0.78**

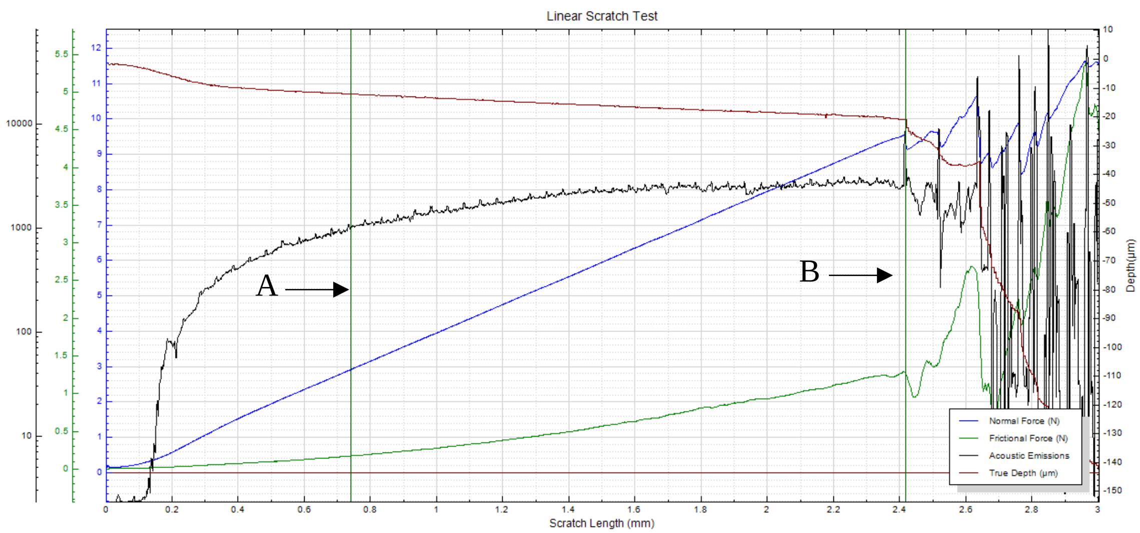


Figure 2: Data graphed from scratch test on Screen Protector A – (A) Critical Load #1, (B) Critical Load #2

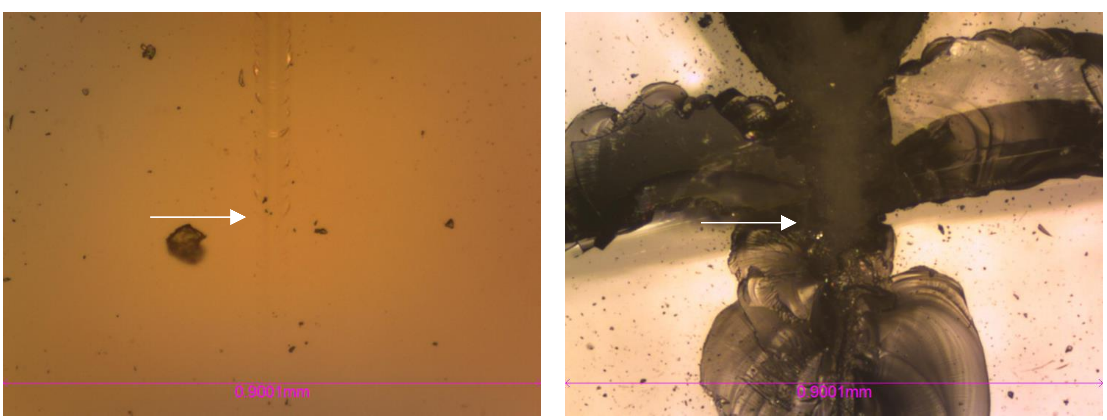


Figure 3: Optical Microscopy of Critical Load #1 (Left) and Critical Load #2 (Right) for Screen Protector A. Taken with 100x and 50x magnification (0.442mm and 0.9001mm image width) respectively.

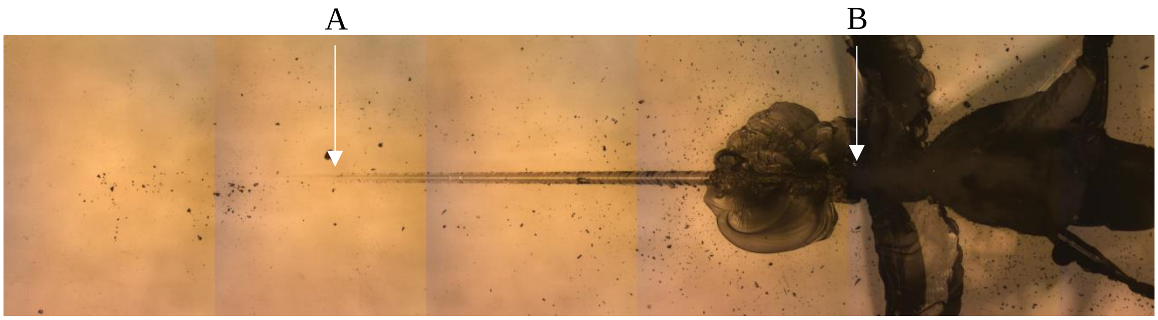


Figure 4:Full length image of post scratch test for Screen Protector A – (A) Critical Load #1, (B) Critical Load #2

Screen Protector B

Table 4: Critical Loads from Scratch Testing on Screen Protector B

	Critical Load #1	Critical Load #2
1	5.647	8.539
2	6.521	9.571
3	4.044	8.054
Average	**5.404**	**8.721**
Standard Deviation	**1.026**	**0.633**

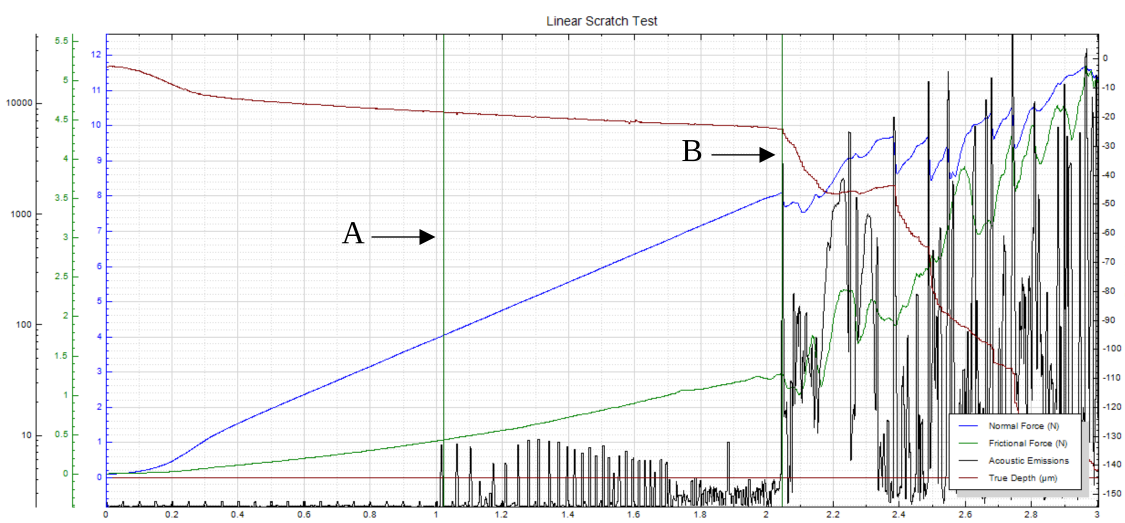


Figure 5: Data graph from scratch test on Screen Protector B – (A) Critical Load #1, (B) Critical Load #2

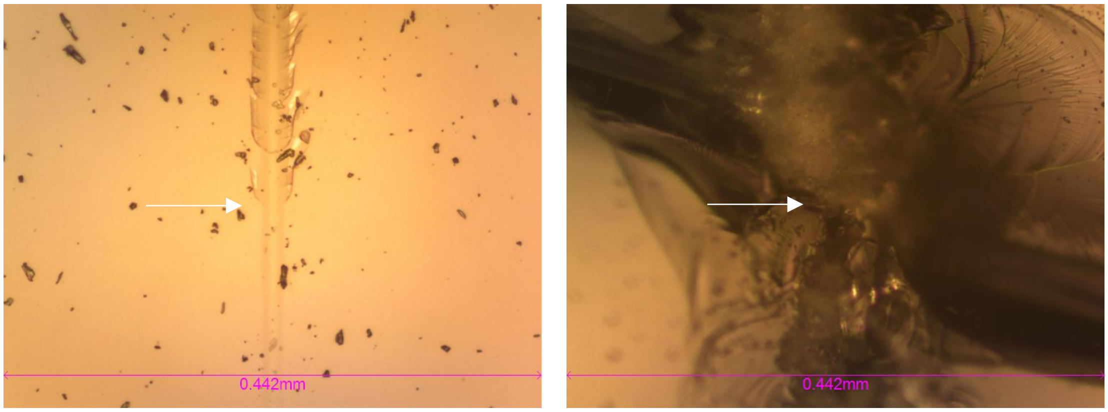


Figure 6: Optical microscopy of Critical Load #1 (Left) and Critical Load #2 (Right) for Screen Protector B. Both images were taken with 100x magnification (0.442mm image width).

A B

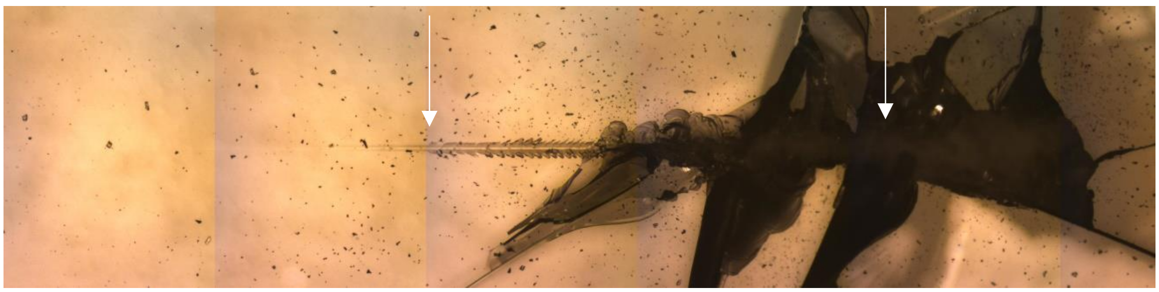


Figure 7:Full length image of post scratch test for Screen Protector B – (A) Critical Load #1, (B) Critical Load #2

CONCLUSION:

Two critical loads, surface cracking and fracturing, were identified from the testing conducted. Screen Protector A appears to damage earlier than Screen Protector B, but fractures at a higher load than Screen Protector B. The critical load #1 were 2.918 ± 0.249 and 5.404 ± 1.026 for Screen Protectors A and B respectively. Critical load #2 were 10.40 ± 0.78 and 8.721 ± 0.633 for Screen Protectors A and B respectively. These values were accurately identified with the help of the acoustic emissions attachment on Nanovea's Mechanical Tester's Micro Module and optical microscopy.

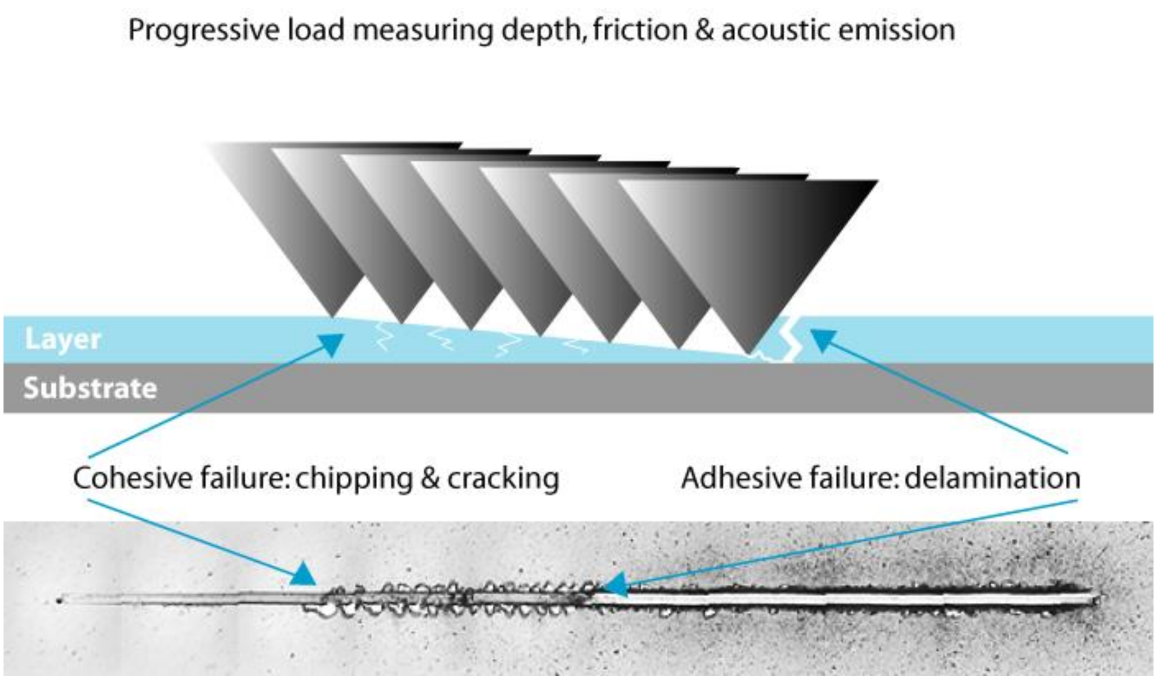
Learn more about the Nanovea Mechanical Tester or Lab Services

Theory of Scratch Testing

Principle

The scratch testing method is a quantitative test in which critical loads at which failures appear in the samples are used to evaluate the relative cohesive or adhesive properties of a coating or the scratch resistance of a bulk material. During the test, scratches are made on the sample with a sphero-conical stylus which is drawn at a constant speed across the sample, under a constant load, or, more commonly, a progressive load with a fixed loading rate. Sphero-conical styluses are available with different radii (which describes the "sharpness" of the stylus). Common radii are from 20 to 200µm for micro/macro scratch tests, and 1 to 20µm for nano scratch tests.

When performing a progressive load test, the critical load is defined as the smallest load at which a recognizable failure occurs. In the case of a constant load test, the critical load corresponds to the load at which a regular occurrence of such failure along the track is observed.



Comments on the critical load

The scratch test is a quantitative test with high repeatability. The critical load depends on the mechanical strength (adhesion, cohesion) of a combined coating-substrate system but also on several other parameters. Some of them are directly related to the test itself, while others are related to the coating-substrate system.

Test parameters affecting critical load:

- Loading rate
- Scratching speed
- Indenter tip radius
- Indenter material (and also indenter tip wear)

Sample specific parameters affecting critical load:

- Friction coefficient between surface and indenter
- Internal stresses in the material
- Substrate hardness and roughness
- Coating hardness and roughness
- Coating thickness

By keeping the test parameters constant one can obtain very repeatable data to quantifiably compare samples.

Means for critical load determination

Microscopic observation is the most reliable method to detect surface damage. This technique is able to differentiate between cohesive failure within the coating and adhesive failure at the interface of the coating-substrate system.

The friction force recording enables the force fluctuations along the scratch to be studied and correlated to the failures observed under the microscope. Typically, a failure in the sample will result in a change (a step, or a change in slope) in coefficient of friction. Frictional responses to failures are very specific to the coating-substrate system in study.

The depth sensor recording can also sometimes indicate where a failure occurs. Typically, a significant fall in the depth will indicate that the indenter has broken through one layer of a sample down to the next. The depth recording can also be used to study deformation of a sample surface. Plastic and elastic deformation can be studied by performing pre- and post-scans of the scratch.