CETR LEADERS IN TRIBOLOGY TEST INSTRUMENTATION AND SERVICES

Micro and Nano Hardness Measurements on UMT Testers

The Universal Mechanical Testers series UMT with their large selection of force sensors (within eleven orders of magnitude from 10 nN to 1 kN), depth sensors (within eight orders of magnitude from 0.1 nm to 100 mm), indenters (from 50 nm Berkovich tips to 12.7 mm balls), and versatile user-friendly software (with automated data analysis), are an effective tool for measuring micro- and nano- hardness of thin films, coatings and bulk materials on all common hardness scales.

A motorized vertical carriage supplies a loading force for micro-scale tests (from 0.1 mN to 1 kN), a voice-coil actuator supplies a loading force for nano-scale tests (from 10 nN to 0.5 N). The depth of indentation can be measured on a macro-scale with a basic optical encoder (from 1 µm to 100 mm), on a micro-scale with a traditional capacitance sensor (from 0.05 to 250 µm), on a nano-scale with a 3-plate capacitance sensor (from 0.1 nm to 200 µm). The diameter or diagonals of the indents can be measured with a digital optical microscope (from 5 µm to 0.5 mm).

The unique UMT tester can be utilized for all common hardness measurements, namely:

- ***Brinell macro-hardness*** per the ASTM E10-01, limited to its lower end with balls 1 mm (loads 10 to 300 N), 2 mm (loads 40 to 400 N), 2.5 mm (loads 250 to 620 N) or 5 mm (loads 250 to 620 N). More common tests with 10-mm balls cannot be performed, as they require loads above the UMT limit of 1 kN. The load is applied for a specified time (10 to 30 s), then diameter of the recovered indent is measured with a microscope.

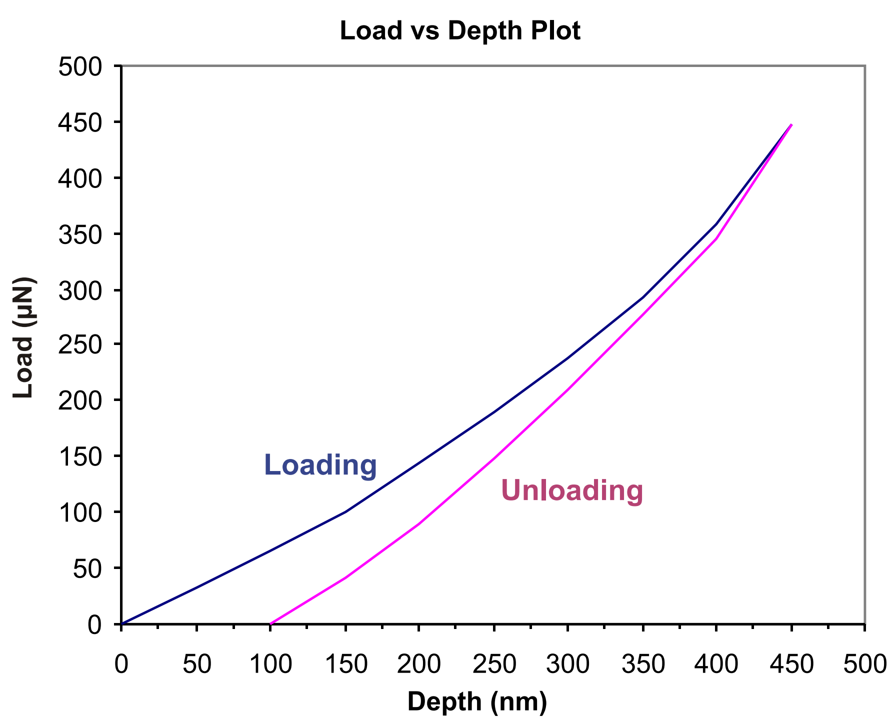
- ***Vickers macro-hardness*** per the ASTM E92-03, based on the Brinell idea of applying a standard load (from 10 N to 1.2 kN) and then measuring a resultant indent. Comparing to Brinell, a diamond square-based pyramid (with the face angle of 136º) used as an indenter allows for testing harder materials, while lower loads allow for testing smaller thicknesses. Instead of diameter, both indent diagonals are measured with a microscope, and their average length is used for hardness calculations.

- ***Vickers and Knoop micro-hardness*** per the ASTM E384-99, substantially similar to the Vickers macro-hardness, but under lower loads (0.1 to 10 N). Both tests use small diamond pyramid indenters with different bases: square for the Vickers and rhomb for the Knoops (with the face angles of 172.5º and 130º, one diagonal being 7.1 times longer than the other). After the indentation, the Vickers hardness is calculated based on the average length of two indent diagonals, while the Knoop hardness is calculated from the length of the longest indent diagonal. Both micro-hardness scales are used for coatings, though the Knoop is more common for thin coatings.

- ***Rockwell hardness*** per the ASTM E18-05, both **macro-hardness** tests with a pre-load of 100 N and final loads of either 0.6 kN or 1 kN and "superficial" **micro-hardness** tests with a pre-load of 30 N and final loads of 150, 300 or 450 N. Unlike Brinell, Vickers and Knoop hardness, the Rockwell tests include post-load measurements of the indent depth (i.e., they require capacitance depth sensing instead of optical microscopy). The Rockwell tests use 15 standard macro-scales and 15 superficial micro-scales and various indenters: tungsten carbide balls 1.588 mm (loads 0.6 and 1 kN in scales B and F, loads 150 - 450 N in scale T), 3.175 mm (loads 0.6 and 1 kN in scales E and H, loads 150 - 450 N in scale W), 6.35 mm (loads 0.6 and 1 kN in scales L and M, loads 150 - 450 N in scale X) and 12.7 mm (loads 0.6 and 1 kN in scales R and S, loads 150 - 450 N in scale Y), as well as diamond sphero-conical Brale tips with a radius of 0.2 mm and face angle of 120º (loads 0.6 and 1 kN in scales A and D, loads 150 - 450 N in scale N).

- ***Instrumented Indentation hardness*** per the ISO 14577-1/02 on **macro-scale** (for loads greater than 2 N), **micro-scale** (loads under 2 N) and **nano-scale** (for depths less than 0.2 µm). It is used with various indenters, including diamond pyramids with orthogonal (Vickers) and triangular (Berkovich) bases, balls from diamond or hard metals, etc. The major specifics of this technique is continuous real-time force and depth monitoring with calculations of the indentation and Martens hardness values, as well as indentation modulus, creep, relaxation and work.

The UMT testers allow for sophisticated comparative studies of different hardness scales on the same tester, with either the same or different indenters, without specimen removal.



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