C227-E024

Access to your success
SHIMADZU

DUH-211
DUH-211S

Shimadzu
Dynamic Ultra Micro Hardness Tester

DUH-211/DUH-211S

DUH-211/DUH-211S

Shimadzu Dynamic Ultra Micro Hardness Tester

Building on our experience with hardness evaluation technology for the micro range, we have taken our quest for greater precision and ease of use to the next level. Our hardness tester can measure the strength properties of material surfaces and microscopic materials using new evaluation methods specified in ISO standards. Perform evaluation using the hardness and materials parameters specified in ISO 14577-1(Annex A)*1) .

Evaluates hardness of a wide range of materials:

- Thin films
- Plastics
- Rubbers and elastomers
- Metallic materials
- Fibers
- Brittle materials
- Microscopic electronic components

Test the surface strength of thin films, surface-treated layers such as ion-implanted layers and nitride layers, as well as nonmetallic materials such as plastics, rubbers, and ceramics.

*1) ISO 14577-1 Metallic materials - Instrumented indentation test for hardness and materials parameters Part1:Test method
Annex A Materials parameters determined from the force/indentation depth date set
Standard used for new evaluation methods that continuously measure changes in test force and indentation depth which occur when an indenter is pressed into a material, and for the evaluation of material hardness and strength properties such as Young's modulus and creep deformation

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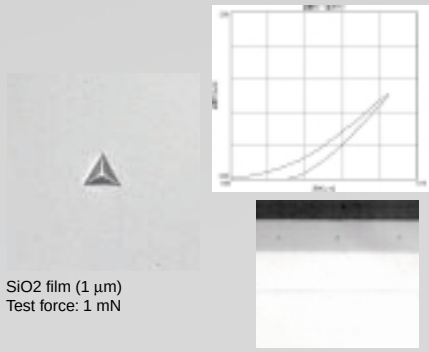
Materials and Applications

Thin Films Such As Vapor-Deposited Films and Semiconductor MaterialsSurface-Treated Layers Such As Ion-Implanted Layers and Nitride Layers

Hardness evaluation of thin-surface films, such as ion-implanted layers and vapor-deposited films produced by CVD (chemical vapor deposition) and PVD (physical vapor deposition), has become increasingly important as film production technology improves and diversifies. Using an ultra micro test force to measure depths of less than one tenth of a film's thickness makes it easy to evaluate only the film, without influence from underlying materials.



SiO2 film (1 μm)
Test force: 1 mN

Plating layer on metal plate
(Plating layer: Approx. 10 μm)

Plastics

An important feature of engineering plastics is hardness.
The DUH-211/211S can even measure the hardness of highly light-absorbent materials, which are difficult to handle with conventional testers.

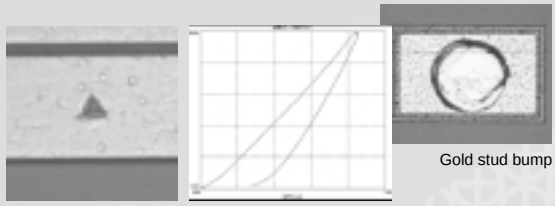
Rubbers and Elastomers

With these materials, indentation depth is used to obtain hardness. Easily perform measurement using a variety of test forces and evaluate deterioration in the outermost surface of a material.

Thin film (30 μm) Test force: 5 mN

Metallic Materials

Perform micro-region hardness measurement, which has become increasingly difficult as structures have become more intricate.



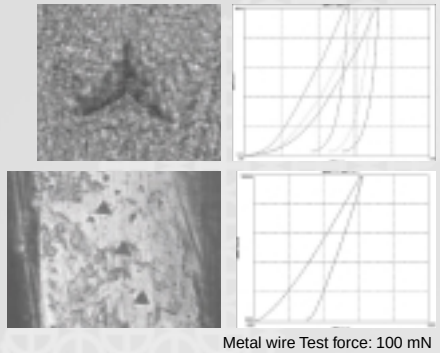
Gold stud bump

Semiconductor pattern Test force: 100 mN

Ultra-Fine Fibers Such As Optical Fibers and Carbon Fibers

Evaluate the strength of specimens taken from composite fiber materials and obtain important information. Measure the hardness of fibers.

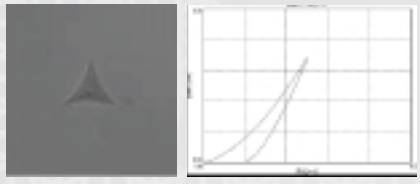
Carbon fiber Test force: 50 mN



Metal wire Test force: 100 mN

Glass and Ceramics — Brittle Materials

Use a low level of test force and evaluate the hardness of brittle materials without generating cracks. Measure the test force required to generate cracks.



Optical glass Test force: 2 mN

Features

1. Evaluation of Hardness and Material Parameters in Accordance with Standards (ISO 14577-1 Annex A)

Measure the behavior of a specimen as an indenter is pressed into it and evaluate the hardness, elastic modulus, and amount of work done during indentation, in compliance with and ISO 14577-1 (instrumented indentation test for hardness) Annex A.

2. Highly Precise Evaluation of Elastic Modulus

Perform highly precise evaluation of the elastic modulus, using correction based on instrument rigidity and the shape of the indenter tip.

3. Low Test Force with Measurement Resolution of 0.196 μN

Control the test force using a high resolution of 0.196 μN. This allows measurement of material strength properties in micro regions and in the outermost surfaces of specimens.

4. Ultra-Wide Test Force Range of 0.1 to 1,961 mN

Use a wide test range of 0.1 to 1,961 mN for measurement, and test a variety of industrial materials, including rubber, plastics, and ceramics.

5. High-Precision Measurement of Indentation Depth

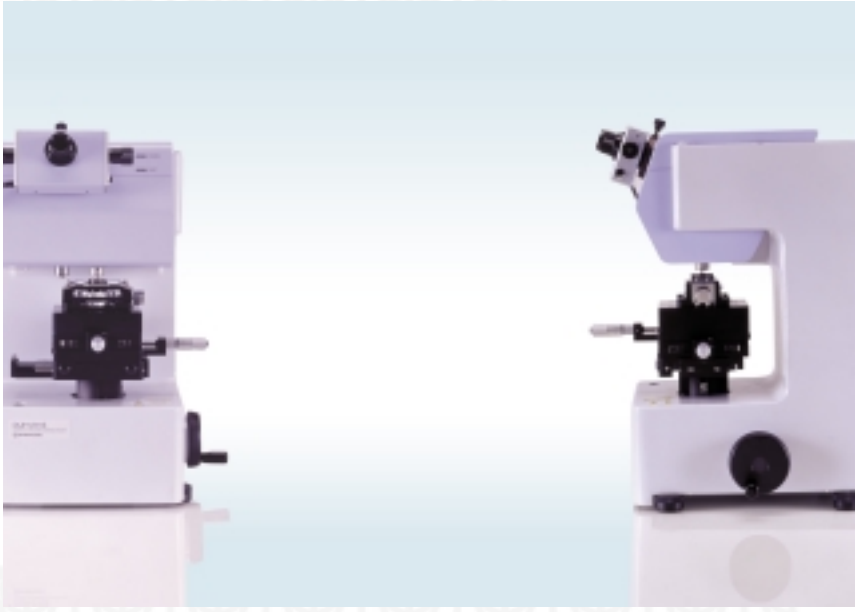
No need to measure the actual indentation.
Specimen indentation depth can be measured in units of 0.0001 μm for depths up to 10 μm.

6. Supports a Wide Range of Testing Methods

Record the relationship between the test force and the indentation depth. Test both the unload and load processes. Use the DUH-211S to perform cyclic load-unload tests and step load-unload tests.

7. Supports Vickers Hardness Test

A function to measure the length of diagonals is provided as a standard feature. This function allows you to measure the hardness that corresponds only to plastic deformation, Vickers hardness, and Knoop hardness. (A Vickers indenter and Knoop indenter are available as options.)
Maximum microscope magnification is 500 x (1000 x is available as an option).



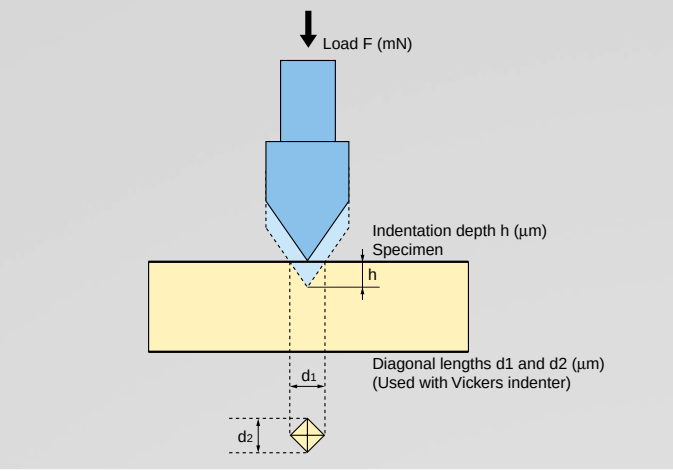
Measurement Principle

Electromagnetic force is used to press an indenter (standard type: 115° triangular pyramid) against a specimen. Pressing force is increased at a constant rate, from 0 to the preset test force. Indentation depth is automatically measured as the indenter is pressed against the specimen. This allows dynamic measurement of changes that occur in the specimen's resistance to deformation during the indentation process, and obtains a wide variety of data. During indentation the DUH-211/211S measures dynamic hardness and evaluates the hardness that corresponds to both plastic and elastic deformation. Also, if the indentation size is large enough to be observed with a microscope, hardness can be calculated using just the plastic deformation, by measuring the diagonal length of the indentation.

Expressions for Dynamic Hardness

1. 115° triangular pyramid indenter (standard)
   $DHT_{115} = 3.8584 \times F / h^2$
2. 100° triangular pyramid indenter (option)
   $DHT_{100} = 15.018 \times F / h^2$
3. Vickers indenter (option)
   $DHV = 3.8584 \times F / h^2$
4. Knoop indenter (option)
   $DHK = 1.5583 \times F / h^2$

Even though the theoretical unit for these hardness expressions is kgf/mm^2, it is normally not used.

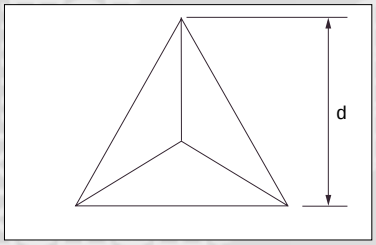


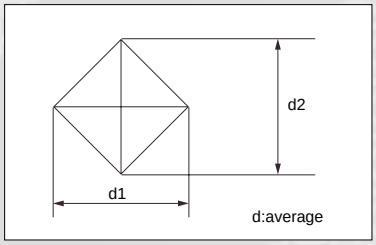
Expressions for Martens Hardness (ISO 14577-1 Annex A)

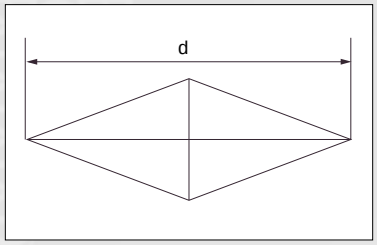
1. 115° triangular pyramid indenter (standard)
   $HM_{115} = 1000 F / 26.43 \times h^2$ [N/mm^2]
2. Vickers indenter (option)
   $HMV = 1000 F / 26.43 \times h^2$ [N/mm^2]

Hardness Expressions Based on Diagonal Length

1. 115° triangular pyramid indenter (standard)
   $HT_{115} = 160.07 \times F / d^2$
2. 100° triangular pyramid indenter (option)
   $HT_{100} = 121.53 \times F / d^2$
3. Vickers indenter (option)
   $HV = 189.10 \times F / d^2$
4. Knoop indenter (option)
   $HK = 1451.1 \times F / d^2$



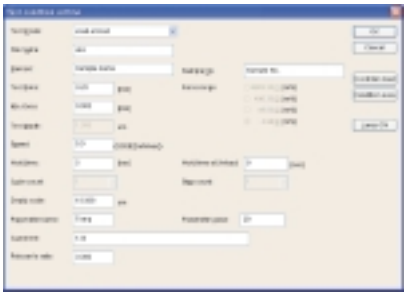


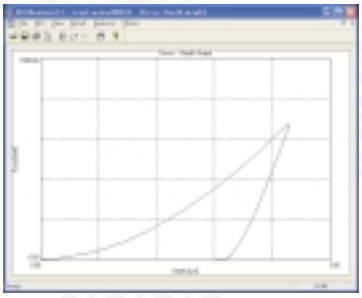


Functions

Combines Easy Operability and High-Level Data Processing Functions

Model used to perform three basic tests: **DUH-211**
Advanced model provides seven test modes: **DUH-211S**



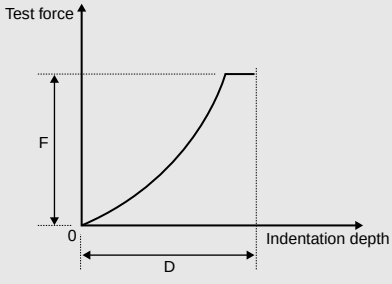


Parameters required for each type of test can be viewed at a glance.

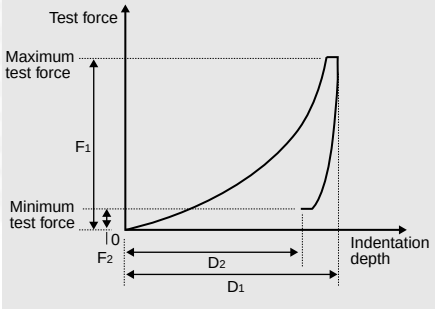
Test Types

Item	DUH-211	DUH-211S
1. Load-Hold Test	○	○
2. Load-Unload Test	○	○
3. Cyclic Test	○	○
4. Depth Setting Test	—	○
5. Depth Setting Load-Unload Test	—	○
6. Step Load Test	—	○
7. Step Load-Unload Test	—	○

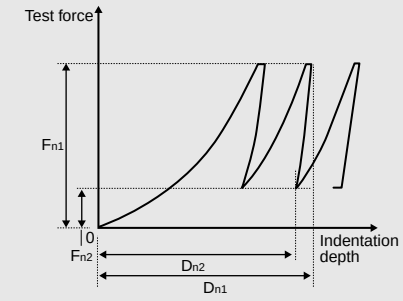
Indentation size can be measured in tests 1, 2, 4, and 5.



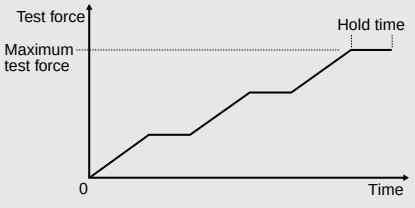
1. Load-Hold Test | 4. Depth Setting Test



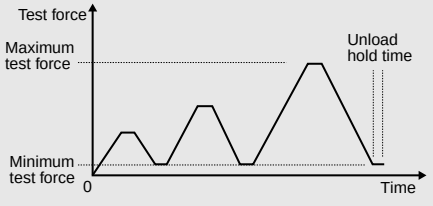
2. Load-Unload Test | 5. Depth Setting Load-Unload Test



3. Cyclic Test



6. Step Load Test



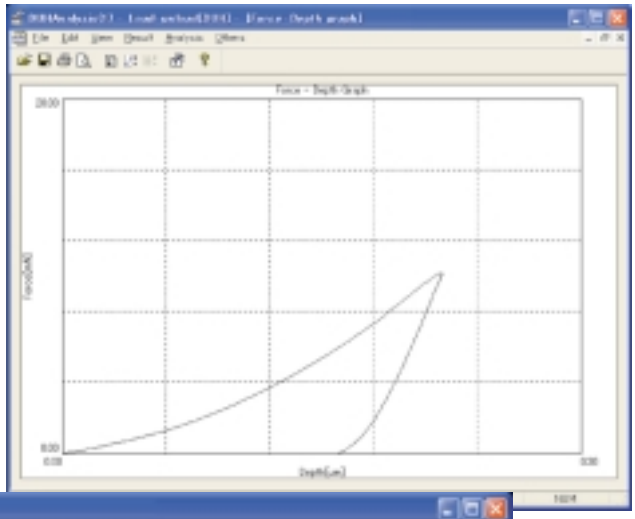
7. Step Load-Unload Test

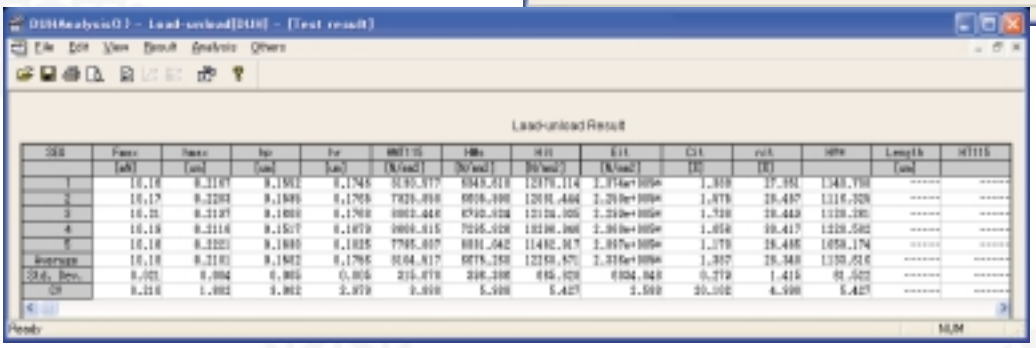
Data Processing

Simply set the required items to obtain the desired information.

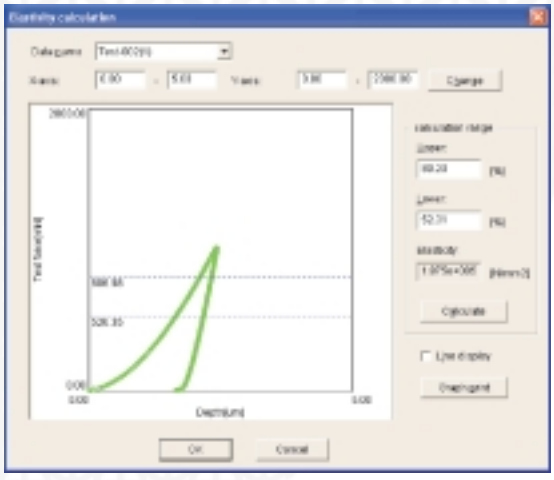
Data Processing Items

- Results display
- Data output for test force and depth
- Graph output for test force and depth
- Graph output for hardness and depth
- Graph output for hardness between 2 points and depth
- Graph output for depth and time
- Graph output for hardness and test force
- Graph output for depth squared and test force
- Hardness calculation based on preliminary test force
- Graph output for hardness and parameters
- Calculation of converted hardness values
- Repeated changes of surface detection points
- Calculation of elastic modulus
- ASCII file output

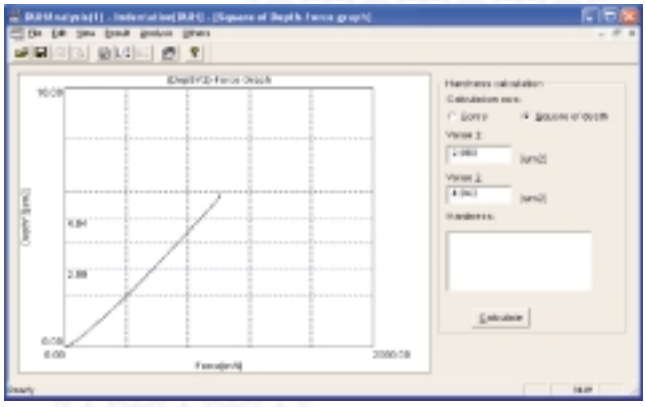




Example of test results display (load-unload test)



Calculation of elastic modulus



Graph of depth squared against test force

ISO 14577-1 (Annex A) Compliant Evaluation (Instrumented Indentation Test for Hardness)

Relationship between test force and indentation depth during indentation process can, in accordance with ISO 14577-1(Annex A), be used to evaluate hardness, elastic modulus, and amount of work done.

HM: Martens hardness

HMs: Martens hardness obtained from gradient of graph of test force versus depth

Hit: Indentation hardness

Eit: Indentation elastic modulus

Cit: Indentation creep

ηit: Indentation work rate

HV*: Vickers hardness obtained by converting Hit

1. Indentation Elastic Modulus (E_{it})

Definition of indentation elastic modulus (E_{it}) states that E_{it} is obtained from the inclination of the tangent used to calculate the indentation hardness (H_{it}), and is equivalent to Young's modulus.

$$\frac{1}{E_r} = \frac{1-\upsilon_s^2}{E_{it}} + \frac{1-\upsilon_i^2}{E_i}$$

$S = dP/dh = 2 \times E_r \times A_p^{0.5}/\pi^{0.5}$

$A_p = 23.96 \times h_c^2$

$h_c = h_{max} - 0.75(h_{max} - h_r)$

Here,

E_r : Converted elastic modulus based on indentation contact

E_i : Young's modulus for indenter (1.14×10^{12} N/m^2)

υ_i : Poisson's ratio for indenter (0.07)

E_{it} : Indentation elastic modulus

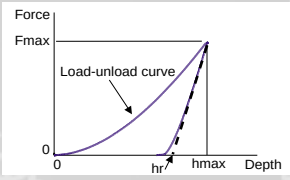
υ_s : Poisson's ratio for specimen

S : Inclination at start of unloading (inclination of straight-line approximation)

Ap : Projected contact area (23.96 is a constant that applies when using a 115° triangular pyramid indenter.)

hc : Depth of the contact of the indenter with the test piece at Fmax

hr : Point of intersection of the tangent to curve b at Fmax with the indentation depth-axis



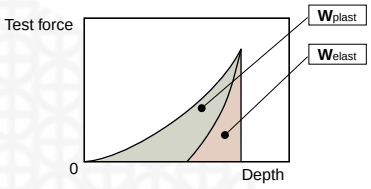
If Poisson's ratio for the specimen is set in the test parameters, the DUH-211/211S calculates E_{it}.
Otherwise, the DUH-211/211S calculates $(1-\upsilon_s^2)/E_{it}$.

2. Plastic and Elastic Portions of Indentation Work (η_{it})

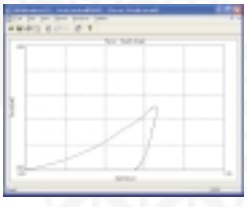
Definition of mechanical work performed by indentation is that part of the total mechanical work, Wtotal, done in indentation corresponds to the amount of plastic deformation, Wplast. The other part of the work performed corresponds to the amount of elastic deformation, Welast, that is restored when the test force is withdrawn. This work is defined by $W = \int F dh$.

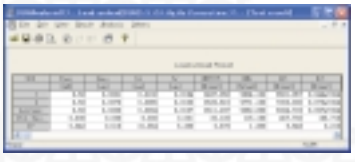
$$\eta_{it} = \frac{W_{elast}}{W_{total}} \ (\%)$$

$W_{total} = W_{elast} + W_{plast}$

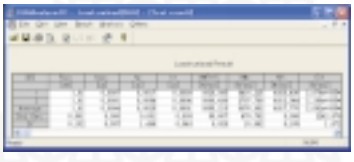


Test Examples





Specimen: Fused silica
Test force: 0.5 mN



Specimen: Copper alloy
Test force: 1 mN

Specifications

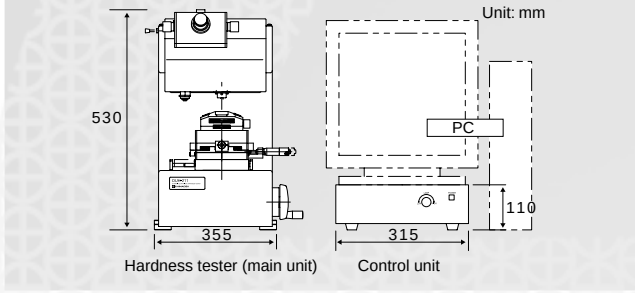
Model		DUH-211	DUH-211S
Part Number		344-04207-11(115V) 344-04207-21(230V)	344-04207-12(115V) 344-04207-22(230V)
Loading Unit	Loading Method	Electromagnetic coil	
	Test Force Range	Full scale of 0.1 to 1,961 mN	
	Test Force Accuracy	±19.6 µN or ±1% of displayed test force, whichever is greater	
	Minimum Measurement Increment	0.196 µN (for a test force not exceeding 1.96 mN)	
Displacement Measurement Unit	Measurement Method	Differential transformer	
	Measurement Range	0 to 10 µm	
	Minimum Measurement Increment	0.0001 µm	
	Linearity	±2% of full scale (20 µm)	
Indenter	Type	Triangular pyramid indenter with tip angle of 115° (Vickers indenter and Knoop indenter are available as options.)	
	Tip Radius	0.1 µm max.	
Optical Monitor	Total Magnification (microscope)	x 500	
	Objective Lens	x 50 (Up to 2 lenses can be attached.)	
	Eyepiece	x 10	
	Lighting Method	Reflected illumination	
	Light Source (lamp)	LED: 3 W, 3 V	
	Light-Path Switching	Observation or photograph (selectable)	
Micrometer	Collimation Method	Direct connection between encoder and control handle; synchronized movement of two indexes	
	Detector	Optical encoder	
	Effective Measurement Range	200 µm (with x 50 objective lens)	
	Minimum Measurement Increment	0.01 µm/pulse	
Specimen Stage	Vertical Distance	Approx. 60 mm	
	Area	Approx. 125 (W) x 125 (L) mm	
	Stage Movement Range	25 mm in both X and Y directions	
	Specimen Holder	Specimen dimensions (i.e., 8 (thickness) x 30 (width) mm) when thin-type attachment (type 3) is used	
Test Modes	Load-Hold Test	○	○
	Load-Unload Test	○	○
	Cyclic Test	○	○
	Depth Setting Test	—	○
	Depth Setting Load-Unload Test	—	○
	Step Load Test	—	○
	Step Load-Unload Test	—	○
Required PC Specifications	OS	Windows® 2000/XP	
	CPU	1 GHz min.	
	Disk Drives	CD-ROM drive and 3.5" floppy disk drive	
	Display Resolution	1024 x 768 min. (recommended)	
	Expansion Bus	PCI bus, 2 slots min. (Must be possible to insert 175-mm and 120-mm cards.)	
Utilities	Power Supply	Single phase, 100±10 V, 50/60 Hz	
	Power Consumption	Approx. 100 W (not including power consumption of PC)	
	Grounding*	The grounding pins of 3-pin connectors must be connected to a resistance of 100 W or less.	
	Temperature	Recommended temperature: 23±1°C Allowable range: 10°C to 35°C	
	Vibration	Horizontal vibration: 0.017 Gal max. (at 10 Hz or more) 0.01 µm max. (at less than 10 Hz) Vertical vibration: 0.010 Gal max. (at 10 Hz or more) 0.005 µm max. (at less than 10 Hz)	
	Humidity	80% max. (no condensation)	
	External Dimensions	Tester: Approx. 355 (W) x 405 (D) x 530 (H) mm Control unit: Approx. 315 (W) x 375 (D) x 110 (H) mm	
	Weight	Tester: Approx. 60 kg Control unit: Approx. 5 kg	

*This product is a precision measuring device. Special consideration is required for the product's installation conditions.

Standard Configuration

Name		Quantity
Hardness Tester (main unit)		1
Objective Lens (x 50)	P/N 344-89964	1
Triangular Pyramid Indenter (tip angle: 115°)	P/N 340-47013	1
Specimen Stage (XY stage)	P/N 347-24205-01	1
Micrometer Head		2
Specimen Holder	P/N 344-17737	1
Control Unit		1
Accessories (Cords, AC adapters, tools, instruction manual, installation disk)		1 set

External Dimensions



Optional Accessories

Length Measurement Kit (Color or Monochrome)

Length measurement kit, color: P/N 347-24447-16
Length measurement kit, monochrome: P/N 347-24447-06
Microscope images of the specimen surface can be displayed on the PC screen. Measure the size of indentations on the screen and save the images. Maximum magnification factor is x 2400 (when using a 17" monitor and an objective lens with a magnification factor of 50). This accessory can be used with computers designated by Shimadzu.

Objective Lens

x 100 objective lens P/N 344-89977
x 40 objective lens P/N 344-20212
x 20 objective lens P/N 344-89924
x 10 objective lens P/N 344-89941
x 40 objective lens with ultra-long operating distance
P/N 344-89300-01
Improves field-of-vision contrast.

Windbreak

P/N 347-24400-01
Minimizes the influence of wind and air vibrations (e.g., sound) on the DUH-211/211S testers.

Vickers Hardness Standard Block

P/N 340-06619-07
Used for measuring hardness with the 700HMV micro Vickers. Used as a rough guide for Vickers hardness measurement.

BK7 (Glass Test Piece)

P/N 339-89207-14
Used to obtain the correction factors required for the indenter when measuring the elastic modulus.

TV Monitor (with TV Camera)

P/N 344-81198-01
Used to display microscope images on a 9" monochrome monitor. (Magnification is approximately x1400 when a x 50 objective lens is used.)

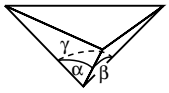
Video Printer System

P/N 347-23173-01
Used to print images from the TV monitor.

Triangular Pyramid Indenter with 100° Tip Angle

P/N 340-47011
This indenter, with a tip angle of 100°, has a smaller tip radius and makes smaller indentations than an indenter with a tip angle of 115°. Used for testing small-size specimens.

Shape of indenter tip



$\alpha = \beta = \gamma = 100°$

Measurement kit for Vickers hardness

P/N 347-24449-01
The verification in accordance with standard (ISO 6507-2) is done at the factory.
Please order simultaneously with the DUH.

Measurement kit for Knoop hardness

P/N 347-24449-11
The verification in accordance with standard (ISO 4545-2) is done at the factory.
Please order simultaneously with the DUH.

Disk-Type Vibration Absorbing Bench

P/N 344-04193-06
This bench with disk-type coil springs is recommended if the DUH-211/211S tester is used in areas that are subject to strong vibrations.

Active Vibration-Absorbing Bench

P/N 344-04211-11:AC120V
P/N 344-04211-12:AC230V
This bench is used together with a special mount and performs active vibration absorption over a wide range, from 0.7 Hz to 100 Hz.

Slender Specimen Holder

P/N 344-82943
This attachment is used to firmly hold thin specimens with an outer diameter of 0.15 mm to 1.6 mm, such as sewing machine needles, watch shafts, thin-shaped medical equipment, wires, sintered wires, and nonferrous wires.

Disk-Type Vacuum Suction Unit

P/N 344-86201-02
Used for 5", 6", and 8" wafers.
(Air supply for suction must be separately prepared.)

Micrometer Head (Digital Display)

P/N 081-02772-01 (1 unit)
Used to digitally display the amount of stage movement (up to a maximum of 25 mm) in the front/back or left/right directions in 1 μm increments. (Photo shows this head attached to a stage.)

Rotation Stage

P/N 344-82857
This stage has a diameter of 125 mm and can rotate in the range ±5°.

Objective Micrometer

P/N 046-60201-02
Used to adjust the microscope's magnification factor. Marked with scale graduations at 10 μm intervals.

Installation Precautions

Consider the following points when deciding on the installation location of the tester.

1. To minimize vibration:

1) Install the tester in a location where floor vibration is minimal. Normally, place the tester on a vibration-absorbing bench.
2) Do not install the tester in a location where people frequently walk by.
3) Do not install the tester near equipment that generates vibrations.
4) If possible, install the tester on the first floor of a building.
5) Install the tester as far away as possible from streets, roads and railway tracks.
6) Do not perform testing if vibration-generating equipment (e.g., a crane) is being used nearby.

2. To minimize air drafts and sounds:

1) Do not install the tester in locations that are directly or indirectly subject to streams of air from air-conditioning equipment.
2) Use a windbreak during testing.
3) Do not open or close nearby doors during testing.
4) Do not install the tester near sound-generating equipment (e.g., telephones).

3. To ensure testing accuracy:

Be especially careful when performing the following types of tests:

- Tests involving test forces of 1 mN or less
- Tests involving the measurement of changes for indentation depths of 0.05 μm or less

In these cases, be sure to maintain the following conditions:

- Temperature: No fluctuations greater than ±1°C.
- Vibration: Refer to specification table.

Related Products

Micro Compression Testing Machine

MCT-W

This machine is used to measure the breaking strength of single particles (of diameter 1 µm or greater). The breaking strength of ceramics, plastics, pigments, food products, and pharmaceuticals can be measured at a particulate matter stage, providing data that is closely related to the final application of these substances.

Loading Method	Electromagnetic force
	9.807 mN to 1.961 N or 9.807 mN to 4.903 N
Indenter	Diamond, cone-shaped, 50-µmø diameter
Displacement Measurement	Differential transformer
	0 µm to 10 µm or 0 µm to 100 µm
Optical Monitor	Equipped with x 500 microscope

High-Temperature Unit for Micro Compression Testing Machine

The high-temperature unit is attached to the MCT-W series of products (500/501/200/201) to perform micro compression testing under actual temperature conditions.

Temperature Setting Range	From 30°C above room temperature to 250°C (temperature control is possible at 50°C or higher)
Accuracy	Within ±2°C of set temperature
Total Magnification of Microscope	x 400 (objective lens: x 40; eyepiece: x 10)
Collimation Method	Individual collimation from both sides
Detector	Optical encoder
Effective Measurement Length	250 µm (length measurement using standard optical unit)

Micro Hardness Tester

HMV

Automatic test-force selection function allows use of the built-in touch-panel to select both the test force and the test-force hold time. Models equipped with a rotating electric turret (HMV-IT/2T) provide automatic switching between loading and surface observation.
A Windows® connection function allows the transfer of data directly to Microsoft® Excel.

Test Force Range	98.07 mN to 9.807 N (HMV-1/1T)
	98.07 mN to 19.1 N (HMV-2/2T)
Minimum Measurement Increment	0.01 µm
Equipped with revolving electric turret (HMV-IT/2T)	

Fully Automatic Micro Hardness Tester

HMV-FA

An automatic reading function, an electric XYZ stage function, and an autofocus function have been added to a micro Vickers hardness tester for hardness evaluation of surface-hardened layers, coatings, and plated layers. This automatic hardness tester performs automatic continuous measurement at a high level of accuracy.

Test Force Range	98.07 mN to 9.807 N (or 19.61 N)
Electric XY Stage	Stroke: ±25 mm
	Resolution: 0.001 mm
Autofocus	Approx. 3 sec.

CERTIFIED JQA MANAGEMENT SYSTEM ISO 9001

JQA-0376

Founded in 1875, Shimadzu Corporation, a leader in the development of advanced technologies, has a distinguished history of innovation built on the foundation of contributing to society through science and technology. We maintain a global network of sales, service, technical support and applications centers on six continents, and have established long-term relationships with a host of highly trained distributors located in over 100 countries. For information about Shimadzu, and to contact your local office, please visit our Web site at **www.shimadzu.com**

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