HitachiCable
Empowering Energy & Communication

HITACHI

OXYGEN-FREE COPPER〈OFC〉

Worlds Purest Form of "Oxygen-Free" Copper

The World's Top Production

Hitachi Cable has been producing various Copper products like Copper Tubings, Bars and Strips since its first successful mass production of Oxygen Free Copper (OFC) in Japan. Currently, in both aspects of quality and volume, Hitachi Cable is the top manufacturer of Oxygen Free Copper products in the world. From electronic components to a huge particle accelerator, Hitachi OFC and OFC based alloy are widely used all over the world.

State of the Art Total Quality Control

From casting ingots through to product shipping, Hitachi Cable maintains its criteria of quality control that is a "top-to-bottom" and an "all-in-one" process control in one factory. It keeps products' quality constantly high, and both the quantity and schedule of production as planned.
Hitachi Cable applies its own cast ingots for not only the pure Oxygen Free Copper products but also the OFC based alloy products, and maintains them at the highest quality.

Unique Process and Speciality Products

Hitachi Cable is the leading company of OFC manufacturing technology, and it developed the world's unique technique, the vacuum degassing process for continuous casting plant (US pat.). This technology effectively reduces the residual gases in Copper and ensures the high yield production of ASTM-F68 Class 1 certified grade Copper that includes the least contaminations in its grains and grain boundaries. Hitachi Class 1 grade OFC is identified as the top grade of Oxygen Free Copper with its extremely low gas content and is widely used for ultra high vacuum facilities like particle accelerators or semiconductor fabrications.
Hitachi Cable also provides the speciality Copper products like CG-OFC (Cryogenic OFC) for a wide range of applications. CG-OFC reduces the residual resistivity to half of the conventional OFC and it is the best material for superconductors.

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Oxygen Free Copper Provides Advantages of Purity, Formability, Thermal Conductivity, etc.

Comparison with Other Coppers

Material			Oxygen Free Copper (OFC)		Phosphorous Deoxidized Copper (P-DCu)	Electrolytic Tough Pitch (ETP)
CDA alloy No.			C10100	C10200	C12200	C11000
Chemical Requirement on ASTM B152 (%)	*1 Cu(min)		99.99	99.96	99.90	99.90
	O2□ (max)		0.0005	0.0010	NA	NA
			(Typically 3ppm, for Hitachi OFC)		(Around 50 ppm)	(Around 400 ppm)
	P		0.0003max	NA	0.015~0.040	NA
Density (g/cm^3)	Ingot		8.90		8.90	8.4~8.6
	Formed		8.94		8.94	8.89~8.94
Gas Desorption in an Elevated Temperature			Extremely low		Vaporization of phosphorus	Relatively low
Homogeneity of Microstructure			Excellent		Good	OK
Electrical Conductyvity (% IACS)			102		82	101
Thermal Conductyvity (W /m・K)			391		339	381
Resistance to Hydrogen Embrittlement			Excellent		Good	Poor
Deep-drawing Quality			Excellent		Good	OK
Oxide Scale Adhesion			Excellent		Poor	Good
Softening Temperature			Slightly high		High	Low

*1: Including Silver

Comparison of OFC, Stainless Steel and Aluminum

Material	Oxygen Free Copper (C10100)	Stainless Steel (SUS304)	Aluminum Alloy (A6063)
Density (g/cm^3)	8.94	8.03	2.71
Melting Point (℃)	1,083	1,425	630
Electrical Conductyvity (%IACS)	102	2	58
Thermal Conductyvity (W /m・K)	391	16	201
Elasticity Modulus (MPa)	118,000	193,000	69,000
Rigidity Modulus (MPa)	44,000	72,000	26,000
Tensile Strength (MPa)	220	680	140
Elongation (%)	45	55	25
Bending Fatigue Strength (MPa)	162	785	107
Coefficient of Thermal Expansion ($x10^{-6}/K$)	17.0	17.3	23.0

SUS304 : Fe+18%Cr+8%Ni
A6063 : Al+0.7%Mg+0.4%Si

OFC Worldwide Specifications

	Nation		Japan		USA		UK		Germany
Material Spec.	Standard No.		JISH2123		ASTMB170		BS6017		DINI787
	Item		Copper Billets and Cakes		Oxygen-Free Electrolytic Copper Refinery Shapes		Oxygen-Free Refined Coper		Oxygen-Free Coper without Deoxidizer
	Classification		Grade 1 C1011	Grade 2 C1020	Grade 1 C10100	Grade 2 C10200	Cu-OFE C103	Cu-OF C110	OF-Cu 2.0040
	Chemical Composition	*2 Cu (%min)	99.99	99.96	99.99	99.95	99.99	99.95	99.95
		O_2	10 max	10 max	5 max	10 max	10 max	NA	NA
		P (ppm)	3 max	NA	3 max	NA	3 max	NA	NA
Related Standards of Formed Copper Products			JIS H3510 Oxygen free copper sheet, plate, strip, seamless pipe and tube, rod, bar and wire for electron devices	JIS H3100 3140 3250 3300 Copper bus bars, rods and bars, seamless pipes and tubes	ASTM F68 Oxygen free copper in wrought forms for electron devices ⌒ Class 1 ≀ Class 5 ⌒	ASTUM B75 B152 B248 Tube, sheet, strip, plate and rolled bar	BS2870~2875 Tube, sheet, strip, plate and rolled bar		DIN40500-Part4 Copper material for electrical use

*2: Including silver

Hitachi OFC products meet all specifications above.

Hitachi OFC Class1 and Other Specialty OFCs Meet Every Requirement.

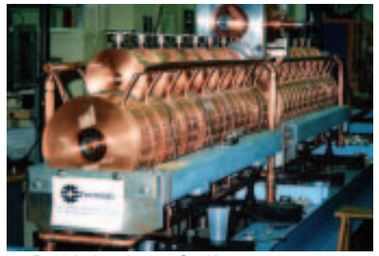
Typical Properties of Hitachi OFC and OFC based

	Product Type	Trade Name [CDA No.]	Chemical*1 Composition [wt%]	Electrical*2 Conductivity [% IACS]	Softening*3 Temperature [℃]	Advantage	Application
Oxygen Free Copper	OFC for Ultra High Vacuum	ASTM F68 Class1 [C10100, ASTM F68,Class 1]	Cu:>99.99	101	200	Least gas desorption Least contamination in microstructure	Accelerator cavities Electron tubes Transmission tubes Target material
	OFC for Cryogenic Use	CG-OFC [C10100]	Cu:>99.99	101	200	Extremely low residual electrical resistivity in cryogenic temperature	Stabilizer materials for superconductors
	OFC for Electron Devices	C10100 [C10100]	Cu:>99.99	101	200	Superb conductivity, weldability and formability Excellent scale adhesion	Vacuum circuit breakers, transmission tubes and magnetrons Target material
	OFC for General Use	C10200 [C10200]	Cu:>99.96	100	200	Superb conductivity, weldability and formability	Conductor of communication cables, heat sinks and for other general use
Zirconium Bearing Oxygen Free Copper	Low	HCL-02Z [C15150]	Cu+Zr:>99.96 Zr:0.015～0.030	97	450	The highest heat resistance among dilute alloys, excellent wire-bondability and resin adhesion	Lead frames for semiconductor devices
	Medium Zirconium	C151 [C15100]	Cu+Zr:>99.96 Zr:0.05～0.15	94	500		
	High Zirconium	C150 [C15000]	Cu+Zr:>99.96 Zr:0.10～0.20	92	500	The highest heat resistance among dilute alloy Excellent fatigue strength	Electrode chips for welders
Tin Bearing Copper	Tin Bearing Oxygen Free	HCL-12S [C14415]	Cu+Sn:>99.96 Sn:0.10～0.15	90	350	Well-balanced electrical conductivity and heat resistance	Lead frames for semiconductor devices Radiator fins
Silver Bearing Oxygen Free Copper	Low Silver	3Ag-OFC [C10400]	Cu+Ag:>99.96 Ag:0.027～0.034	97	350	Good abrasive resistance, electrical conductivity and heat resistance	Commutator bars Trolley wires
	Medium Silver	8Ag-OFC [C10700]	Cu+Ag:>99.96 Ag:0.085～0.102	97	360		
	High Silver	20Ag-OFC [—]	Cu+Ag:>99.96 Ag:0.15～0.25	97	360		

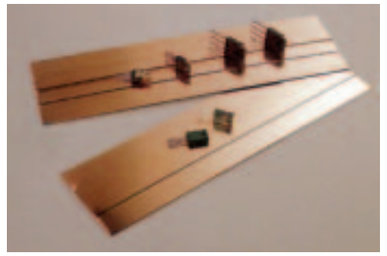
*1 : Specified range
*2, *3 : Typical value and may change according to material temper.

OXYGEN-FREE COPPER

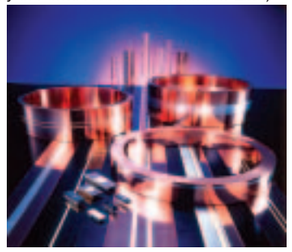
Hitachi OFC is Widely Used in Cutting-Edge Technology Field.



Particle Accelerator Cavities
(courtesy of Fermi National Accelerator Lab.)



Multi Gauge Copper Strips



Lead Frames for Semiconductor Devices

Materials for Electron Devices

Material Recommendation Chart

Requirement / Application	Electrical Conductivity	Thermal Conductivity	Mechanical Strength	Formability	Low Gas Desorption	Heat Resistance	Hydrogen Embrittlement Resistance	Corrosion Resistance	Solderability Brazability Weldability	Oxide Scale Adhesion	Abrasion Resistance	Recommended Material
Electron Tube for Particle Accelerator	●●	●			●●		●		●			ASTM F68 Class1 C10100
Vacuum Equipments [Magnetrons, Wave Guides, etc.]	●●	●			●●		●			●●		C10100
Stabilizer Materials for Superconductors	●●	●●	●	●								CG-OFC C10100
Lead Frames for Semiconductor Devices	●●	●●	●	●●		●	●		●	●		C151 HCL-02Z HCL-12S
Bus Bars, Bus Ducts	●●	●●	●	●		●●		●●	●●			C10200
Commutator Bars	●●		●	●		●●			●		●●	Ag-OFC
Hollow Conductors	●●	●●						●●	●			C10200
Trolley Wires	●●		●				●				●●	Ag-OFC
Connectors [Pins, Sleeves]	●●		●	●●			●		●●			C10200
Conductors for Communication Cables	●●								●●			C10200
Conductors for Sound Equipment Cables	●●								●			ASTM F68 Class1 C10100
Chip Electrodes for Welders	●●		●			●●					●	C150
Target material	●●	●●			●●		●					ASTM F68 Class1 C10100

●● =indispensable ● =required

OFC

Materials for Ultra High Vacuum Use

C10100 ASTM F68 Class1

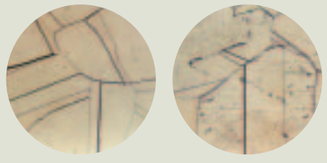
Accelerator Cavities
(courtesy of Fermi National Accelerator Lab.)

Magnetrons

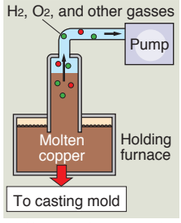
Electron Tubes

Features

- Oxygen Free Copper (OFC) is the best material for electron tubes, wave guides and other vacuum equipments because of its superb electrical and thermal conductivity.
- A Minimum-Risk of contaminations in microstructure ensures a leak tight operation.
- The vacuum degassed OFC that meets ASTM F68 Class1 is strongly recommended for its lowest gas desorption and highest discharge breakdown field.



Microstructure improvement by vacuum degassing



Schematic view of degassing plant

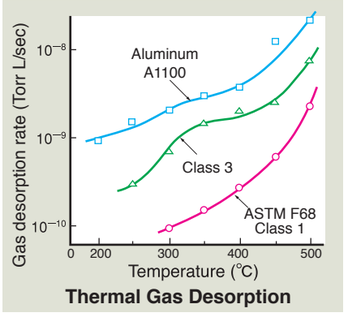
Applications

Electronics Components	Magnetrons, back plates of sputtering apparatus and hearths for CVD systems. Target material
Telecommunication Infrastructures	Microwave transmission tubes and vacuum circuit breakers
High Energy Physics	Accelerator cavities, wave guides, klystrons, and gaskets
Medical Instruments	CT scanner and laser components
Others	Magnet wires and audio/video cables

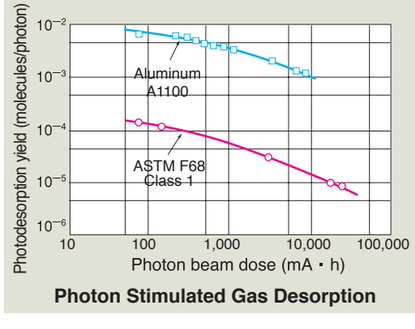
Available Shapes

Bars, Plates, Tubes and other custom shapes upon customers' request.

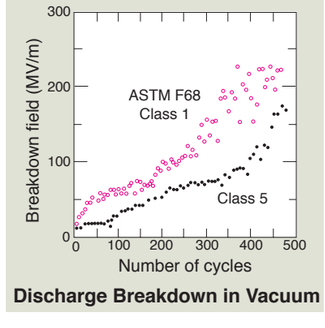
Properties



Thermal Gas Desorption



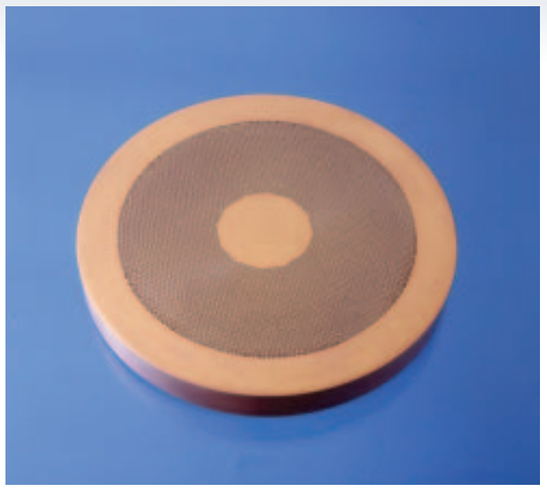
Photon Stimulated Gas Desorption



Discharge Breakdown in Vacuum

Stabilizer for Superconductor / Thermal Conductor for Cryogenic Use

C10100 CG-OFC



Nb-Ti Superconductor

Nb_3Sn Superconductor

Features

- Residual Resistivity Ratio (RRR) of CG-OFC is increased from 200-300 of conventional OFC to 500 or more by purifying with the vacuum degassing process.
- Other general properties meet ASTM B170 specification of Oxygen Free Copper Grade 1.

Applications

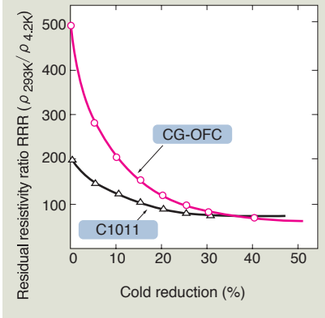
Stabilizer materials for superconductors, and thermal conductors for cooling astronomical CCD cameras or specimens in electron microscopes.

Available Shapes

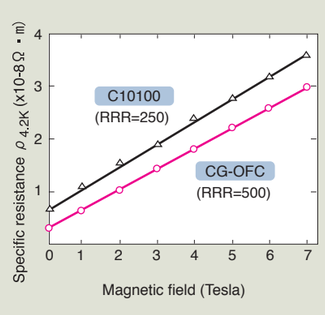
Bars, Plates, Strips, Tubes and other custom shapes upon customers' request.

Properties

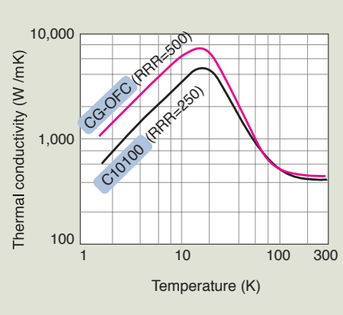
	CG-OFC	C10100
Residual Resistivity Ratio (RRR)	500 min	200-300
Thermal Conductivity (W /m·K at 4.2K)	3,300 min	1,300-2,000



Effect of Cold Reduction on RRR



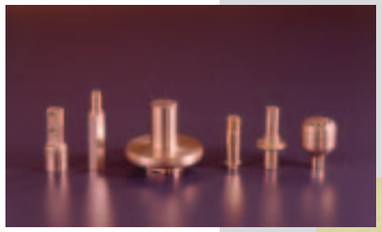
Effect of Magnetic Field on Specific Resistance



Thermal Conductivity in Cryogenic Range

Power Distributor (Plates, Rods and Formed Bars)

C10200 C150 Ag-OFC



Machined Rods

Formed Bars

Bus Bars

Features

- Made of Oxygen Free Copper (OFC) for its superb electrical and thermal conductivity. OFC based silver or zirconium bearing alloy also available.
- Various shapes including plates, rods and formed bars are available.
- Superb formability at a room temperature and brazability in a hydrogen atmosphere.
- Bent, stamped or machined products are available for order.

Applications

Plates : heat sinks, bus bars for power distributors, switchbars, end rings of motors.

Rods : terminals, base plates for thyrister, electrodes.

Formed bars : connectors, trolley wires, commutator bars.

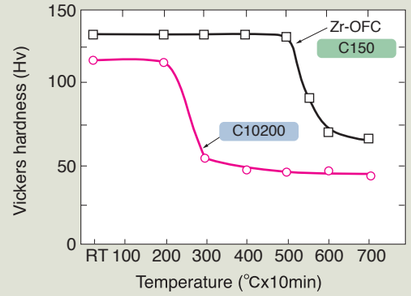
Available Dimensions

Plates : thickness=3mm min, width=530mm max
(In some conditions, thickness less than 3mm is available)

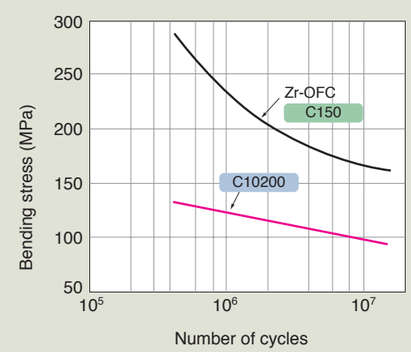
Rods : from 4 to 100mm diameter
(Larger diameter is available by forging)

Formed bars : ask for desirable shapes.

Properties



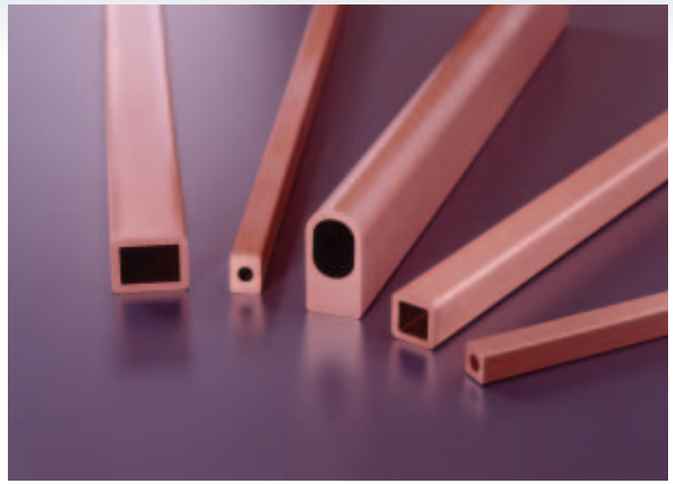
Isochronal Annealing Curves of OFC and Zr Bearing OFC



Bending Fatigue Curves of OFC and Zr Bearing OFC

Power Distributor (Hollow Conductors)

C10200



Hollow Conductors

Features

- Hitachi OFC certifies excellent electrical and thermal conductivity, and its superb formability provides the production of seamless hollow conductors by drawing.
- Seamless tube also ensures no water leakage.
- High purity provides superb weldability or solderablity, and maintains high corrosion resistance.

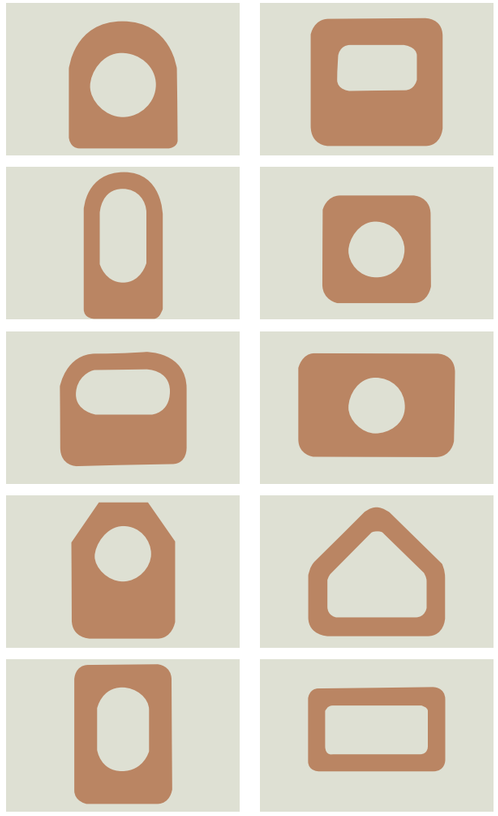
Application

Water cooling coils for induction furnaces, generators, magnets of particle accelerators or plasma research equipments and other heavy duty power loads.

Standard Grade and Temper

Standard Grade	C10200
Temper	O, 1/2H, H

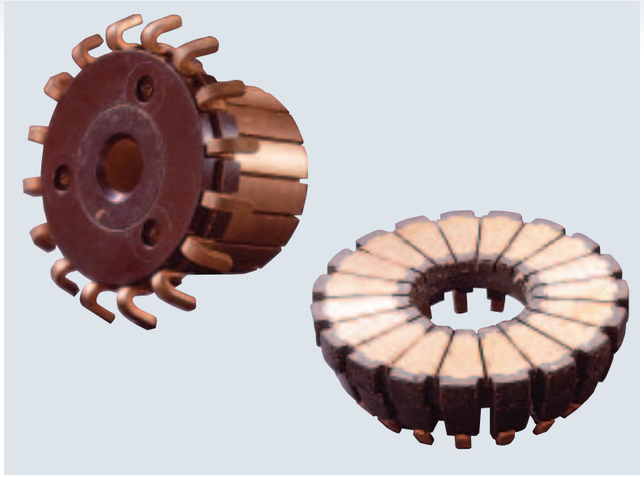
Please refer to our exclusive brochure for standard shapes and dimensions. The examples of cross sectional shapes are shown on the right.



Examples of Cross Sectional Shapes

Commutator Bars

Ag-OFC



Molded Commutator Bars

Features

- Silver is the additive element to improve the heat resistance of OFC without significant degradation of electrical conductivity.
- Silver bearing OFC prevents itself from abrasion by brush owing to its high heat resistance during assembly and use.

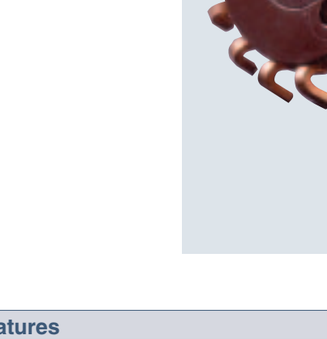
Applications

Trolley wires and commutator bars.

Specification

	Chemical Composition [wt %]	Temper	Tensile Strength [MPa]	Vickers Hardness [Hv]	Electrical Conductivity [% IACS]	Softening Temperature [°C]
3Ag-OFC	Cu+Ag :>99.96, Ag:0.027 - 0.034	H	340	105	97	350
8Ag-OFC	Cu+Ag :>99.96, Ag:0.085 - 0.102	H	340	105	97	360
20Ag-OFC	Cu+Ag :>99.96, Ag : 0.15 - 0.25	H	340	105	97	360

Properties



Effects of Additive Elements on Electrical Conductivity

Isothermal Annealing Curves of OFC and Silver Bearing OFC

Process Flow and Quality Assurance System

Raw Material

Only selected materials (copper cathodes and additive elements) are used for high quality ingots.

Emission Spectrometric Analyzer

Copper Cathodes

Casting

Fully continuous casting makes ingot stable and sound. Vacuum degassing process improves the quality of ingots. (optional)

Fully Continuous Casting Plant

Ingots (Cakes, Billets)

Hot Working

Cold Working

Optimized condition makes for both a superb copper microstucture and appearance.

Hot Extrusion Press

Hot Rolling Mill

In-Line Inspection

In-line sensors are installed to measure dimensions and detect flaws or foreign matters.

Eddy Current Detector

Laser Scanner Flaw Detector

Product Inspection

The final inspection and tracability system maintain the product quality. Full inspection is also available.

EPMA (Electron Probe Micro-Analyzer)

AES/XPS (Auger-Electron / X-ray Photoelectron Spectroscopy) surface analyzer

Tensile Tester

*Specifications subject to change without notice.

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