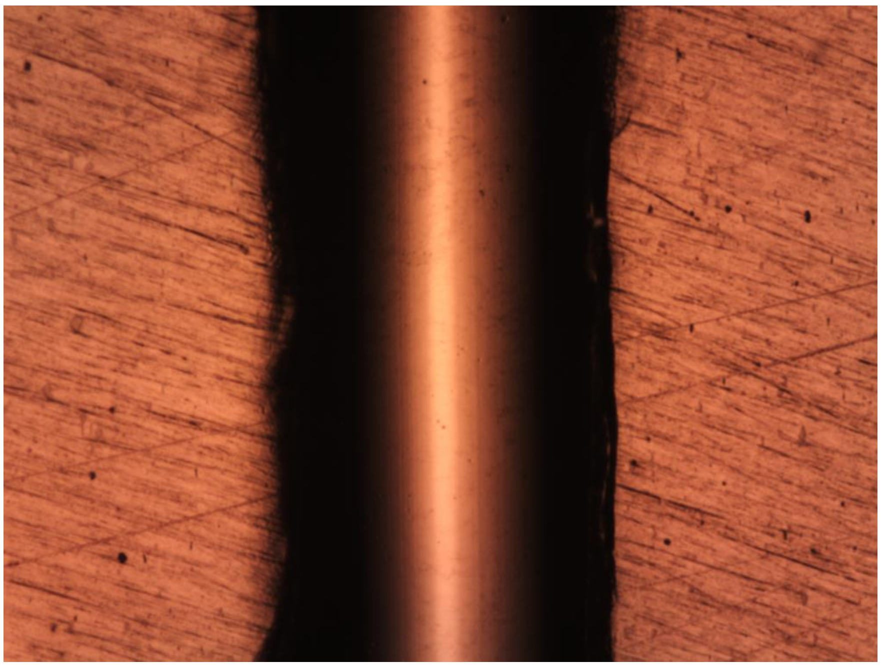
SCRATCH HARDNESS MEASUREMENT USING MECHANICAL TESTER



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INTRODUCTION

In general, hardness measures the resistance of materials to permanent or plastic deformation. There are three types of hardness measurements – scratch hardness, indentation hardness and rebound hardness. Scratch hardness test determines the hardness of a material to scratches and abrasion due to friction from a sharp object[i]. It was originally developed by German mineralogist Friedrich Mohs in 1820 and is still widely applied to rank the physical property of minerals[ii]. This test method is also applicable to metals, ceramics, polymers, and coated surfaces.

During the scratch hardness measurement, a diamond stylus of specified geometry scratches in the surface of the tested material along a linear path under a constant normal force with a constant speed. The average width of the scratch is measured and used to calculate the scratch hardness number (HS_P). This technique provides a simple solution of scaling the hardness of different materials.

MEASUREMENT OBJECTIVE

In this study, the Nanovea Mechanical Tester is used to measure the scratch hardness of different metals. We would like to showcase the capacity of Nanovea Mechanical Tester in performing scratch hardness measurement with high precision and reproducibility.

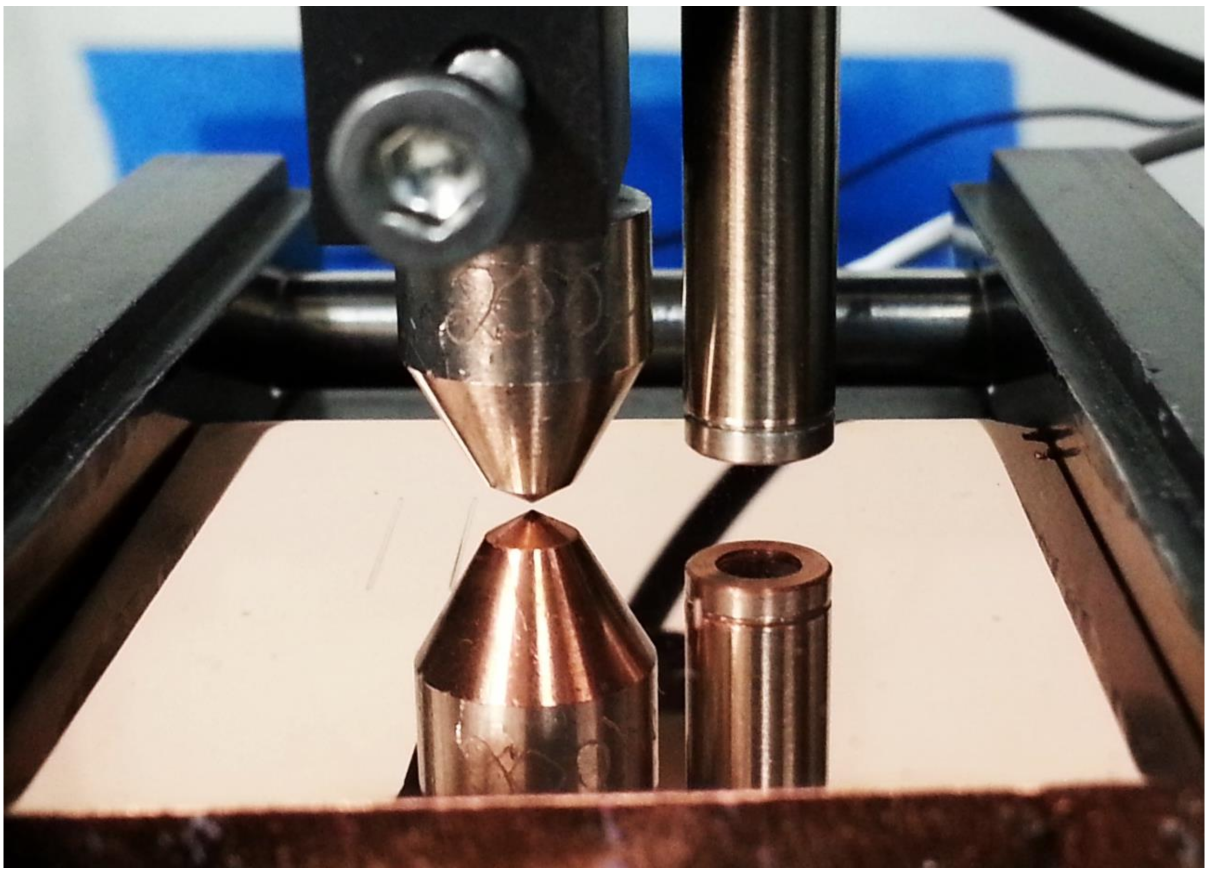


Fig. 1: Scratch stylus and depth sensor on the test specimen.

MEASUREMENT PRINCIPLE

Scratch hardness of materials using a diamond stylus is based on the standard ASTM G171-03[iii]. The test sample is prepared to represent the application of interest or polished to facilitate scratch width measurement. A constant normal force is applied by the stylus to the test sample and the scratch track is formed by the relative sliding movement of the stylus against the sample surface (see Fig. 2).

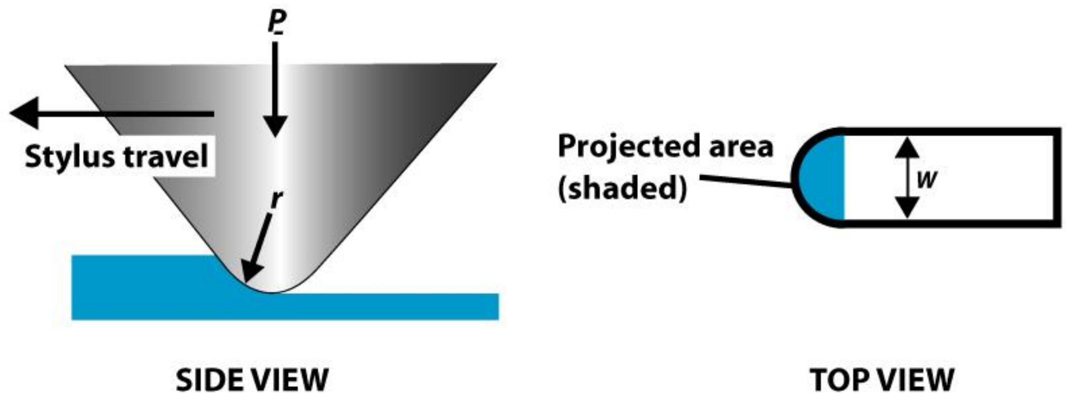


Fig. 2: Schematic of scratch hardness measurement.

The average width of the scratch track is determined optically under the microscope, and the scratch hardness number, HS_P is determined using the following formula:

$$HS_P = \frac{8P}{\pi w^2}$$

where HS_P is the scratch hardness number, P is the normal force, and w is the scratch width.

Other possible measurements by Nanovea Mechanical Tester:
Indentation hardness and Young's Modulus, Stress-Strain & Yield Stress, Creep, Fracture Toughness, Compression strength, Fatigue and many others.

TEST CONDITIONS

The Nanovea Mechanical Tester was employed to perform the scratch hardness tests on three polished metals (Cu110, Al6061 and SS304). A conical diamond stylus of apex angle 120° with tip radius of 200 μm was used. Each sample was tested for three scratches under the same parameters to ensure reproducibility of the results. The test parameters are summarized in Table 1. A profile scan at a low normal load of 10 mN was performed before and after the scratch test to measure the change of the surface profile of the scratch.

Test parameters	Value
Normal force	10 N
Sliding speed	20 mm/min
Sliding distance	10 mm
Atmosphere	Air
Temperature	24°C (room)

Table 1: Test parameters of the scratch hardness measurement.

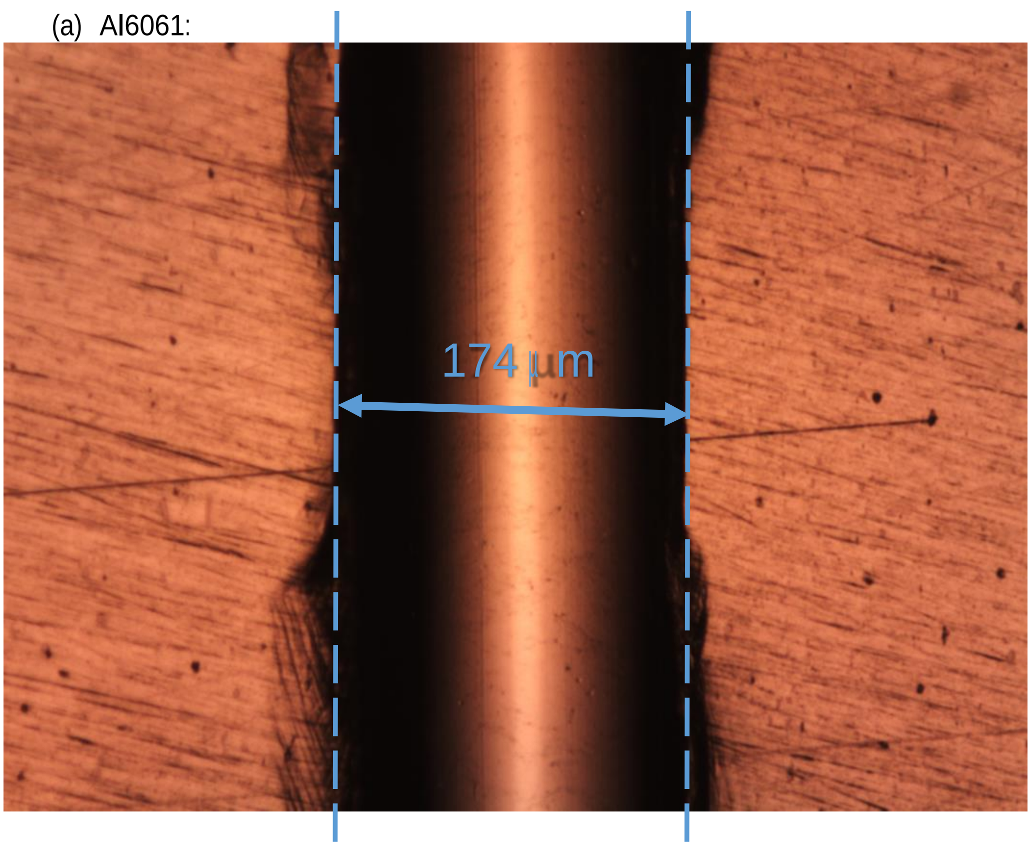
RESULTS AND DISCUSSION

The images of the scratch tracks of three metals (Cu110, Al6061 and SS304) after the tests are shown in Fig. 3 In order to compare the scratch hardness of different materials. The mapping function was used to create three parallel scratches tested under the same condition in an automated protocol. The measured scratch track width and calculated scratch hardness number (HS_P) are summarized and compared in Table 2. The metals show different wear track width – 174, 220 and 89 μm for Al6061, Cu110 and SS304, respectively, resulting in the calculated HS_P of 0.84, 0.52 and 3.2 GPa.

In addition to the scratch hardness computed from the scratch track width, the evolution of coefficient of friction (COF), true depth and acoustic emission were recorded in situ during the scratch hardness test. Here, the true depth is the depth difference between the penetration depth of the stylus during the scratch test and the surface profile measured in the pre-scan. The COF, true depth and acoustic emission of Cu110 is shown in Fig. 4 as an example. Such information provides insight of mechanical failures taking place during scratching, enabling users to detect mechanical defects and further investigate the scratch behavior of the tested material.

The scratch hardness tests can be finished within a couple of minutes with good precision and repeatability. Compared to conventional indentation procedure, the scratch hardness test in this study provides an alternative solution for hardness measurement, which is useful for quality control and development of new materials.

(a) Al6061:



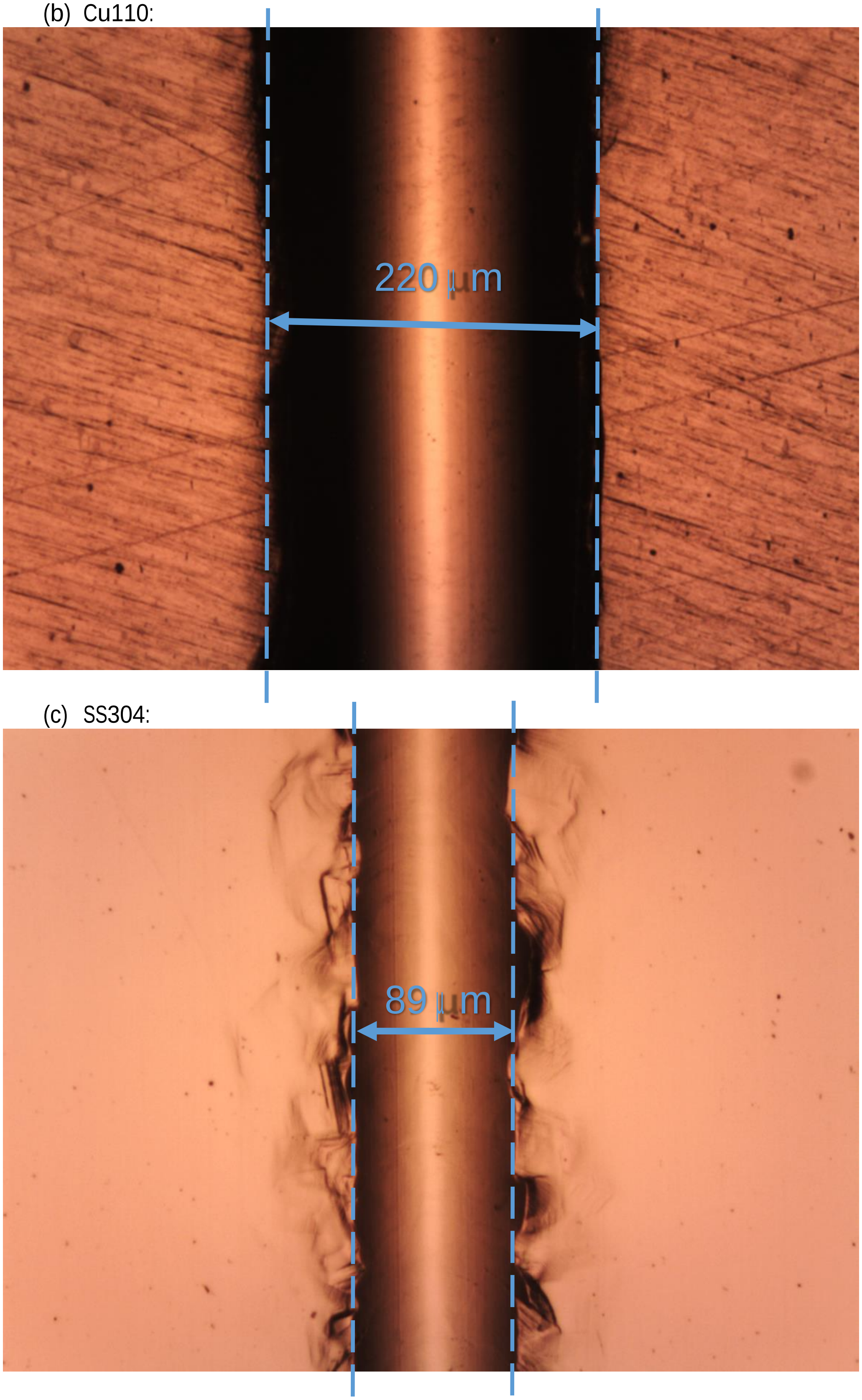


Fig. 3: Scratch tracks under the microscope after the measurements (100X).

	Scratch track width (μm)	HS_P (GPa)
Al6061	174± 11	0.84
Cu110	220± 1	0.52
SS304	89± 5	3.20

Table 2: Summary of scratch track width and scratch hardness number.

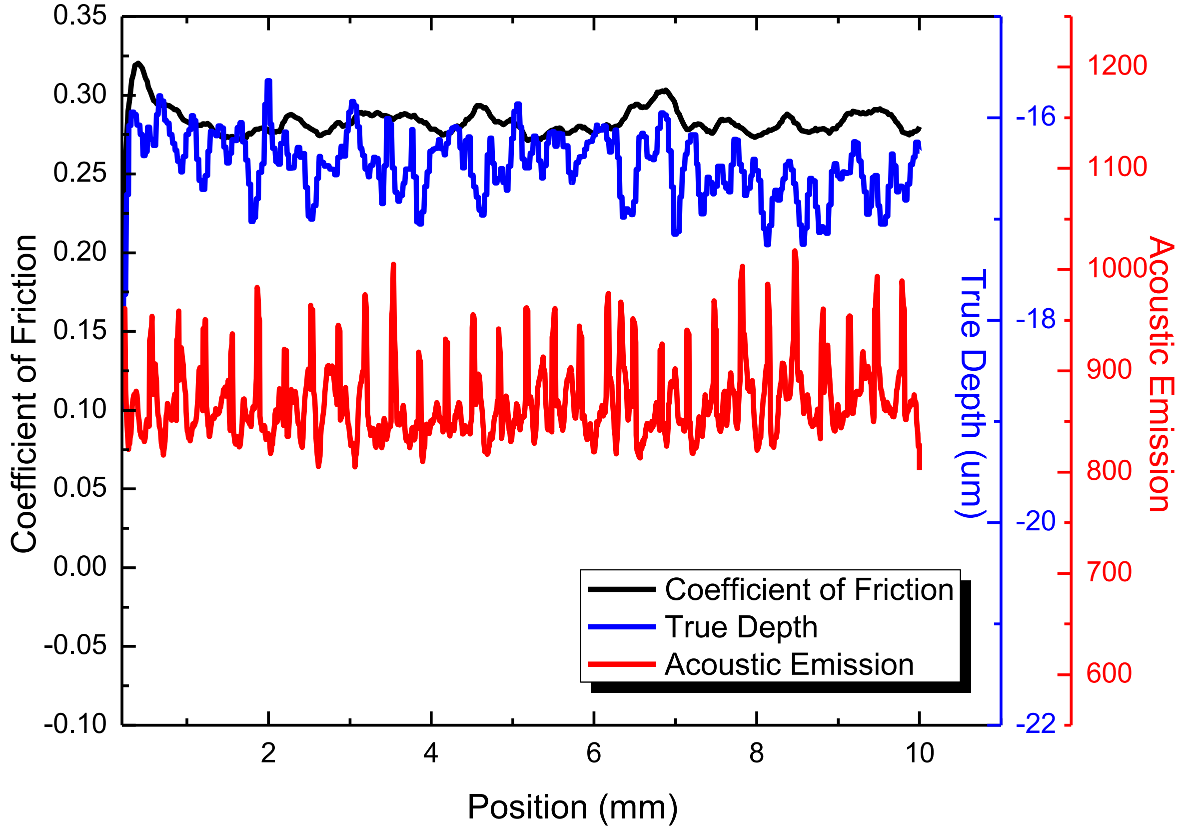


Fig. 4: The evolution of coefficient of friction, true depth and acoustic emission during the scratch hardness test on Cu110.

CONCLUSION

In this study, we showcased the capacity of Nanovea Mechanical Tester in performing scratch hardness tests in compliance to ASTM G171-03. In addition to coating adhesion and scratch resistance, the scratch test at a constant load provides an alternative simple solution for comparing the hardness of materials. Compared to conventional scratch hardness testers, Nanovea Mechanical Tester offers optional modules for monitoring the evolution of coefficient of friction, acoustic emission and true depth in situ.

The Nano, Micro or Macro modules of the Nanovea Mechanical Tester all include ISO and ASTM compliant indentation, scratch and wear tester modes, providing the widest and most user friendly range of testing available in a single system. Nanovea's unmatched range is an ideal solution for determining the full range of mechanical properties of thin or thick, soft or hard coatings, films and substrates, including hardness, Young's modulus, fracture toughness, adhesion, wear resistance and many others.

To learn more about Nanovea Mechanical Tester or Lab Services.

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[i] Wredenberg, Fredrik; PL Larsson (2009). "Scratch testing of metals and polymers: Experiments and numerics". *Wear* 266 (1–2): 76.
[ii] Encyclopædia Britannica. 2009. Encyclopædia Britannica Online. 22 Feb. 2009 "Mohs hardness."
[iii] ASTM G171 - 03(2009), "Standard Test Method for Scratch Hardness of Materials Using a Diamond Stylus."