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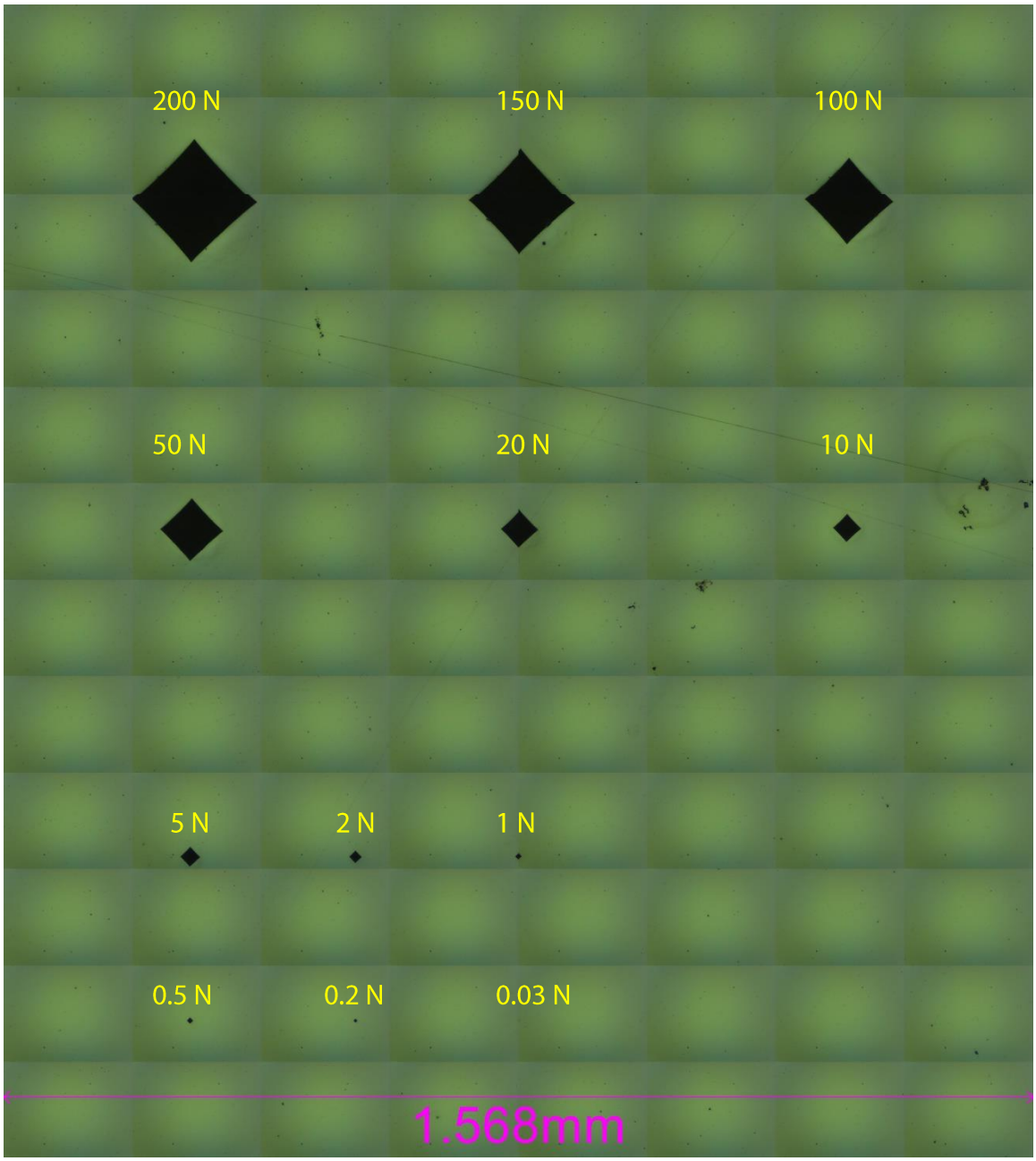
NOW THE WORLD'S LEADING MICRO MECHANICAL TESTING



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INTRO

Standard Vickers Micro hardness Testers have useable ranges from 10 to 2000 gram-force (gf). Standard Vickers Macro Hardness Testers are from 1 to 50Kgf. These instruments are very limited in range of loads and they also become inaccurate when dealing with rougher surfaces or at low loads when indents become too small to be measured visually. These limitations are intrinsic to a now becoming obsolete past century technology. Instrumented indentation is replacing it at an increasing rate as it becomes the standard choice for higher accuracy and performance. With Nanovea's world leading micro mechanical testing Vickers hardness is automatically calculated from depth versus load data with the widest load range on a single module ever available (0.3grams to 2Kg or 6grams to 40Kg). Because it measures hardness from depth versus load curves, the Nanovea Micro Module can measure any type of materials including very elastic ones. It also can provide not only Vickers hardness but also accurate elastic modulus and creep data in addition to other type of test such as scratch adhesion testing, wear, fatigue testing , yield strength and fracture toughness for a complete range of quality control data.

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In this applications note, it will be explained how the Micro Module has been designed to offer the world's leading instrumented indentation and scratch testing. The wide range of testing capability is ideal for many applications. For example, the range of load allows measuring accurately hardness and elastic modulus of a thin very hard coating and then uses much higher loads to measure the adhesion of the same coating.

MEASUREMENT OBJECTIVE

We showcase the capacity of the new Micro Module on the CB500 Mechanical Tester performing both indentation and scratch tests with superior precision and reliability in a wide load range from 0.03 to 200 N (optional from 0.003 to 20 N).

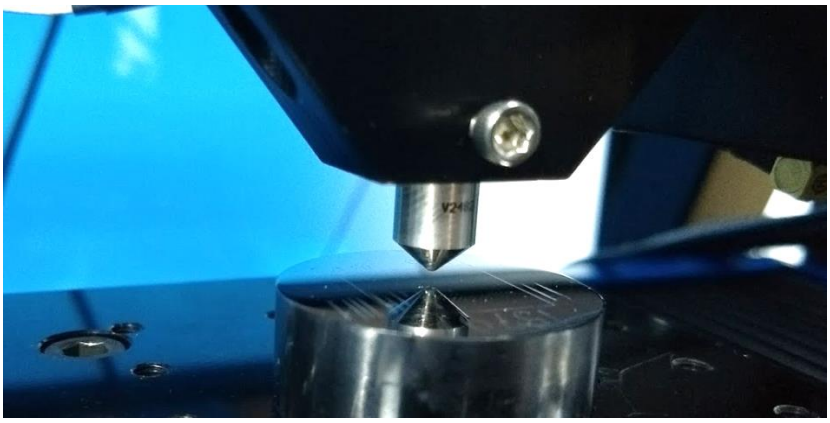


Fig. 1: Microindenter on the steel standard sample.

TEST CONDITIONS

A series (3×4, 12 indents in total) of Microindentations were completed on a steel standard sample using a Vickers indenter. The load and depth were measured and recorded during the indentation. The indentations were performed to different maximum loads ranging from 0.03 N to 200 N (0.0031 to 20.4 kgf) to showcase the capacity of the new micro module in performing accurate indentation tests at different loads. The test conditions are summarized in Table 1. It is worth noting that an optional load cell of 20 N is also available to provide 10 times higher resolution for tests in the lower load range from 0.3 gf up to 2 kgf.

Maximum force (N)	200	150	100
	50	20	10
	5	2	1
	0.5	0.2	0.03
Indenter type	Vickers		
Mapping	3 by 4 Indents		

Table 1: Test parameters of the indentation mapping.

Two scratch tests were performed using the Micro Module with linearly increased load from 0.01 N to 200 N and from 0.01N to 0.5N, respectively, using conico-spherical diamond stylus with tip radius of 500 µm and 20 µm.

Twenty Microindentation tests were carried out on the steel standard sample at 4N. It shows the superior repeatability of the Micro Module results compared to the conventional Vickers hardness testers.

RESULTS AND DISCUSSION

As shown in Fig. 2, the new Micro Module has a unique combination of Z-motor, high-load load cell and a high precision capacitor depth censor. The unique use of independent depth and load sensors ensures high accuracy in all conditions. Conventional Vickers hardness uses a diamond in the form of a square-based pyramid. It indents on the sample surface and creates a square imprint. By measuring the average length of the diagonal, *d*, the Vickers hardness can be calculated. In comparison, the instrumented indentation technique used by Nanovea's Micro Module directly measures the mechanical properties from indentation load & displacement measurements. No visual observation of the indent is required. This eliminates user or computer image processing errors in determining the *d* values of the indentation.

The high accuracy capacitor depth sensor with a very low noise level of 0.3nm can accurately measure the depth of indents that are difficult or impossible to be measured visually under a microscope with traditional Vickers hardness testers.

In addition, the cantilever technique being used by competitors applies the normal load on a cantilever beam by a spring, and this load is in turn applied on the indenter. Such a design has a flaw in case a high load is applied – the cantilever beam cannot provide sufficient structural stiffness, leading to deformation of the cantilever beam and in turn misalignment of the indenter. In comparison, the new Micro Module by directly applies the normal load by the Z-motor on the load cell, in turn acting on the indenter. All the elements are vertically aligned for maximum stiffness, ensuring repeatable and accurate indentation and scratch measurements in the full load range.

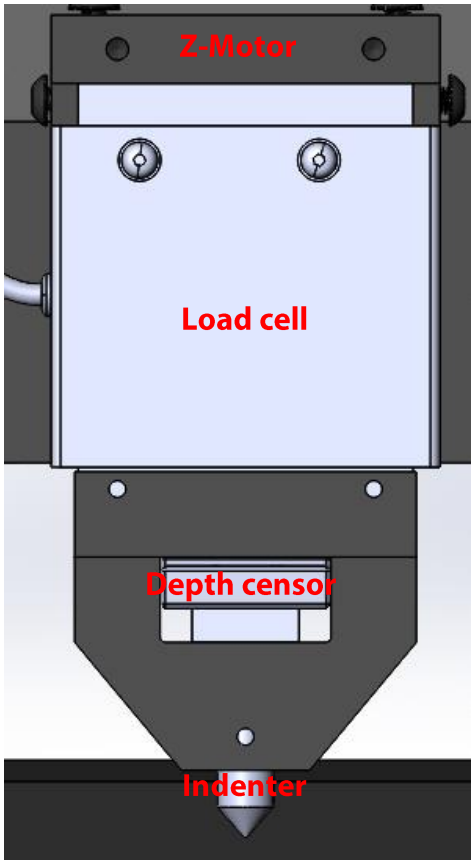


Fig. 2: Up-close view of the new micro module.

Indentation from 0.03 to 200 N

The image of the indentation map is displayed in Fig. 3. The distance between the two adjacent indents above 10 N is 0.5 mm, while the one at lower loads is 0.25 mm. The high-precision position control of the sample stage allows users to select the target location for mechanical properties mapping. Thanks to the excellent stiffness of the micro module due to the vertical alignment of its components, the Vickers indenter keeps a perfect vertical orientation as it penetrates into the steel sample under a load of up to 200 N (400 N optional). This creates impressions of a symmetric square shape on the sample surface at different loads.

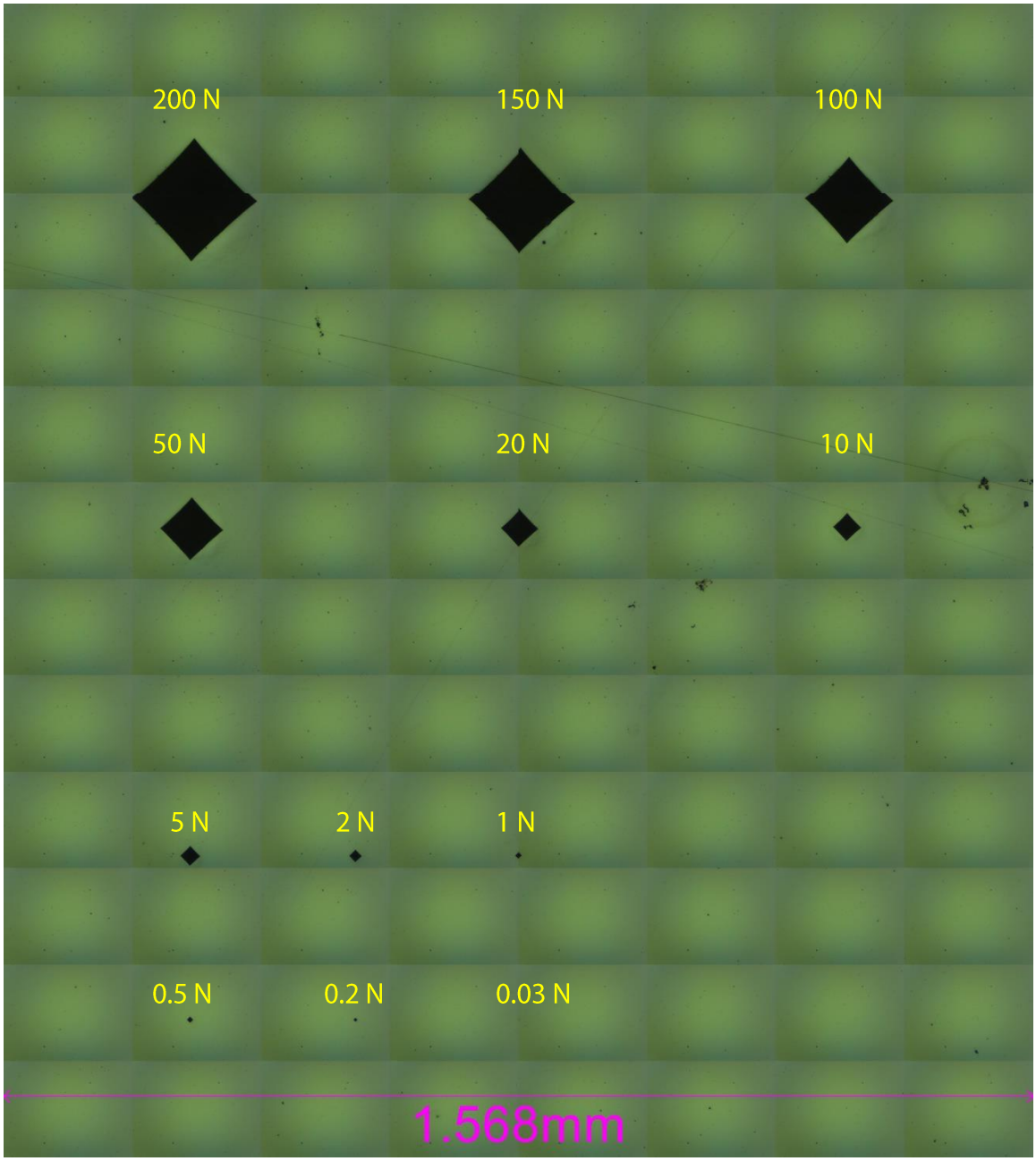
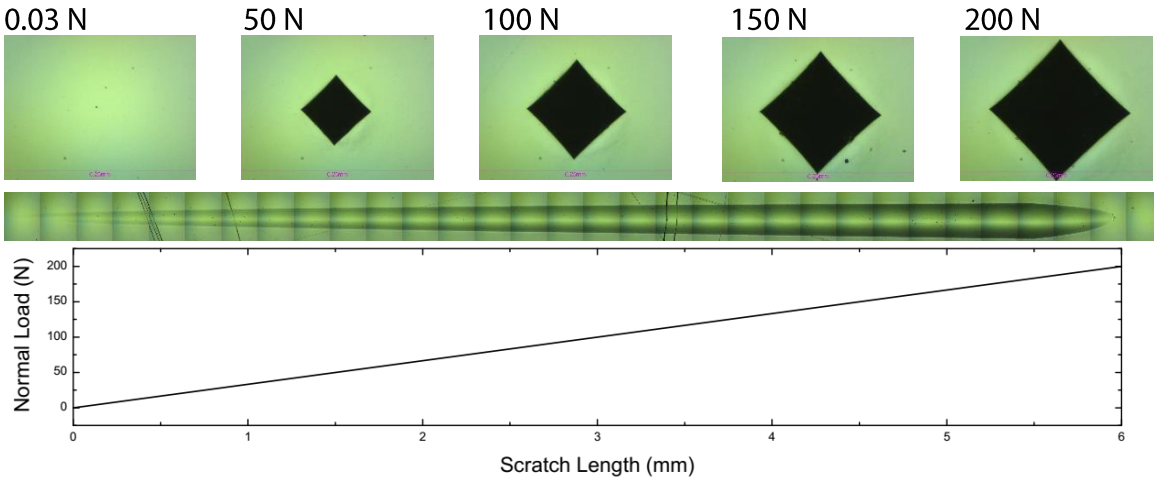


Fig. 3: Indentation Map.

The individual indentations at different loads under the microscope are displayed alongside of the two scratches as shown in Fig. 4, to showcase the capacity of the new micro module in performing both indentation and scratch tests in a wide load range with a high precision. As shown in the Normal Load vs. Scratch Length plots, the normal load increases linearly as the conico-spherical diamond stylus slides on the steel sample surface. It creates a smooth straight scratch track of progressively increased width and depth. In contrast, the loading system of a cantilever beam

structure used by competitors may suffer from undesired bending and unstableness of the stylus during the scratch tests under high loads, which results in zigzags taking place in the scratch tracks. Such a behavior introduces errors in scratch track width measurement and determination of critical loads for further analysis of the scratch track.

(a) Indentation under the microscope (360X):



(b) Indentation under the microscope (3000X):

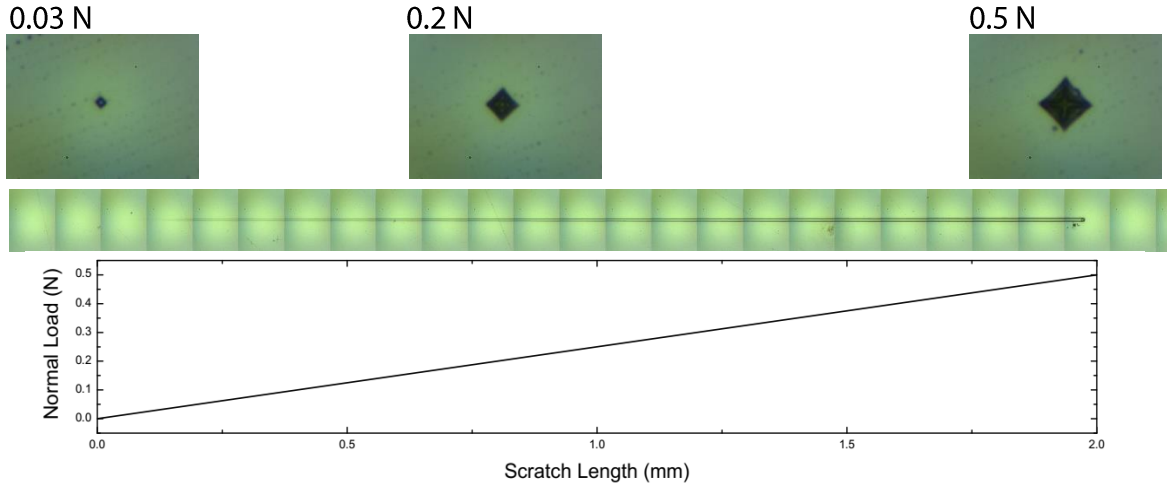


Fig. 4: Indentation and scratch tests at different loads.

The load-displacement curves during the indentation at different maximum loads are shown in Fig. 5, and the hardness and elastic modulus are summarized and compared in Fig. 6. The steel sample exhibits a constant elastic modulus throughout the test load ranging from 0.03 to 200 N (possible range 0.003 to 400 N), resulting in an average

value of ~211 GPa. The hardness exhibits a relatively constant value of ~6.5 GPa measured under a maximum load above 100 N. As the load decreases to a range of 2 to 10 N, an average hardness of ~9 GPa is measured.

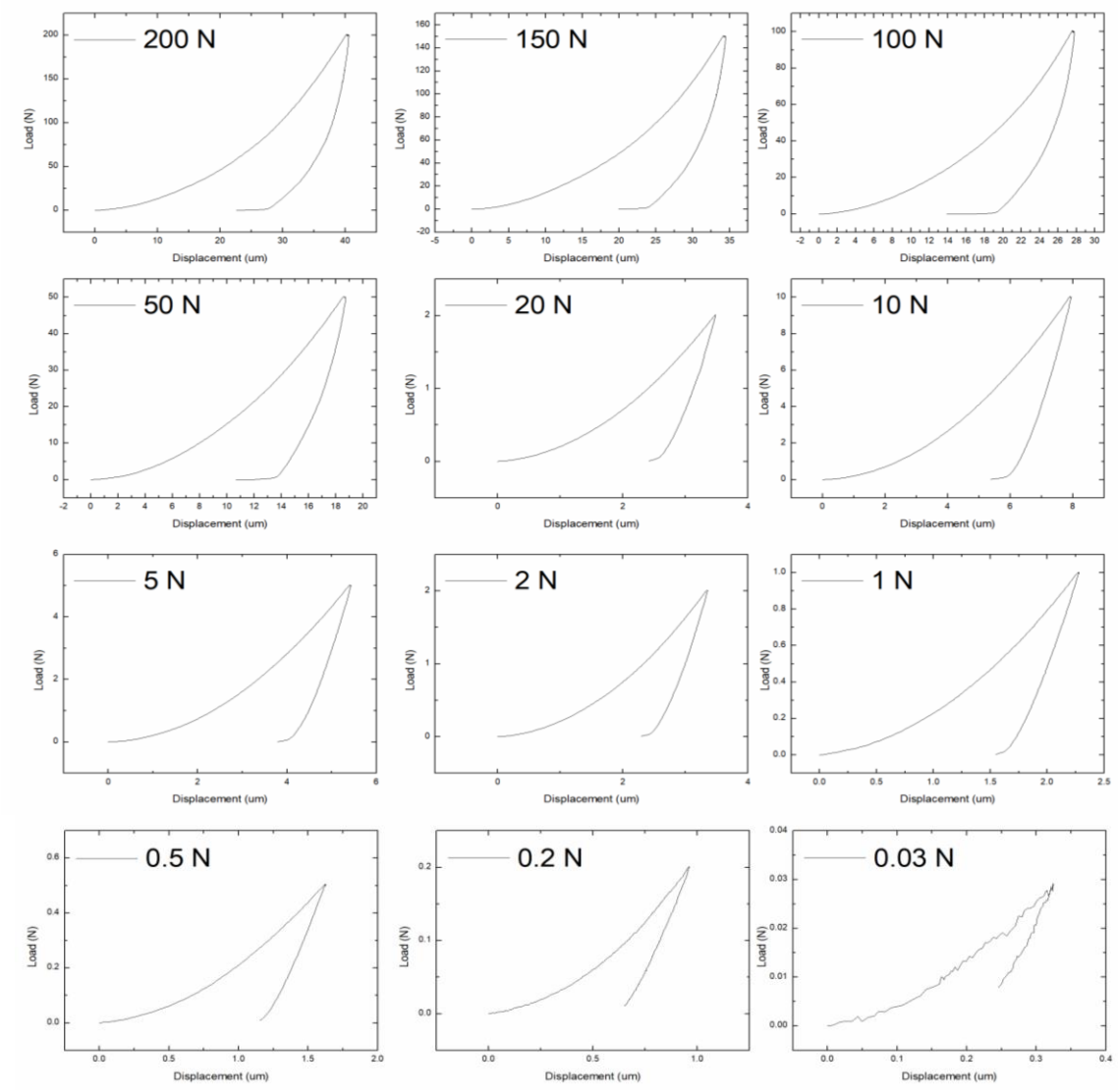


Fig. 5: Load vs Displacement plots at different maximum loads.

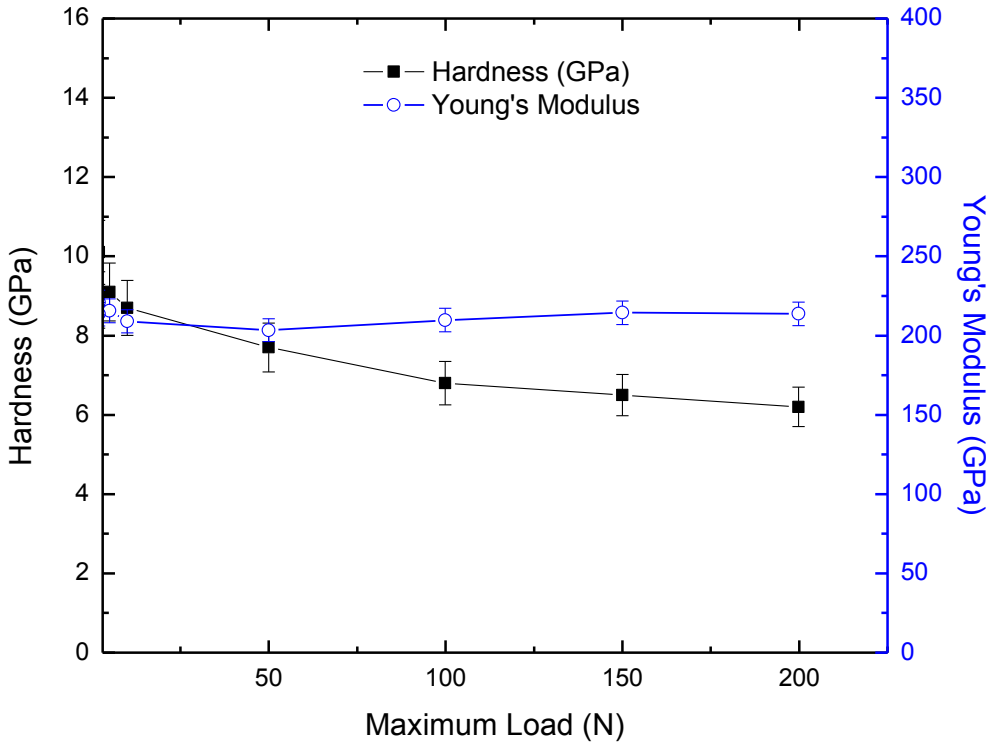


Fig. 6: Hardness and Young's modulus of the steel sample measured by different maximum loads.

Microindentation at 4 N

Twenty Microindentation tests were performed at 4N maximum load. The load-displacement curves are displayed in Fig. 7 and the resulting Vickers hardness and Young's modulus are shown in Fig. 8. The load displacement curves demonstrate the superior repeatability of the new Micro Module. The steel standard possesses a Vickers hardness of 842±11 HV measured by the new Micro Module, compared to 817±18 HV as measured using the conventional Vickers hardness tester. The small standard deviation of the hardness measurement ensures reliable and reproducible characterization of mechanical properties in the R&D and quality control of materials in both the industrial sector and academia research. In addition, a Young's Modulus of 208±5 GPa is calculated from the load-displacement curve, which is not available for conventional Vickers hardness tester due to the missing depth measurement during the indentation. As load decrease and the size of the indent decreases, the Nanovea Micro Module advantages in terms of repeatability compare to Vickers Hardness Testers increase until it is no longer possible to measure the indent through visual inspection. The advantage of measuring depth to calculate hardness also becomes evident when dealing with rougher or when samples are more difficult to observe under standard microscopes provided on Vickers Hardness Testers.

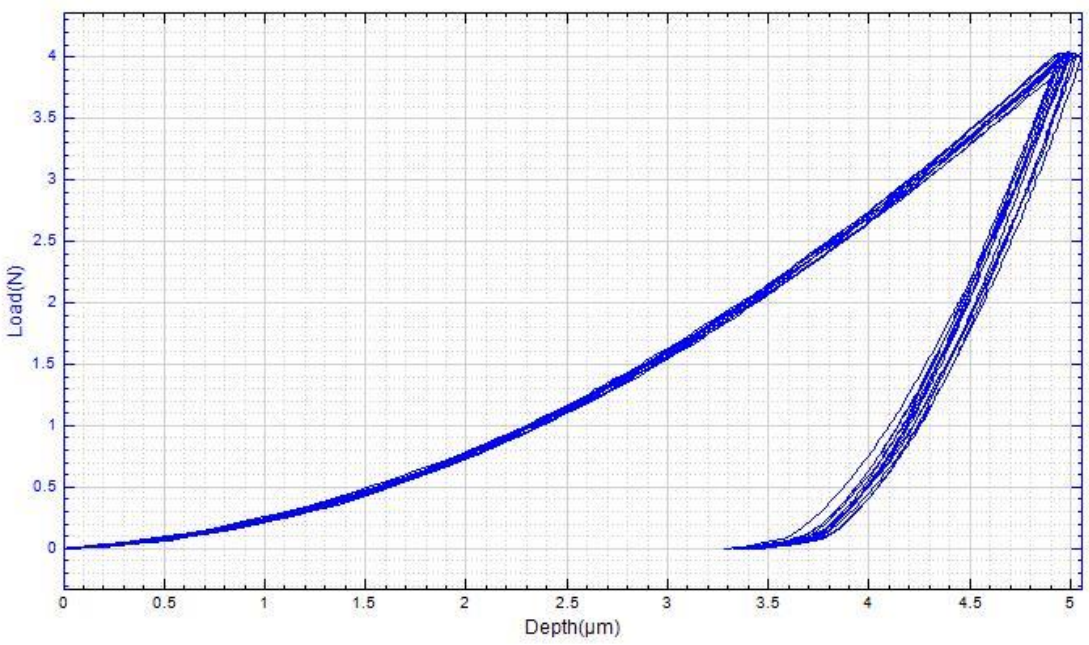


Fig. 7: Load-displacement curves for microindentation tests at 4 N.

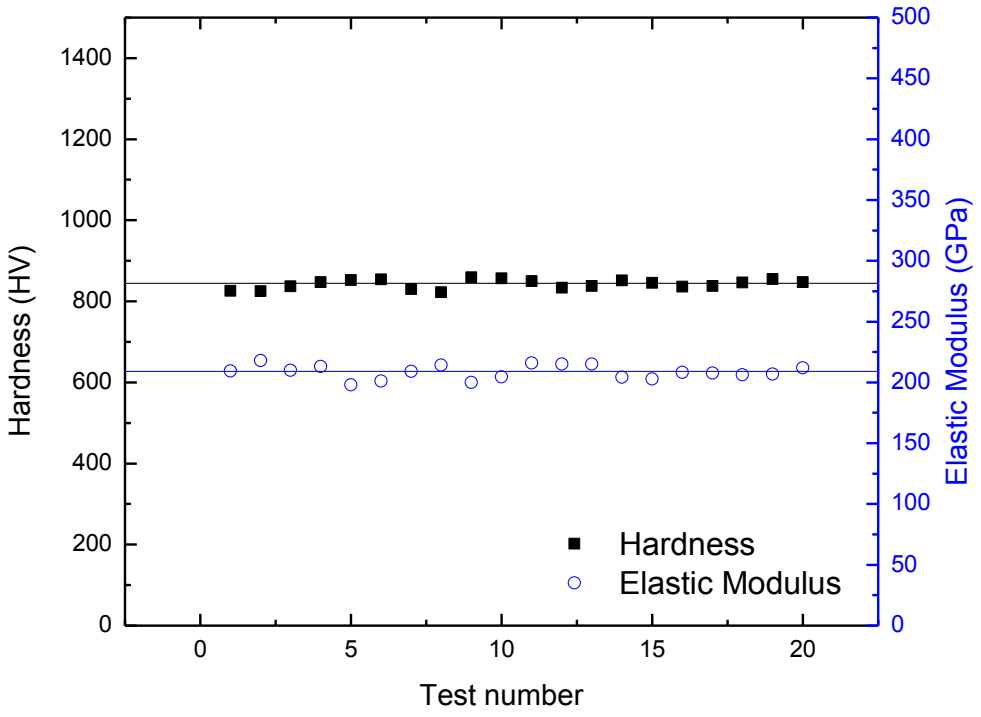


Fig. 8: Vickers hardness and Young's Modulus for 20 microindentations at 4 N.

CONCLUSION

In this study, we have shown the new world leading Nanovea Micro Module (200 N range) performs unmatched reproducible and precise indentation and scratch measurements under a wide load range from 0.03 to 200 N (3 gf to 20.4 kgf). An optional lower range Micro Module can provide testing from 0.003 to 20 N (0.3 gf to 2 kgf). The unique vertical alignment of the Z-motor, the high-load load cell and the depth sensor ensures maximum structural stiffness during measurements. The indentations measured at different loads all possess a symmetric square shape on the sample surface. A straight scratch track of progressively increased width and depth is created in the scratch test of a 200 N maximum load.

The new Micro Module can be configured on the PB1000 (150x200 mm) or the CB500 (100x50 mm) mechanical base with a z motorization (50 mm range). Combined with a powerful camera system (position accuracy of 0.2 microns) the systems provide the best automation and mapping capabilities on the market. Nanovea also offers a unique patented function (EP No. 30761530) which allows verification and calibration of Vickers indenters by doing only one indent across the full range of loads. Standard Vickers Hardness Testers only provide a standard sample good at one load.

For users needing to measure hardness through the size of the indent, the Nanovea software can also provide Vickers hardness (ASTM E92 & E384) by measuring directly the size of the indent. As shown, in this document, reproducibility of depth versus load hardness testing (ASTM E2546 and ISO 14577) is better on perfect samples and it becomes a lot better when dealing with challenging surfaces difficult to observe under microscopes necessary to do ASTM E92 &E384.

In conclusion, the higher accuracy and repeatability of the Micro Module design with its broad range of loads and tests, high automation and mapping options renders the traditional Vickers hardness testers obsolete. But likewise with scratch and micro scratch testers still currently offered but designed with flaws in the 1980's.

Nanovea, with these latest developments, truly is the world leader in micro mechanical testing.

To learn more about Nanovea Mechanical Tester or Lab Services.