Scratch resistance as a key parameter in the selection of fingerprint scanners

A JENETRIC WHITE PAPER

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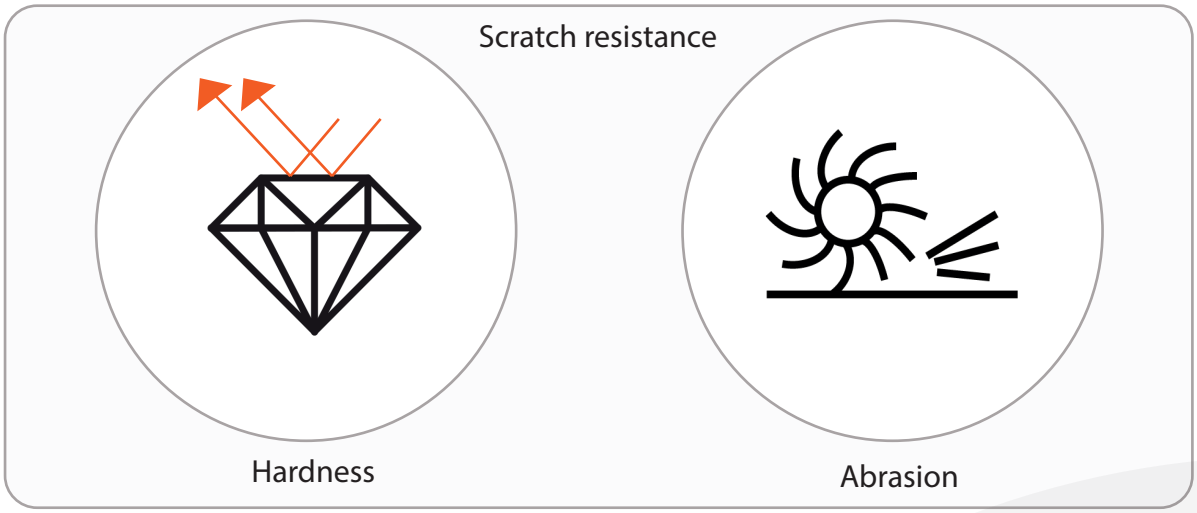
INTRODUCTION

Scratches are indentations on an otherwise smooth surface. For fingerprint scanners, scratches are relevant if they are located on the contact surface used for taking fingerprints. Scratches can be caused by daily use, for example by users with rings on their fingers. In addition, the cleaning of the scanner is a potential source of scratches when tiny dust and dirt particles are area adhere to the cleaning cloth. This white paper explains scratch, which standards and test exists and how fingerprint scanners can be protected against scratches.

SCRATCH RESISTANCE

The scratch resistance of a material is determined by its hardness and abrasion.



Hardness is the mechanical resistance of a material to the mechanical penetration by another object. For fingerprint scanners, the material of the scanning surface is relevant in terms of hardness.

In addition to hardness, abrasion resistance is another important factor that influences the scratch resistance of a surface. Abrasion is the loss of material on a surface due to mechanical stress. For example, surfaces can be hard, but still be easily scratched if the mechanical stress (e. g. friction of dust particles on the surface during cleaning) causes material to detach from the surface.

Besides the type of material, its microscopic structure is also important for the abrasion resistance (e. g. solidified glass from a glass melt compared to a glass coating from the gas phasethat has grown by insular growth). In addition to proper adhesion (binding forces between the coating and the substrate), cohesion (binding forces of the molecules withina substance) also determines the abrasion resistance of the protective layer.

MEASUREMENT OF HARDNESS AND ABRASION

Hardness and abrasion can be measured using various testing methods. Care should be taken when comparing test results that were obtained using different measurement approaches.

There are a variety of hardness scales available, e.g. universal hardness (Martens hardness), Rockwell hardness, Brinell hardness, Knoop hardness and Shore hardness. Not all scales are equally suitable for all materials and test tools.

One scale that covers a wide range of hardness and can be tested easily is the Mohs hardness. This is a scratch resistance test in which soft materials are scratched by harder materials. By testing the mutual scratchability, the tested materials can be classified according to their hardness. The concrete numerical value of Mohs hardness is obtained by comparing it with reference materials such as plaster, quartz, or diamond (see Table 1). However, this scale only allows a very rough classification into material groups.

Material	*Mohs hardness*	*Vickers hardness*	*Comments*
Talc	1	2.4	Can be scratched by fingernail
Plaster	2	36	Can be scratched by fingernail
Calcite	3	109	Scratchable by copper coin
Fluorpar	4	189	Easily scratched by a pocket knife
Apetite	5	536	Can be scratched by a knife; (hardness of enamel)
Feldspar	6	795	Can be scratched with steel file
Quartz	7	1,120	Scratches window glass
Topaz	8	1,427	Scratches quartz
Corundum	9	2,026	Scratches topaz, e.g. ruby or sapphire
Diamond	10	10,060	Scratches corundum, hardest naturally mineral

Table 1: Mohs hardness und Vickers hardness[1]

A more detailed classification of hardness is provided by the Vickers hardness [HV].

For measuring the Vickers hardness, a defined diamond tip is pressed into a test object with a defined test force. The pressure mark is then measured with a microscope. The Vickers hardness is calculated from the test force and the area of the pressure point.

Figure 1 compares Vickers hardness and Mohs hardness. This illustrates that the Mohs hardness scale is not linear and thus the Vickers hardness allows more precise hardness data to be obtained.

1 partially modified table, translated from German with reference to https://de.m.wikipedia.org/wiki/H%C3%A4rte

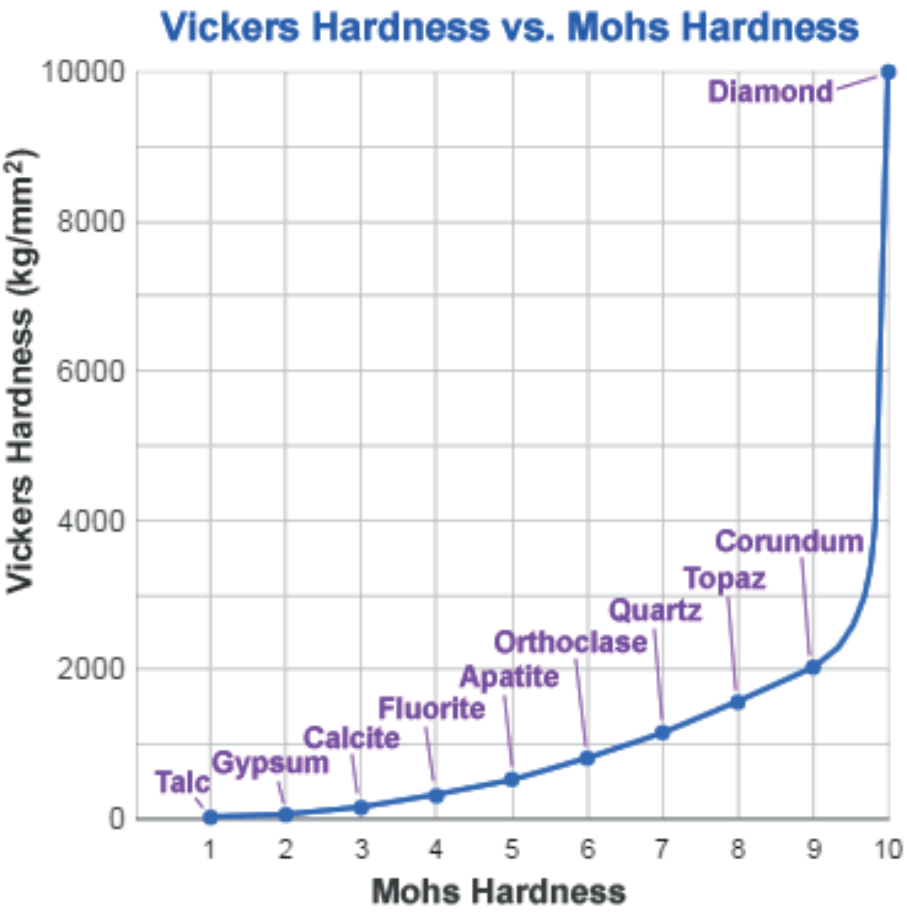


Figure 1: Vickers hardness and Mohs hardness of different materials

The abrasion resistance can be evaluated by using a Crockmeter (linear lifting device). Here, a test stamp with known hardness moves on the surface to be tested with a defined number of repetitions and with a defined and adjustable test force. Subsequently, the tested surface is analysed regarding scratches, removed material, destruction of the surface, etc.

Figure 2: Linear lifting device (Crockmeter)

INTERNATIONAL STANDARDS FOR TESTING HARDNESS AND ABRASION RESISTANCE

Depending on a variety of parameters such as the application, testing machines, geometry of the indenters, test load distance of test depressions and the evaluation method there are numerous standards available for determining the hardness and abrasion.

Examples of national and international standards are:

Vickers hardness	*Abrasion resistance by Crockmeter*	*Abrasion test for coa-ted optical components*
DIN EN ISO 6507-1:2018 to -4:2018	DIN 55654:2015-08	MIL-C-675C

Table 2: International Standards for testing hardness and abrasion resistance

The Military Specification MIL-C-675C. defines in point 3.8.4 a test of the abrasion resistance of coated optical components. In this test, strong abrasion ("severe abrasion") is simulated by an eraser ("eraser conforming to MIL-E-12397"), which rubs over the surface for 20-40 cycles with an additional weight of approximately 1 kg. The surface is then visually inspected for damage.

This test is especially suitable for thin films which do not adhere well to their substrates. However, for hard layers or surfaces with good adhesion, as should be the case with fingerprint scanners, no damage to the surface is caused in this test. Therefore, the MIL specifications have a very limited applicability for the assessment of the abrasion resistance of fingerprint scanners.

SCRATCH PROTECTION FOR FINGERPRINT SCANNERS

Importance of scratch protection

Scratches on the contact surface of a fingerprint scanner can be visible in the fingerprint image, so that the fingerprint image is distorted. This circumstance can be observed with all contact-based fingerprint scanners, whether they are devices with glass prisms or capacitive, ultrasonic or foil-based sensors. Fingerprint scanners that work with a direct sensor, i.e. where a large-area sensor (e.g. TFT sensor) is located directly below the contact surface, scratches can cause damage to the sensor, making error-free fingerprint capture impossible.

The protective layer of fingerprint scanners must therefore be sufficiently hard and abrasion-resistant to prevent damage from scratches during typical use. Typical use includes the placement of fingers, including rings, and the cleaning of the contact surface. Cleaning can be especially problematic, as harder dirt and dust particles can easily scratch an unsuitable scanner surface.

Concepts for scratch protection of fingerprint scanners

The contact surface of prism-based fingerprint scanners is made of glass. Glass typically has a Mohs hardness of 5 to 6, and a Vickers hardness between 500 and 800. This degree of hardness is considered sufficient for typical application scenarios for fingerprint capture. Also, proper cleaning does not damage a surface of this hardness.

Fingerprint scanners with direct sensor do not have a thick glass block as a support and contact surface. The contact surface is formed by the sensor and a relatively thin protective component or layer on top of it. Depending on the type of sensor (optical, capacitive, ultrasonic) and the specific technical design, there are physical upper limits for the maximum thickness of the protective component. For example, a 500-ppi system may use between a few 10 µm up to a few 100 µm for the protection layer.

There are limitations on which materials can be used as protective components, depending on the type of sensor and the technical design parameters of the scanner. For scanners with an optical direct sensor, the protective component must be sufficiently transparent, unless a luminescent layer consisting of organic material (polymers) is used. Using this technology requires that the polymer layer is both sufficiently hard and abrasion resistant. For capacitive sensors, the protective layer must be sufficiently electrically conductive and therefore can only be made very thin.

Coating the direct sensor is one possibility for scratch protection that provides a hard surface with low thickness. Although those coatings can be very hard (e.g. SiO_2 coating with Vickers hardness > 500), usually they are not sufficiently resistant to abrasion, since cohesion and adhesion are limited.

SCRATCH PROTECTION FOR FINGERPRINT SCANNERS

Principle structure of LIVETOUCH scanners

In figure 3 a layer build-up of LIVETOUCH fingerprint scanner is shown. The semitransparent optical direct sensor is equipped with an additional cover glass, which guarantees a sufficient scratch resistance of the contact surface. The illumination, either from a display or a homogenous separate source, is placed underneath the optical sensor.

Figure 3: Principle structure of LIVETOUCH fingerprint scanners

Measurement of the hardness and abrasion of LIVETOUCH scanner

i. Hardness test

In an independent laboratory, the Vickers hardness of the scanning surface was determined with cover glass in accordance to DIN EN ISO 6507-1:2018-07. This was done by applying a test force of 50 g (HV0.05) to indentations on the surface and then measuring them.
The average Vickers hardness was 690 (kg/mm²).

ii. Abrasion resistance

The abrasion resistance was tested with a Crockmeter according to DIN 55654:2015-08.

This standard specifies a method for determining the resistance of a coating to scratching by a loaded surface with a linearly moving scraping material. The method can also be applied to other material surfaces, such as plastics, coatings, and metals.
The Crockmeter was equipped with a stamp using steel wool as a scratch medium with a load of 25 N.

As a result, even after 10,000 cycles no scratches were visible on the protective glass of the sensor.

Figure 4: Test set-up Abrasion resistance

The tests performed by an independent institute are available at **sales@jenetric.com**.

SUMMARY

Assessing the resistance against scratches requires a comprehensive understanding of the chemical and physical parameters of materials used on the contact surface of fingerprint scanners.

The use of international standards and their applicability is crucial to accurately compare the scratch resistance between fingerprint scanners.

LIVETOUCH scanners from JENETRIC are equipped with an additional glass protection on top of the capture area making them robust against scratches in daily use.