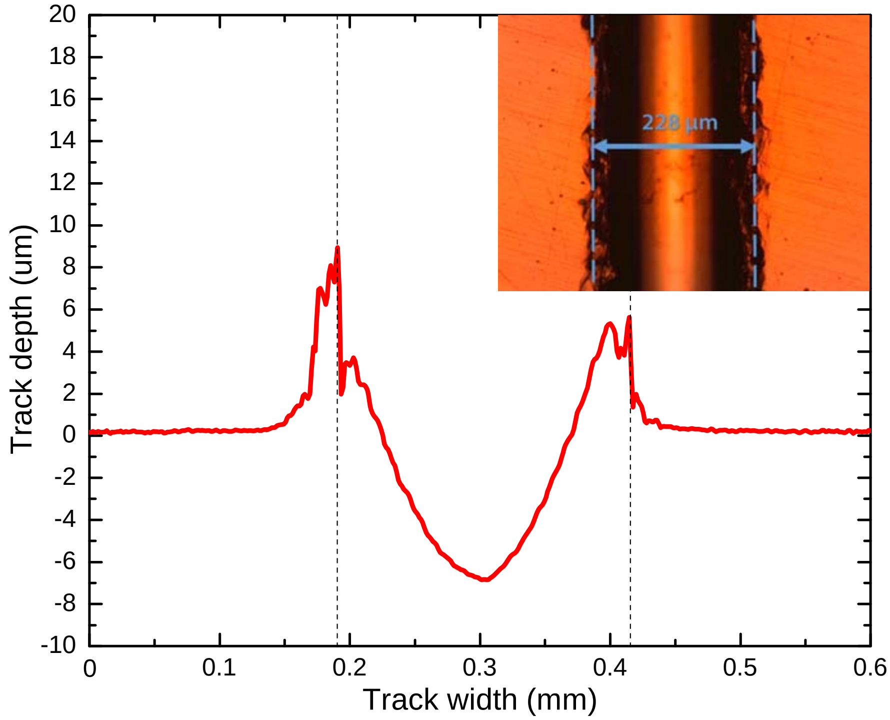
SCRATCH HARDNESS MEASUREMENT USING TRIBOMETER



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INTRODUCTION

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 with talc assigned a value of 1 and diamond assigned a value of 10 and is still widely applied to rank the physical property of minerals[ii].

Mohs' scale was not linear, therefore more accurate and qualitative scratch hardness measurement was developed as described in ASTM standard G171-03[iii]. In this scratch hardness measurement, a diamond stylus of specified geometry scratches in the surface of the tested material along a 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, including metals, ceramics, polymers, and coated surfaces.

MEASUREMENT OBJECTIVE

In this study, the Nanovea Tribometer is used to measure the scratch hardness of different metals. The capacity of performing scratch hardness measurement with high precision and reproducibility makes Nanovea Tribometer a more complete system for tribological and mechanical evaluations.

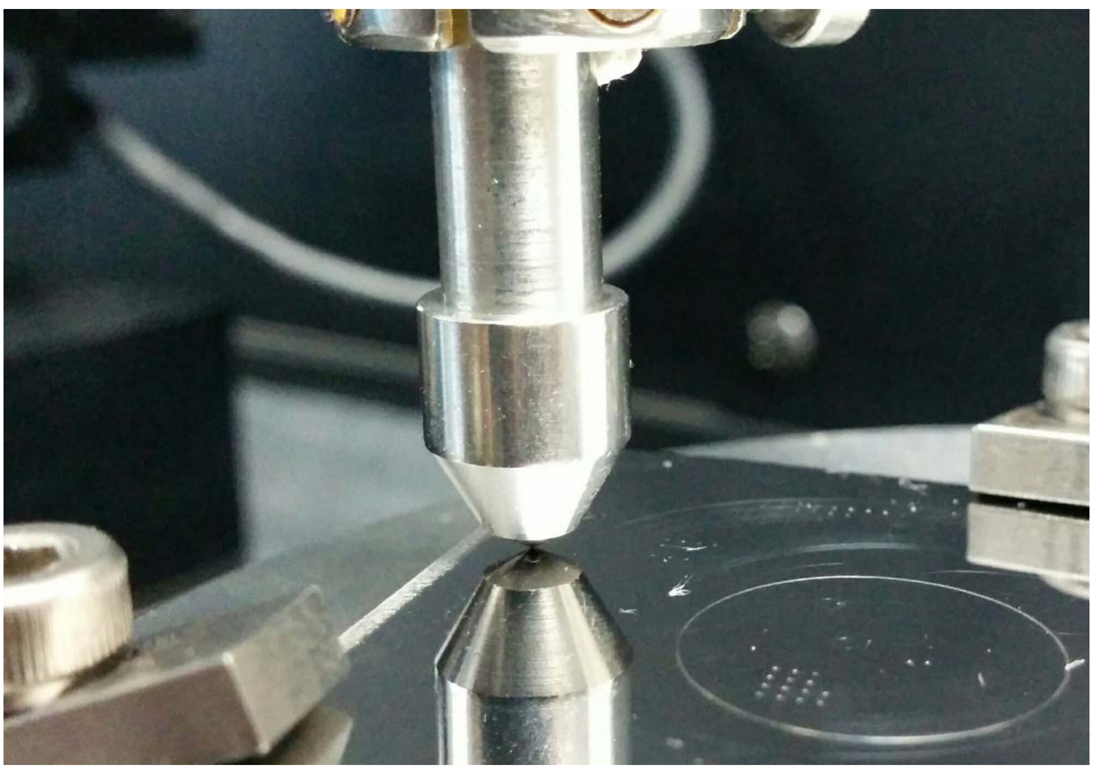


Fig. 1: Scratch stylus on the test specimen.

TEST CONDITIONS

The Nanovea Tribometer was employed to perform the scratch hardness tests on three polished metals (Al6061, Cu110 and SS304). A conical diamond stylus of apex angle 120° with tip radius of 200 µm was used. The scratch test was performed on the sample fixed on the rotative sample stage with a large distance of 3 cm to the stage center, in order to ensure local linearity of the scratch track for accurate track width measurement. 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. Scratch track profile scan was performed after the scratch test using the integrated non-contact optical profilometer.

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 scratch track profiles of three metals (Al6061, Cu110 and SS304) measured by the integrated non-contact optical profilometer is shown in Fig. 2 in order to compare the scratch hardness of different materials. The pile-ups at the sides of the scratch tracks form as the stylus travels at a constant load of 10 N and ploughs into the metal, pushing and deforming the metal in the scratch track to the side. The track width used for the calculation of scratch hardness can be determined using the peaks of the two pile-ups.

The images of the scratch tracks after the tests by Tribometer were examined under the optical microscope as shown in Fig. 3. The scratch tracks created using Nanovea Mechanical Tester are displayed for comparison. 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 – 170, 228 and 92 µm for Al6061, Cu110 and SS304, respectively, resulting in the calculated HS_P of 0.88, 0.49 and 3.01 GPa. The measured scratch track width by the microscope is in agreement with that measured by the profilometer equipped on the Tribometer. The scratch tracks created by ways of tribometer and mechanical tester exhibit comparable width, which in turn results in calculated scratch hardness in close HS_P values.

In addition to the scratch hardness computed from the scratch track width, the evolution of coefficient of friction (COF) was recorded in situ during the scratch hardness test as shown in Fig. 4. Such information provides insight of mechanical failures that might take 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 using the single Nanovea Tribometer equipped with the integrated profilometer. The scratch hardness test in this study provides an alternative solution for hardness measurement, and make Nanovea tribometer a more complete system for comprehensive tribo-mechanical evaluation.

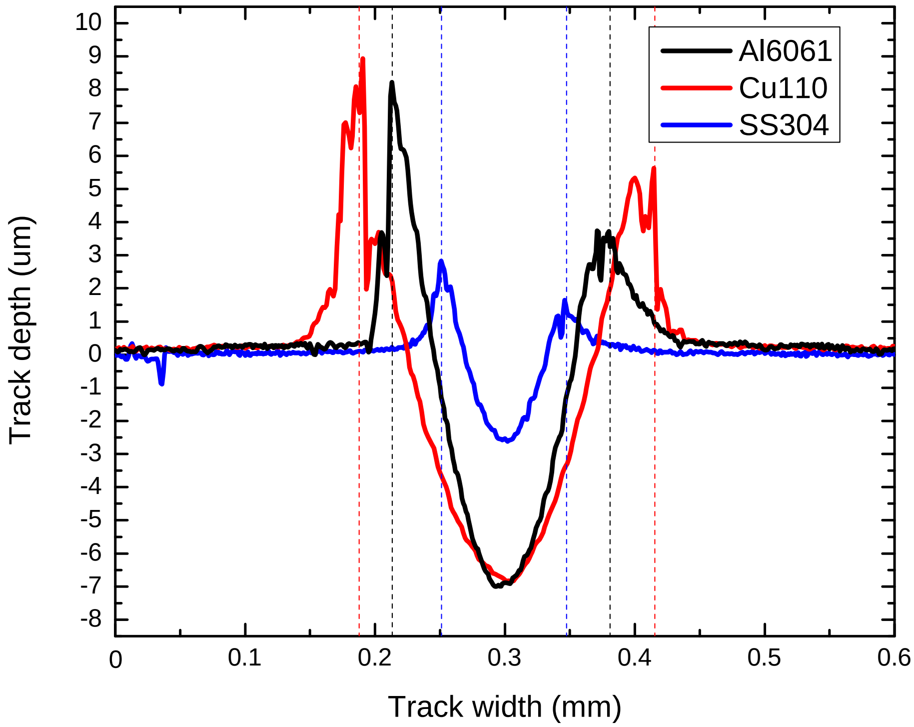
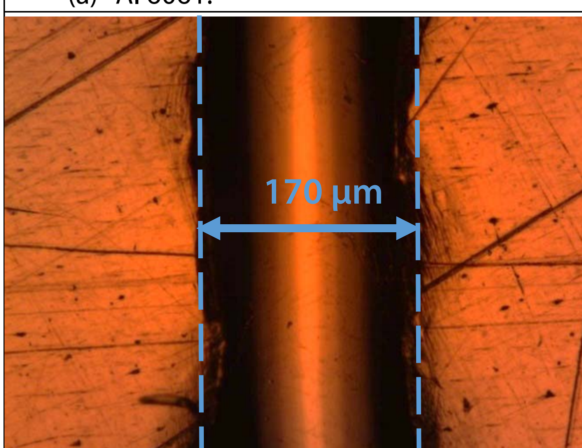
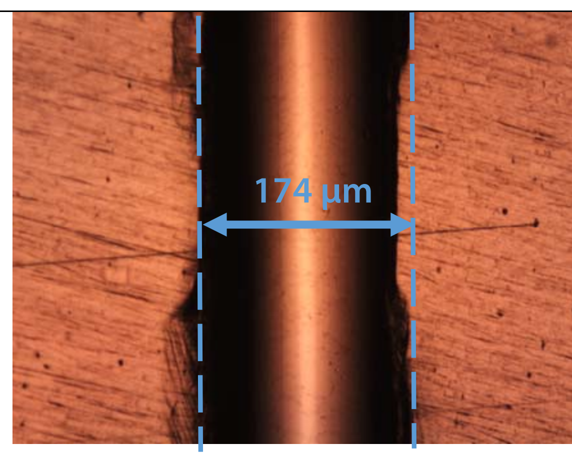
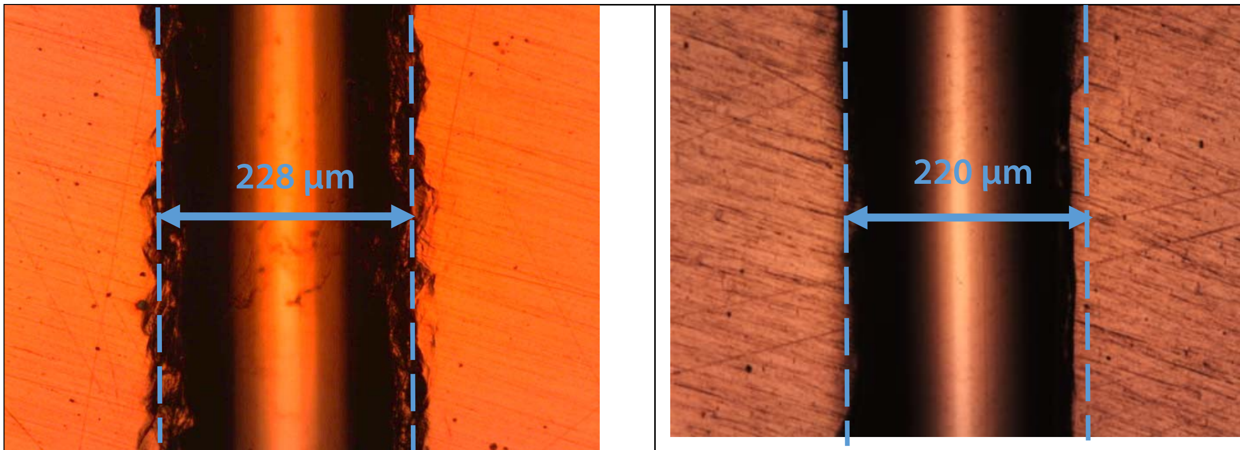


Fig. 2: Scratch track profiles after the scratch hardness tests.

Scratch tracks by Tribometer:	Scratch tracks by Mechanical Tester:
(a) Al 6061:	
	



(c) SS304:

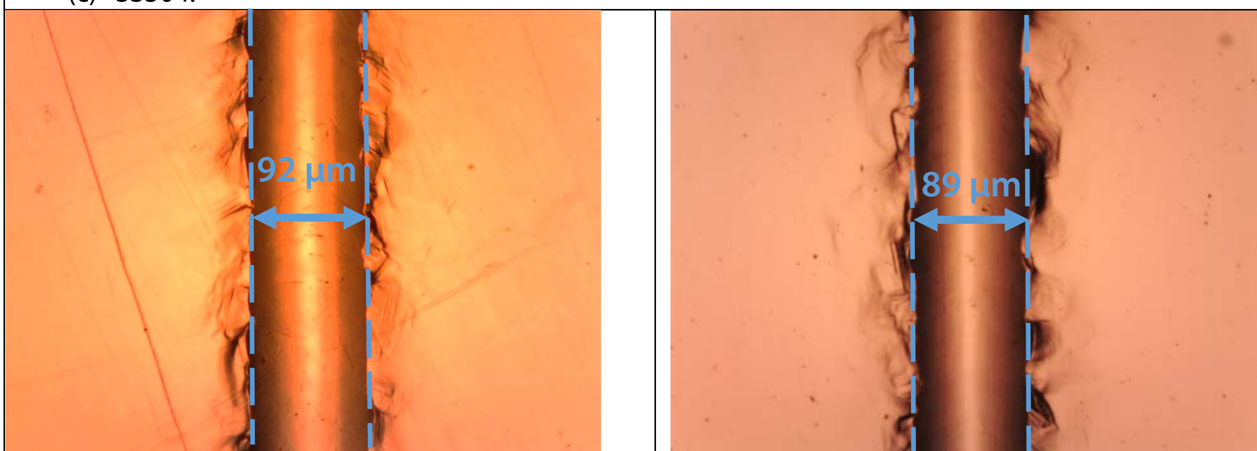


Fig. 3: Scratch tracks under the microscope after the measurements (100X).

	Scratch hardness by Tribometer		Scratch hardness by Mechanical Tester	
	Scratch track width (µm)	HS_P (GPa)	Scratch track width (µm)	HS_P (GPa)
Al6061	170±6	0.88	174±11	0.84
Cu110	228±8	0.49	220±1	0.52
SS304	92±4	3.01	89±5	3.20

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

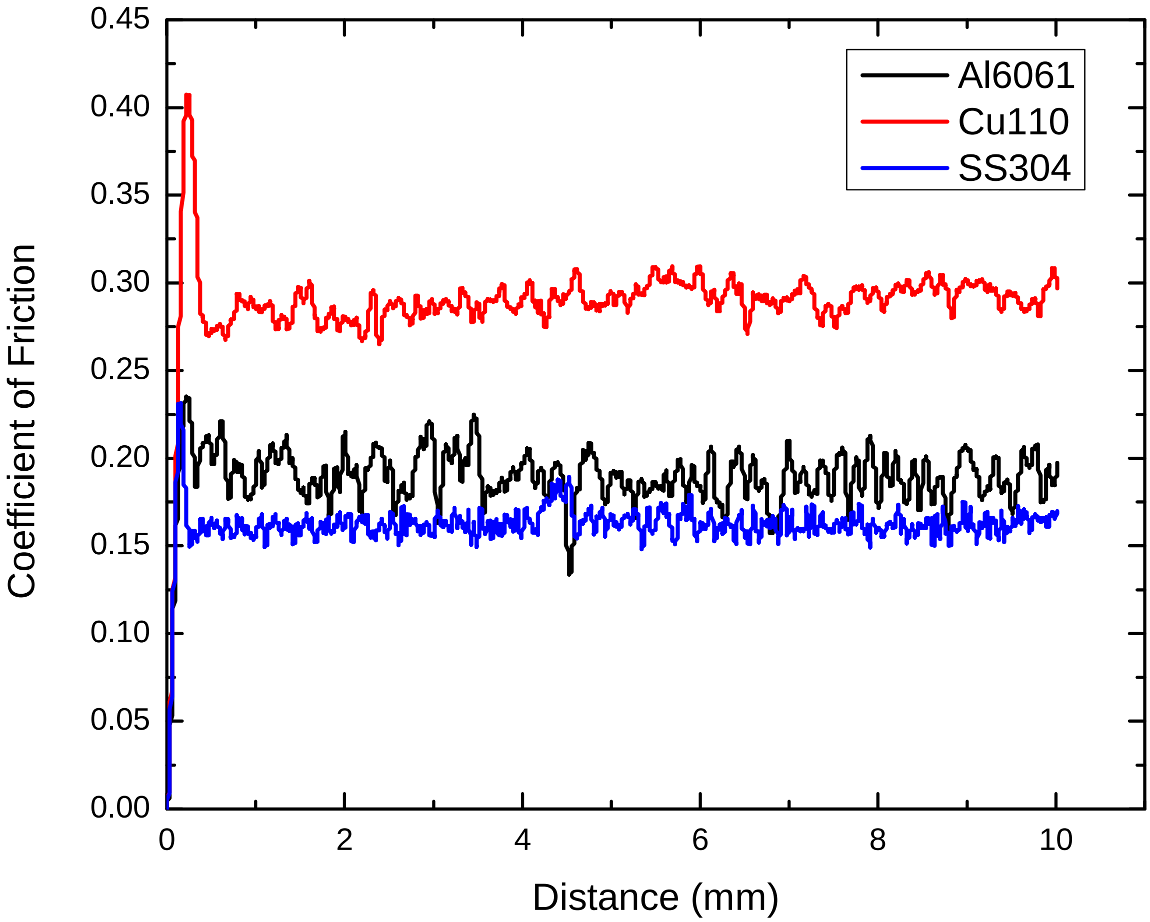


Fig. 4: The evolution of coefficient of friction during the scratch hardness tests.

CONCLUSION

In this study, we showcased the capacity of Nanovea Tribometer in performing scratch hardness tests in compliance to ASTM G171-03. The scratch hardness test at a constant load provides an alternative simple solution for comparing the hardness of materials using the tribometer equipped with a profilometer. Compared to conventional Mohs scratch hardness tests, Nanovea Tribometer can accurately measure the quantitative hardness value and monitor the evolution of coefficient of friction in situ.

Nanovea Tribometer also 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 wear track in addition to other surface measurements such as roughness. Learn More about the Nanovea Tribometer and 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."**

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. 1).

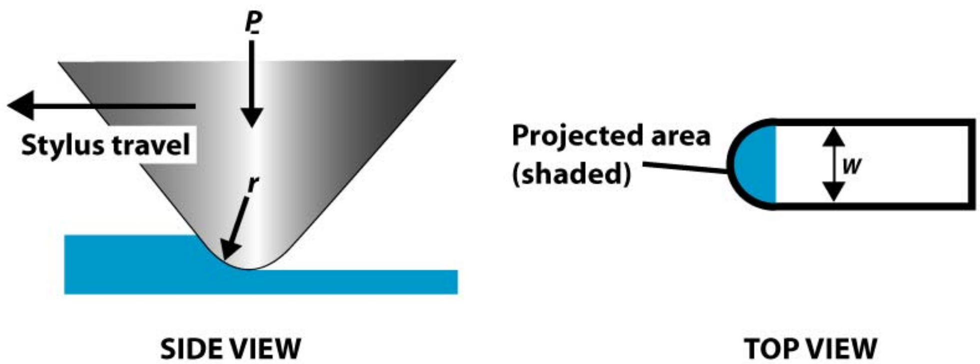

Fig. 1: Schematic of scratch hardness measurement.

The average width of the scratch track is determined, 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 Tribometer:

Rotative (pin-on-disc) wear, linear (reciprocating wear), wear in different environment, including high temperature, corrosive and lubrication, etc.