TUNGSTEN
MOLYBDENUM

Guidebook on

Resistance Welding Electrodes

for Tungsten-and Molybdenum-Based Electrodes

Second Edition

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MC METALCUTTING CORPORATION

● Contents

● Resistance Welding of Non-Ferrous Metals Such as Copper

Resistance welding is a process in which pressure is applied to the parts to be joined with electrodes and electrical current is passed through the parts to generate heat locally by self-resistance heating, thereby welding the parts together. Resistance welding is used in various industries, including the automotive, electrical component, and home electronics industries, for spot welding, copper wire fusing, and a wide range of other workpiece materials and applications.

The welding of non-ferrous metals like copper employed in numerous manufacturing processes of electrical components demands special attention, since copper has low electrical resistance and high thermal conductivity, making it difficult to achieve the level of resistance heating necessary for welding. This means welding non-ferrous materials requires large electrical currents.

Copper alloy electrodes cannot be used for welding under such strict conditions because they lack sufficient hardness at high temperature. Electrodes that exhibit superior characteristics at high temperatures, such as tungsten (W) or molybdenum (Mo), are required. Nippon Tungsten offers electrodes that exhibit the superior performance needed for resistance welding of non-ferrous metals.

Workpiece to be welded	Resistance heating during welding	Welding conditions	Electrode material
Ferrous materials	High due to high electrical resistance and low thermal conductivity	Low electrical current/ short period	Copper alloys
Non-ferrous materials such as copper	Low due to low electrical resistance and high thermal conductivity	High electrical current/ extended period	**Tungsten, molybdenum, etc.**

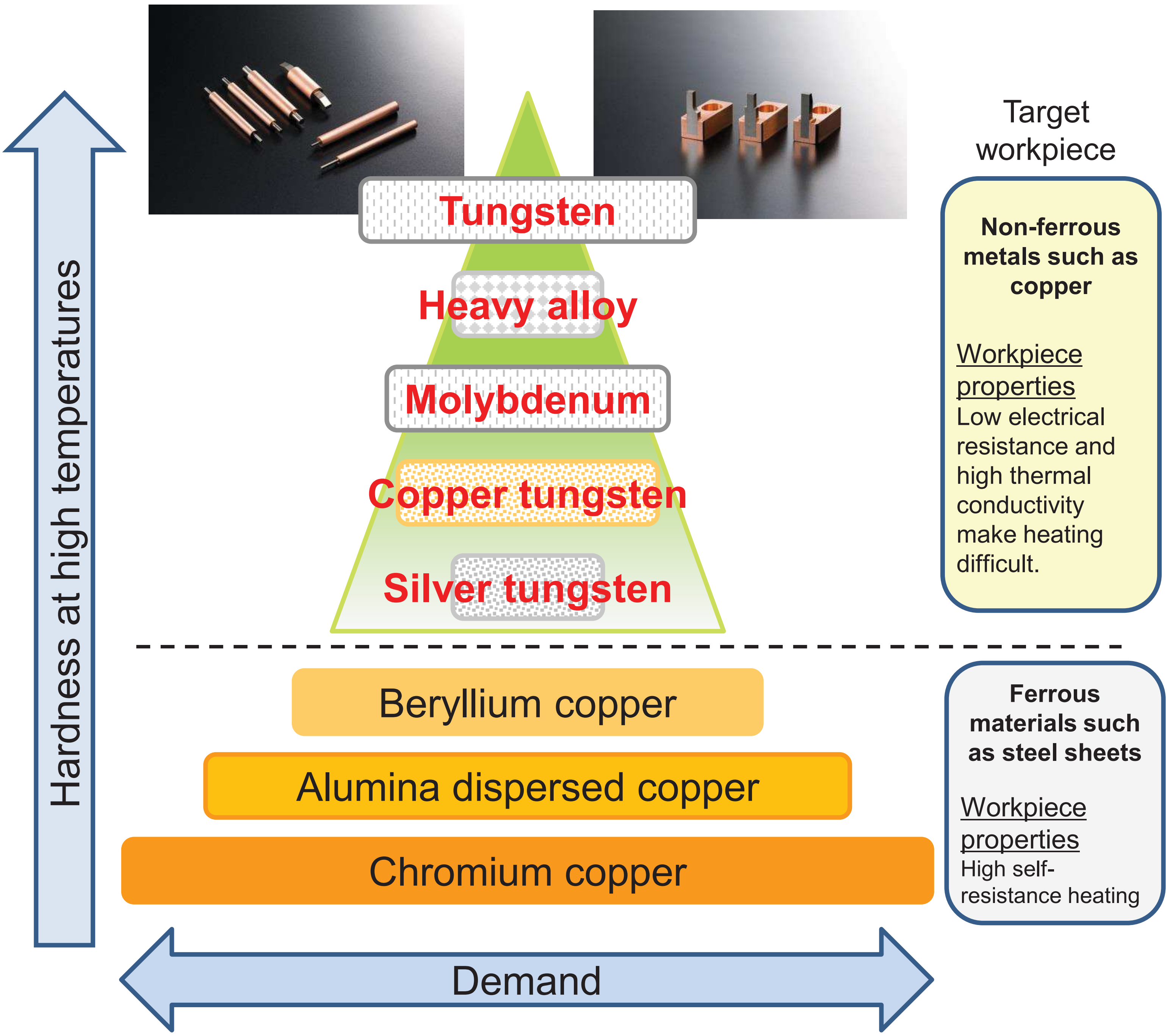
On tungsten- and molybdenum-based materials

Characteristics	Benefits during welding
• Superior hardness at high temperature • Limited chemical reaction with other metal components • High electrical resistance, low thermal conductivity	• Stable form, capable of maintaining current density • Low adhesion of electrode • Enables welding using heat generated in electrode

W and Mo exhibit superior performance in welding processes involving workpieces of low electrical resistance and high thermal conductivity and coated products, contributing to extended electrode life and improved production efficiency.

● Positions of Tungsten- and Molybdenum-Based Electrodes for Resistance Welding

The diagram below shows the relationship between demand, hardness at high temperatures, and the target workpiece.



Overall, copper alloy electrodes like those of chromium copper for steel sheets are in high demand in the resistance welding electrode market. Tungsten-based electrodes, which exhibit superior hardness at high temperatures, are used in the welding of non-ferrous metals like copper.

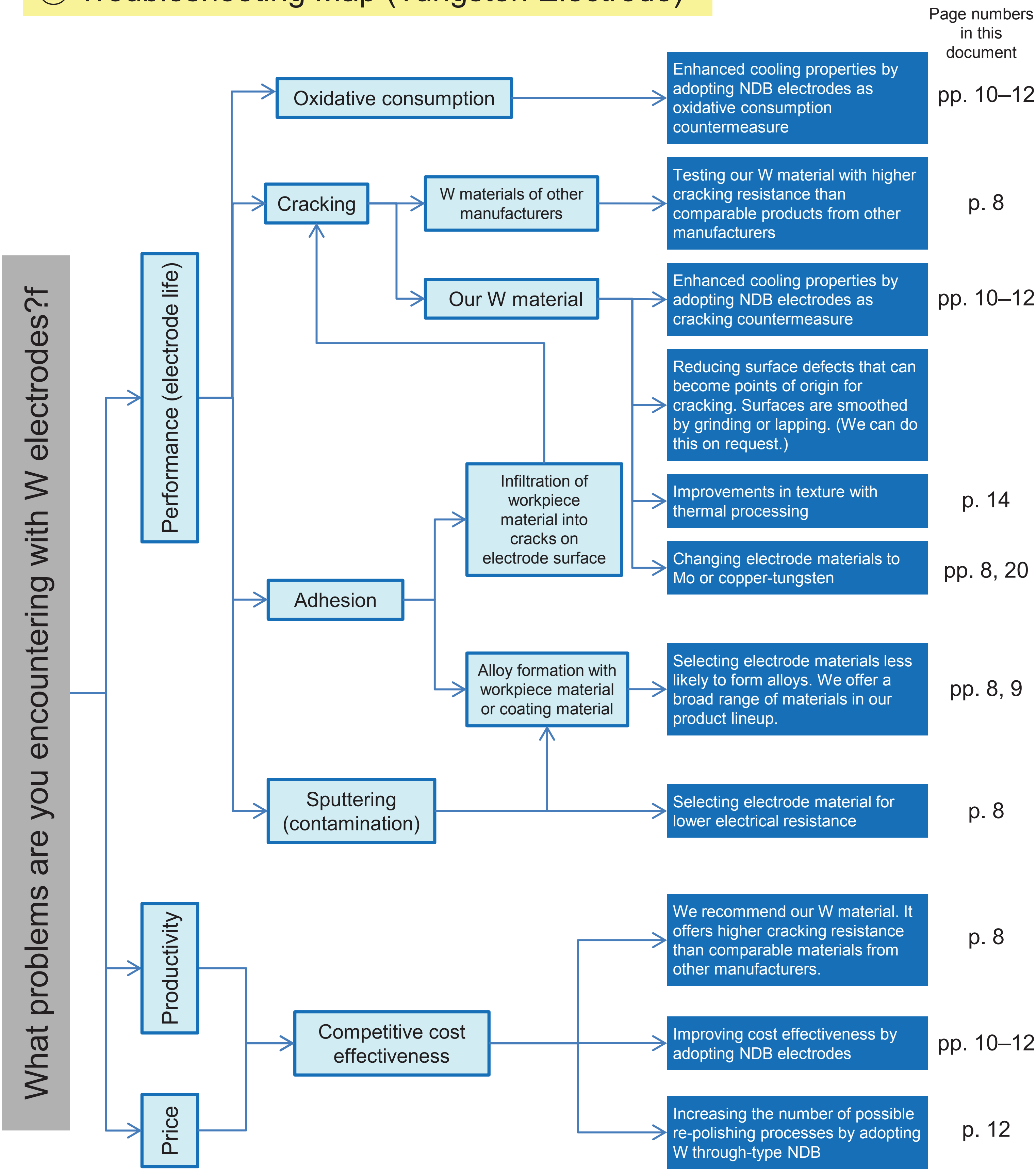
● Recommended Electrode Materials and Troubleshooting

① Work materials and recommended electrode materials

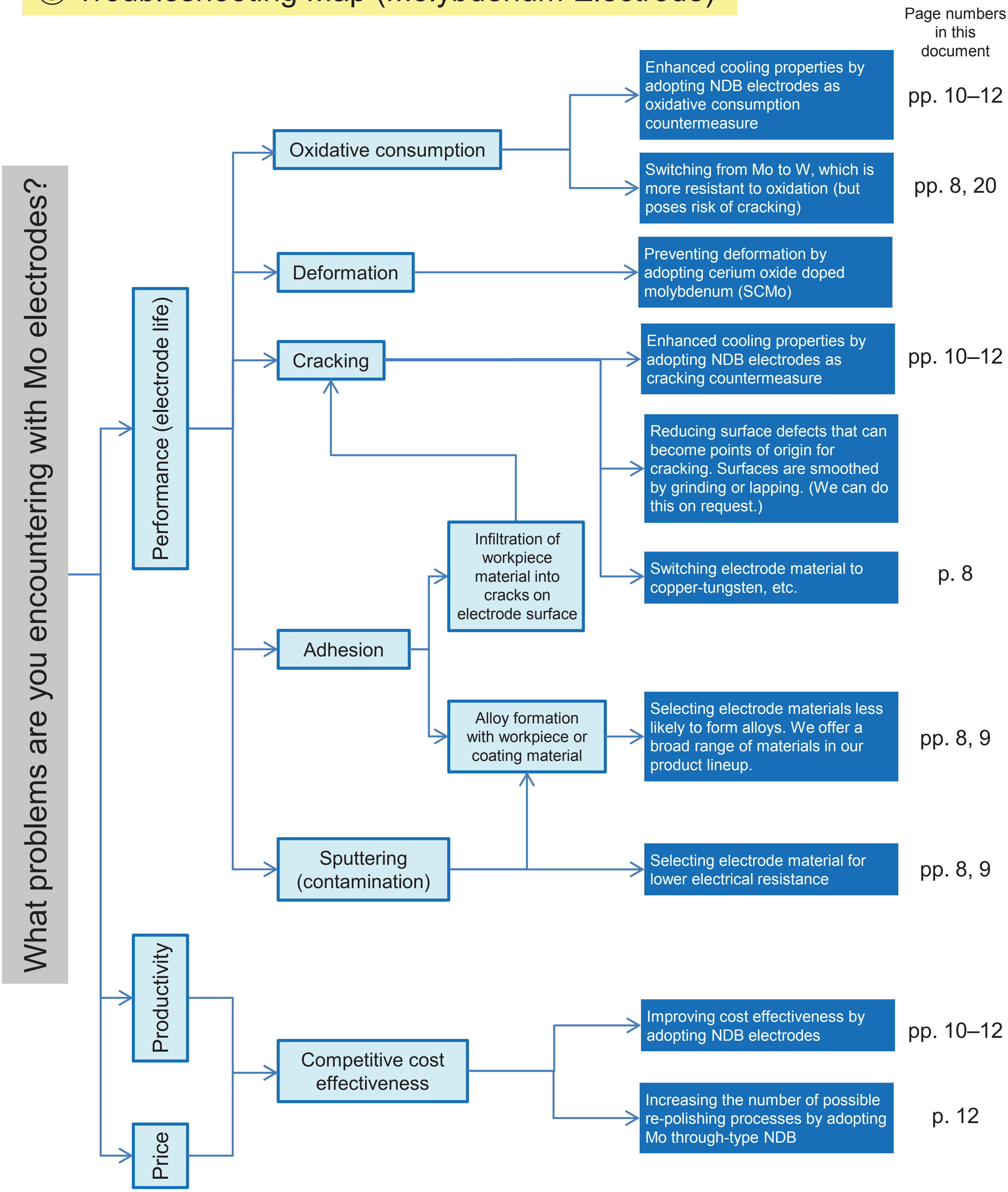
Below is a list of recommended electrode materials corresponding to each workpiece material provided as a reference in selecting the ideal electrode for your application. Please feel free to contact us if you have any questions.

Workpiece material to be welded			Recommended electrode material	Page number in this document	Notes	Typical products and welding type
Ferrous materials	Surface-processed steel sheets	Galvanized steel sheets	W, NDB-W	p. 6	For NDB-W, tungsten (W), which has low reactivity to most coating materials, is used only for the electrode part that comes into contact with the workpiece, making this suitable for use with coated workpieces. Welding conditions for chrome-free stainless steel workpieces are especially restricted, and conventional copper alloy electrodes have been known to exhibit short service life under such conditions. W electrodes provide a solution for such applications.	Various welding processes used for automobile bodies, materials for automotive parts, exterior parts, etc.
		Aluminized steel sheets				
		Chrome-free steel sheets				
		Other				
	Stainless steel		AgW-based materials such as S35A2	p. 9	Silver-tungsten alloys made by forming a composite of silver (Ag), which has low reactivity to ferrous metals, and tungsten (W), which exhibits superior hardness at high temperature, are effective for such applications.	
Non-ferrous metals	Tin-coated copper sheets		W, NDB-W, Mo, NDB-Mo	W, Mo: p. 8 NDB: p. 10–	Copper exhibits low electrical resistance and copper welding or fusing requires high electrical current and extended resistance welding times, which generate heavy thermal loads on the electrodes. Under such conditions, copper alloy electrodes tend to demonstrate short service life. W or Mo electrodes, which exhibit excellent hardness at high temperature, are better suited for such materials. The NDB electrodes feature improved shot cycles and longer electrode life.	Wiring harness in electrical components of automobiles, line switch for battery packs, electrical components for manufacturing lines of circuit breakers and electrical switches, etc.
	Nickel-coated copper sheets					
	Copper and copper alloys	Welding				
		Fusing				
		Brazing	W, NDB-W, Mo, NDB-Mo, HAC2, C30A2 CuW-based material	W, Mo, C30A2: p. 8 NDB: p. 10– HAC2: p. 9	As explained above, W, Mo, and NDB electrodes are suitable. When higher heat generation is required, use HAC2. CuW electrodes may also be used to achieve good electrode heat balance.	
	Nickel foil and nickel sheets		S35A2 AgW-based material	p. 9	Silver-tungsten complex alloys made by forming a composite of silver (Ag), which has low reactivity to nickel (Ni), a ferrous metal, and tungsten (W), which exhibits superior hardness at high temperature, are effective for such applications.	
	Silver and silver alloys		S35A2 AgW system		When silver materials are welded using copper based electrodes, Ag-Cu alloy, which has a low melting point, tends to form on and adhere to the surface of the electrode. Since Cu adhesion to the surface of the silver material may lead to corrosion, electrodes are formed from silver-tungsten complex alloys made of Au and W, which exhibit superior hardness at high temperature.	

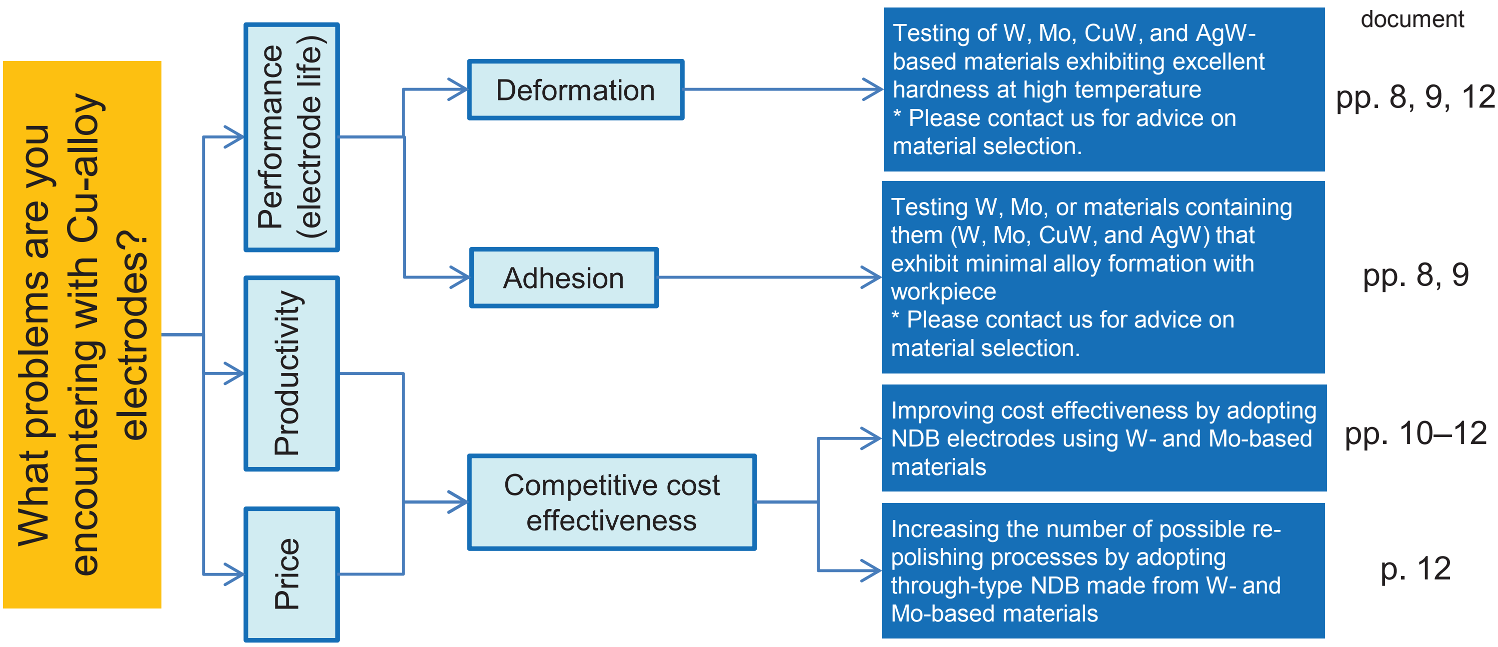
② Troubleshooting Map (Tungsten Electrode)



③ Troubleshooting Map (Molybdenum Electrode)

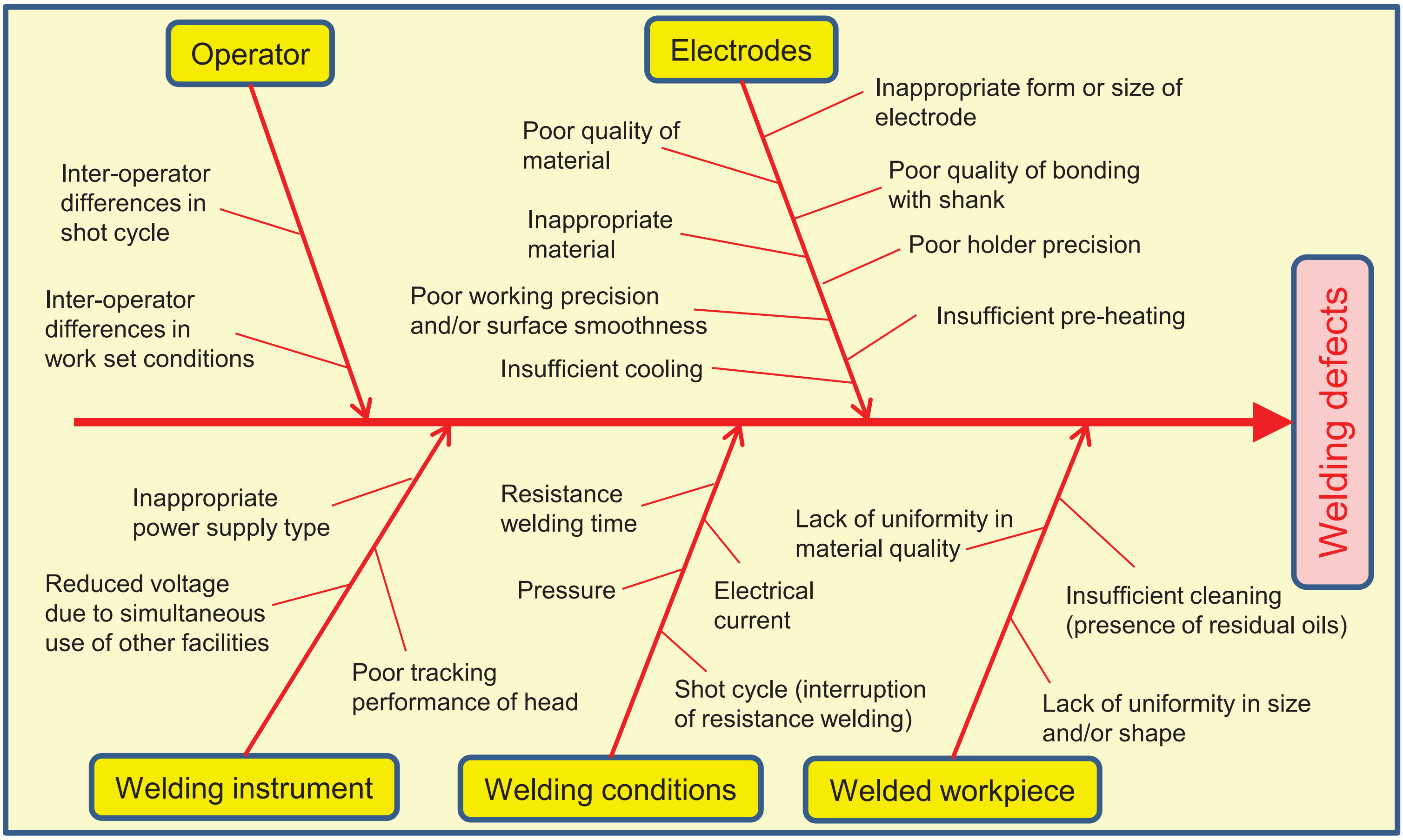


④ Troubleshooting Map (Copper-Alloy Electrode Such as Chrome-Copper Alloy)



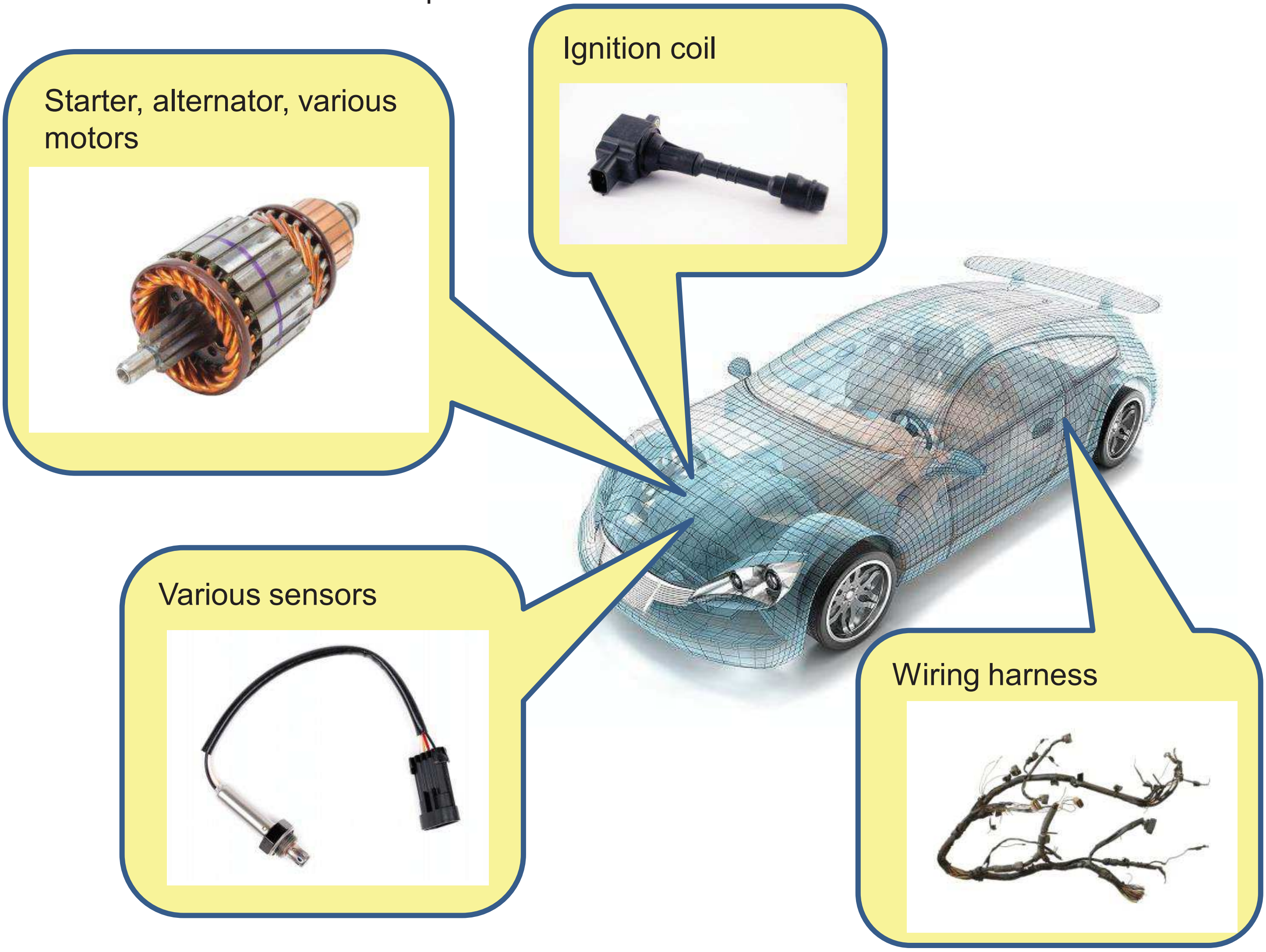
⑤ Fishbone Diagram of Welding Defects

There are numerous factors that cause welding defects besides the electrode, so the problem must be examined from various perspectives to devise an effective solution. We're committed to finding solutions for your electrode issues. Please feel free to contact us.



● Examples of Applications for Tungsten- and Molybdenum-Based Electrodes

Tungsten- and molybdenum-based electrodes are mainly used in welding processes for automobile electrical components.



Main applications	Notes on the electrode material
Various motors, harnesses, and other electrical components	Workpieces include copper materials such as copper wires and terminals. The load on the electrode is large because welding conditions require high electrical currents and due to extended resistance welding times. Thus, conditions are not favorable for welding with copper alloy electrodes. The electrodes used are W and Mo electrodes, which exhibit superior hardness at high temperatures.
Secondary batteries and associated parts	W, Mo, copper-tungsten, and silver-tungsten electrodes are used in manufacturing processes for lithium ion batteries and nickel-hydrogen batteries and in the welding of battery tubs. Copper-alloy electrodes are often used as well, but W- and Mo-based materials, which exhibit higher hardness at high temperature, result in their longer electrode life.
Coated products	Copper components of copper-alloy electrodes react with the coating material to form alloys, leading to adhesion and shortened electrode life. Adopting W- or Mo-based materials help overcome these problems, because they do not readily form alloys with the coating.

● Lineup of Nippon Tungsten Electrode Materials and Their Characteristics

① Tungsten (W)

- Excellent hardness at both room and high temperatures
- Highest melting point among metals (3,387°C)
- Susceptible to mechanical and thermal shock and cracking
- Does not readily react with other metal components.
- High electrical resistance (5.5×10^{-8} Ωm, IACS%: 30)

Photo of vertical cross-section texture of tungsten circular rod

② Molybdenum (Mo)

- Hardness at room and high temperatures is less optimal than W.
- One of the higher melting point among metals (2,623°C)
- More resistant to mechanical and thermal shock than W.
- Does not readily react with other metal components.
- Electrical and thermal properties is nearly equivalent to those of W.

Comparison of characteristics of tungsten and molybdenum

Properties	Tungsten (W)	Molybdenum (Mo)
Hardness at high temperature	High	Lower than W
Shock resistance	Low	Higher than W
Oxidative consumption	Susceptible to consumption	Consumption more severe than W
Workability	Cutting is difficult; grinding and electrical arc machining are generally used for working.	Cutting possible

③ Copper-tungsten (CuW)

- Complex alloy of copper and tungsten
- Exhibits physical properties intermediate between copper alloy and tungsten; exhibits moderate hardness at high temperature and electrical conductivity.
- Generally, the composition is Cu30% and W70% in weight ratio (our material: C30A2). Our product lineup consists of materials with Cu content ranging from 10% to 50%.

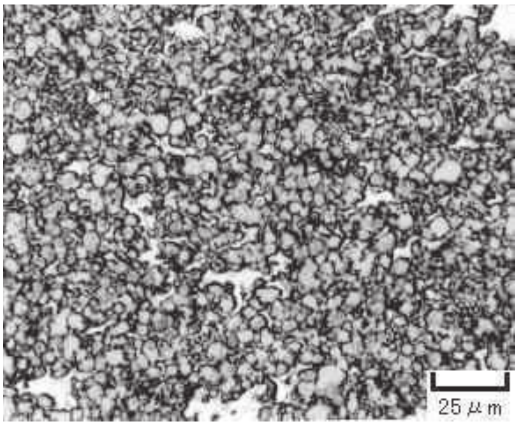


Photo of texture: copper-tungsten 30Cu-70W (our material: C30A2)

④ Silver-tungsten (AgW)

- Complex alloy of silver and tungsten
- As with copper-tungsten, AgW exhibits moderate hardness at high temperature and electrical conductivity.
- In general, the composition is Ag35% and W65% in weight ratio (our material: S35A2). Our product lineup consists of materials with Ag content ranging from 20% to 50%.
- Since silver doesn't readily react with iron and nickel, it is used for welding SUS and/or nickel foils.

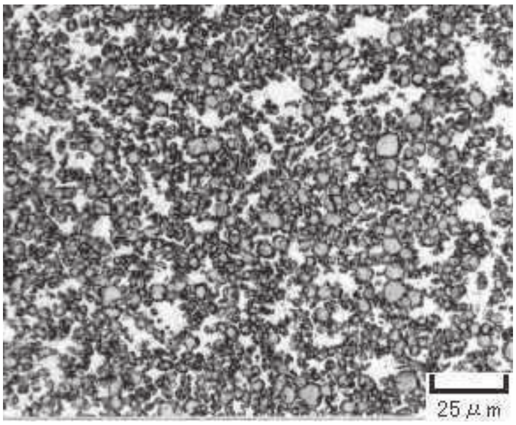


Photo of texture: silver tungsten
35Ag-65W (Our material: S35A2)

⑤ Heavy Alloy

- W alloy is formed using W as the main component and Cu, Ni, or Fe as sintering agents.
- While W continues to be the main ingredient, cutting is possible.
- Electrical resistance is nearly twice that of pure W. This alloy is used for welding that utilizes heat generated in the electrode.
- Ideal solution for preventing heater tip cracking

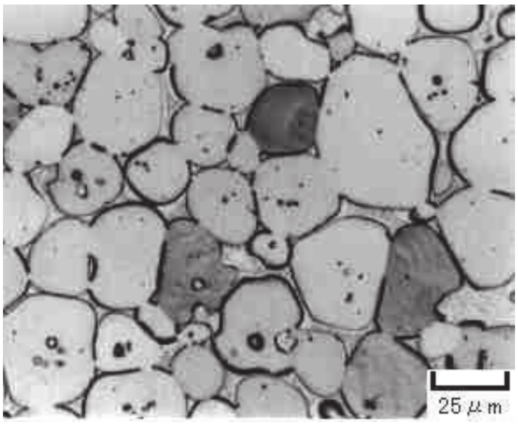


Photo of texture: Heavy Alloy
94W-4Ni-2Cu (Our material: HAC2)

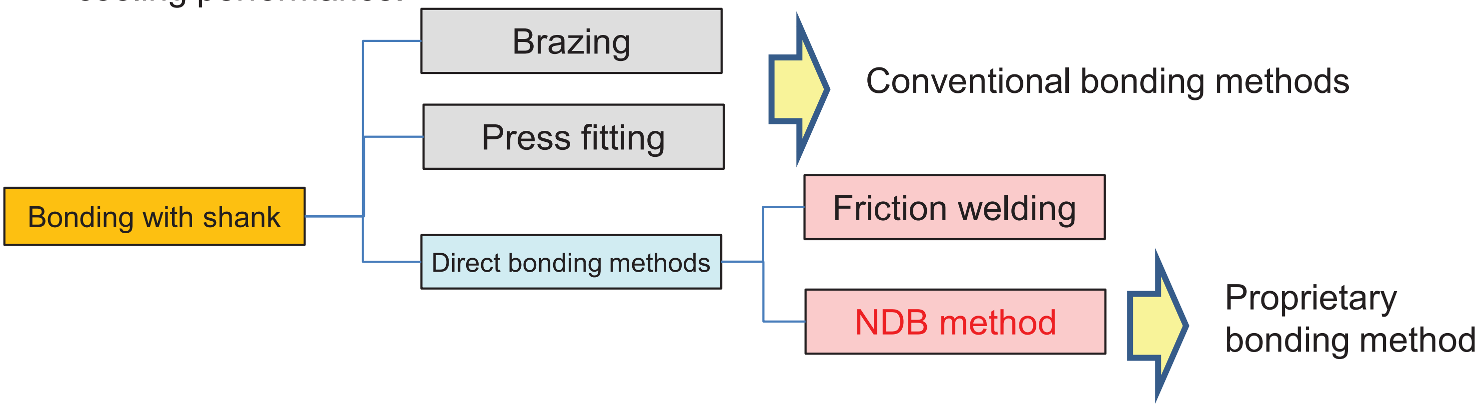
➢ Characteristics of our electrode materials

	Material name	Composition	Specific gravity	Hard-ness Hv	Electrical conductivity IACS%	Electrical resistivity $\times 10^{-8}\ \Omega m$	Cutting work-ability	NDB
Our materials	Tungsten (W)	W99.9% or higher	19.2	450	31	5.5	×	○
Our materials	Molybdenum (Mo)	Mo99.9% or higher	10.2	250	30	5.7	○	○
Our materials	Copper-tungsten (C10B2)	11%Cu-W	16.8	330	30	5.7	◎	○
Our materials	Copper-tungsten (C30A2)	30%Cu-W	14.2	225	48	3.5	◎	○
Our materials	Copper-tungsten (C50A2)	50%Cu-W	12.1	160	63	2.7	◎	○
Our materials	Silver-tungsten (S35A2)	35%Ag-W	14.8	210	53	3.2	◎	×
Our materials	Heavy Alloy (HAC2)	94%W-Ni-2%Cu	17.9	280	19	8.8	○	×
Reference materials	Chromium copper	Cu-1%Cr	8.9	150	80	2.1	◎	—
Reference materials	Alumina dispersed copper	Cu-0.5%Al_2O_3	8.7	150	80	2.1	◎	—

● Response to Customer Needs

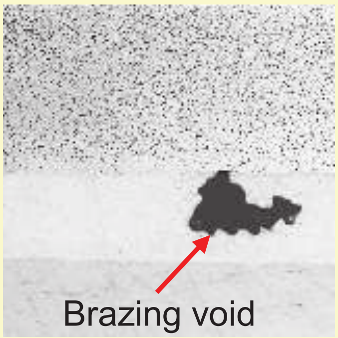
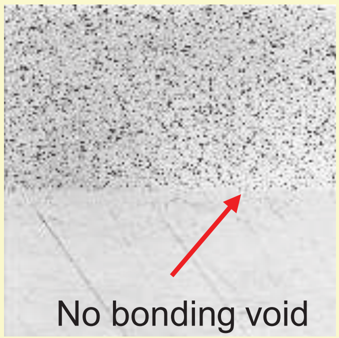
① Longer electrode life (NDB method)

To compensate for the cooling performance of W and Mo based materials, they are bonded with shanks made of copper or other materials. While conventional bonding methods for the electrode and shank involve press fitting and brazing, we’ve developed a unique method for direct bonding called friction welding as well as the NDB method, which makes it possible to offer electrodes with superior cooling performance.



NDB method is a bonding method whereby copper is melted and hardened in a non-oxidizing atmosphere and bonded directly to W, Mo, or CuW to form a shank. The difference in bonding quality compared to brazing is described below.

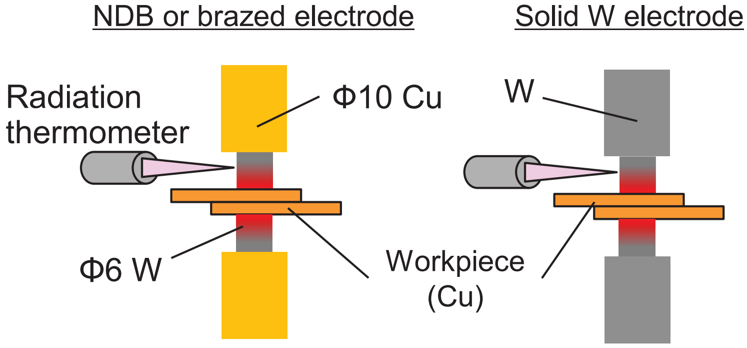
➢ Comparison of bonding quality

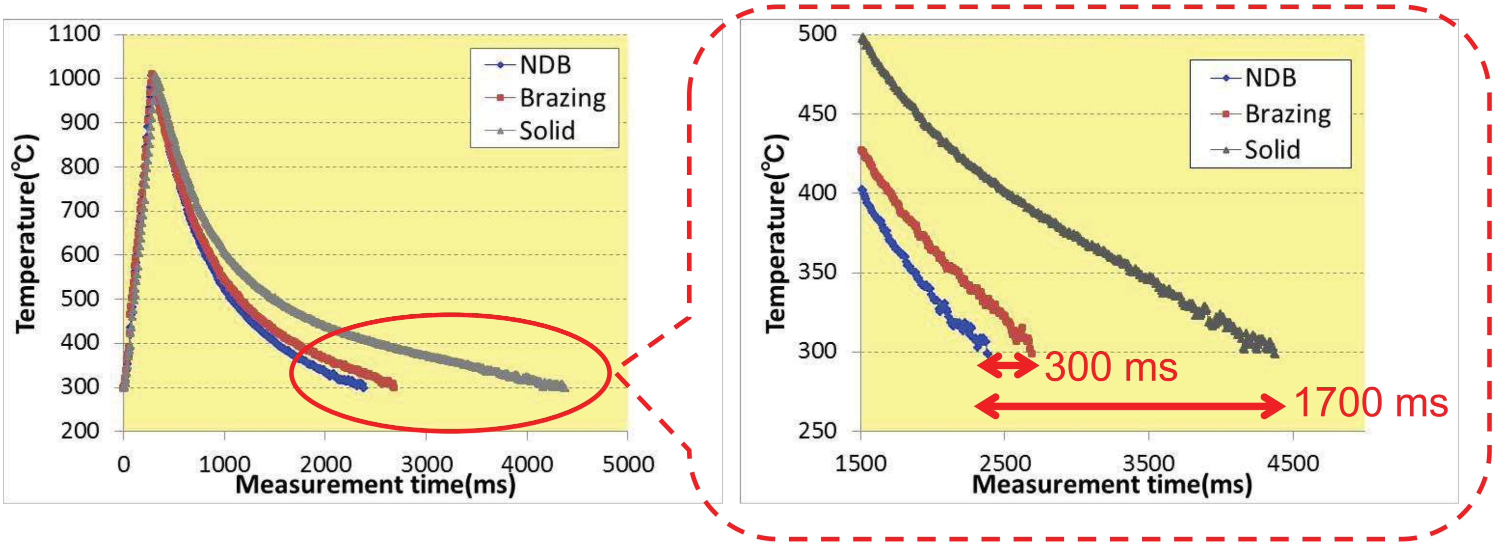
	Brazing	NDB method
Characteristics	• Low thermal conductivity • Unstable bonding quality due to presence of brazing voids	• High thermal conductivity • Stable bonding quality
Bonding area ratio	60–80%	Almost 100%
Bonding strength	≥98 MPa	≥127 MPa
Cross-section of bond	W Brazing filler material Cu  Brazing void	W Cu  No bonding void

The NDB method achieve high bonding area ratios because it doesn’t require a bonding layer. That makes it possible to produce high quality bonds and products that offer superior cooling performance after the resistance welding stops, which in turn increases shot cycles and production efficiency.

➢ Comparison of heat dissipation capabilities

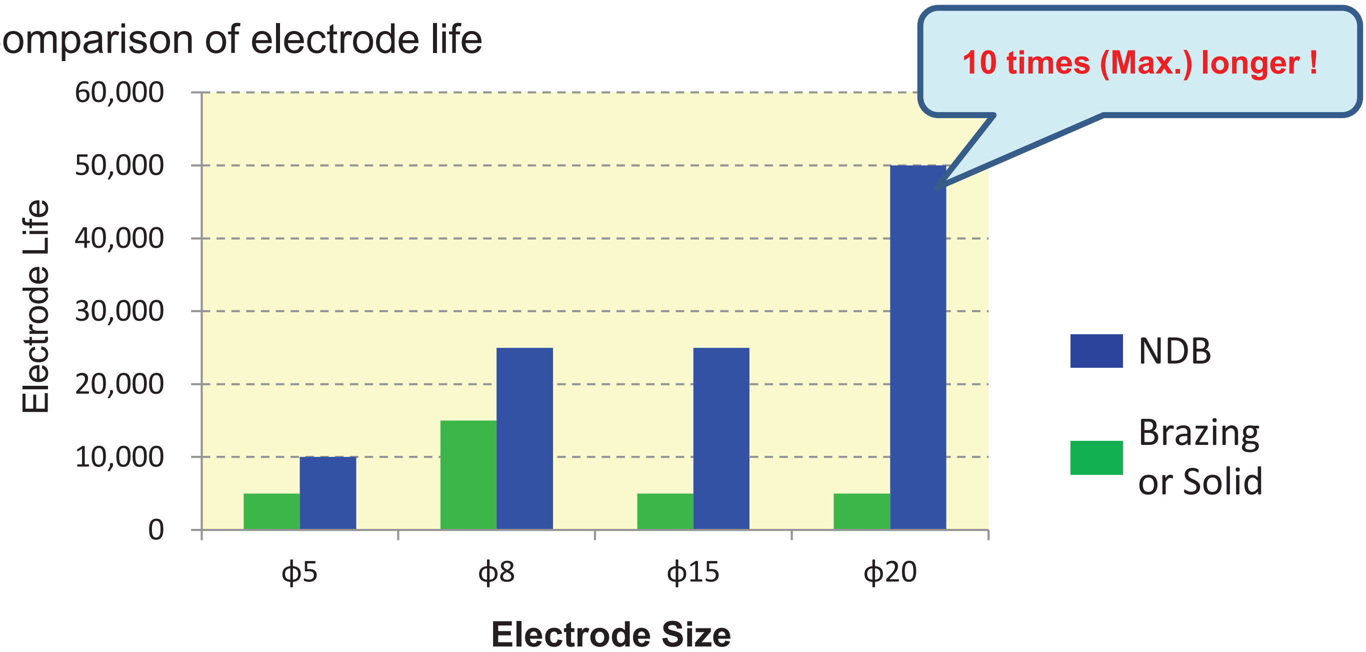
A comparison of the heat dissipation capabilities of NDB electrodes, brazed electrodes, and solid W electrodes: Using a radiation thermometer (pictured to right), we measured the time required for the electrode to cool from 1,000°C to 300°C. The results are shown below.





Due to the higher thermal conductivity of NDB electrodes, heat transfers faster to the shank, allowing the electrode to cool faster after the resistance welding stops. This results in less thermal damage (oxidative consumption) of the electrodes and longer electrode life.

➢ Comparison of electrode life



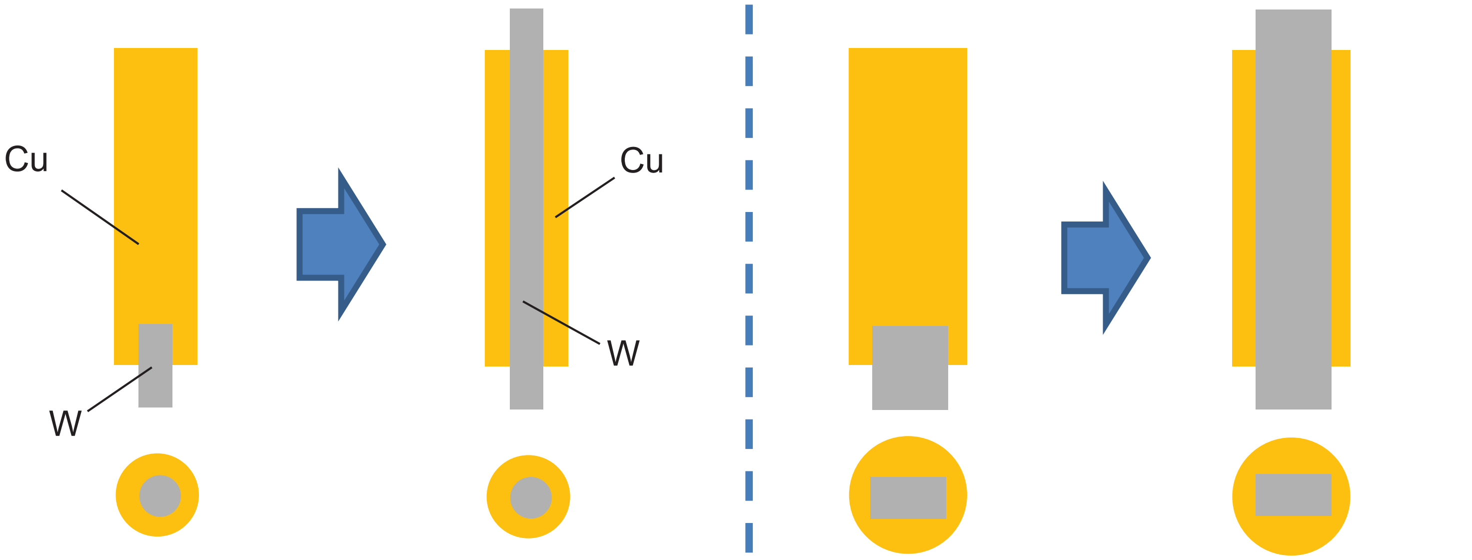
Depending on welding conditions, switching to NDB electrodes can achieve up to a 10-fold increase in electrode life.

➢ Some other NDB advantages

① Increases the number of possible re-polishing processes

The NDB method allows the production of through-type W electrodes, as shown below.

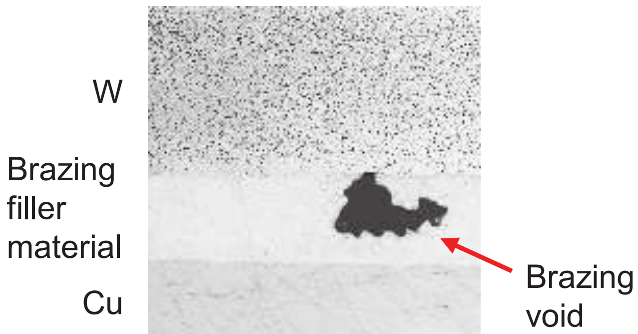
Configuring the W rod to penetrate the entire length of the electrode makes it possible to use both ends. The through-type design can also extend the re-polishing limit dimension (i.e., increase the number of times re-polishing may be performed).



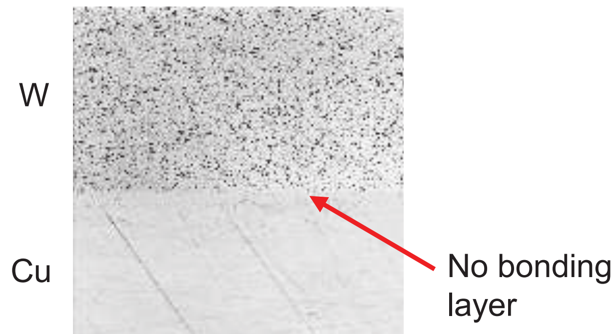
Conventional Brazing, press fitting	Through-type Realized by NDB method	Conventional Brazing, press fitting	Through-type Realized by NDB method

② Allows use in high temperature conditions

With brazed electrodes, the brazing filler material will begin to melt once the temperature of the electrode exceeds the melting point of the brazing filler material (normally 600–700°C), generating problems like separation of the W rod. Since the NDB method doesn't involve a brazing filler material and forms a direct bond, the bond can withstand heating up to the melting point of copper (1,083°C), allowing use at much higher temperatures than brazed electrodes.



Thermal resistance of brazed bond
⇒ melting point of brazing filler material
(approx. 600–700°C)



Thermal resistance of NDB bond
⇒ melting point of copper (1,083°C)

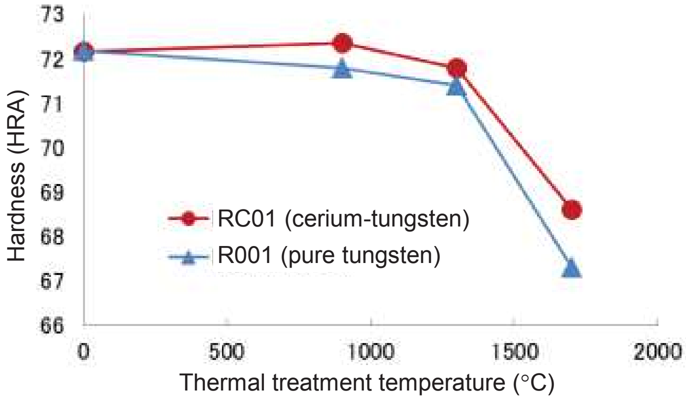
② Electrode materials that exhibit superior performance under high temperature conditions

While tungsten offers excellent hardness at high temperatures, the internal texture may become coarse after repeated exposure to overheating during welding (recrystallization), depending on welding conditions. This in turn may result in undesirable characteristics, such as deformation and rough electrode working surfaces, due to decreased hardness.

If you're experiencing such difficulties, we recommend trying our cerium-tungsten electrode, which is made by dispersing cerium oxide (CeO_2) in the tungsten matrix.

➢ Characteristics of cerium-tungsten electrodes

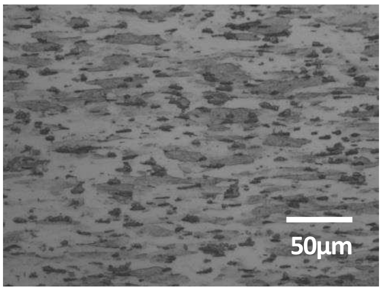
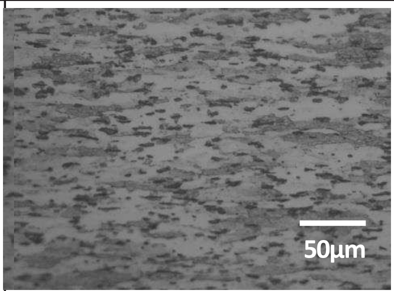
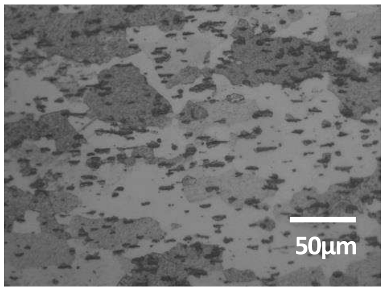
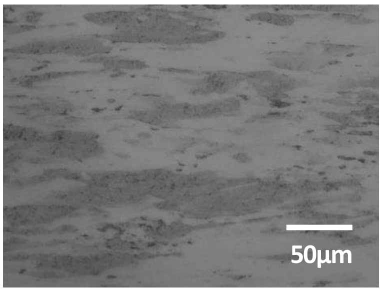
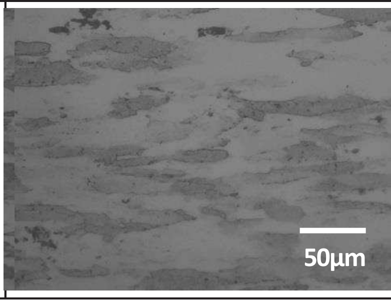
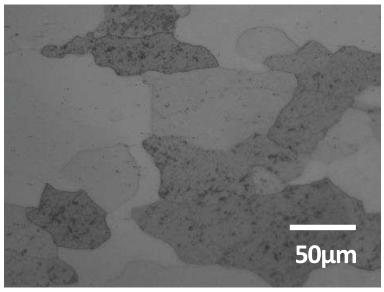
1. Offers higher hardness than pure tungsten



Retains high hardness even after thermal treatment at high temperatures, minimizing deformation and surface roughening.

2. Higher recrystallization temperature than pure tungsten

The photos below show the internal texture of the materials after thermal treatment. Due to the effects of the additive, the degree of coarsening of the texture (recrystallization) is lower in cerium-tungsten than pure tungsten, even after exposure to thermal treatment at high temperature.

	No thermal treatment	1,300°C	1,700°C
RC01 (cerium-tungsten)			
R001 (pure tungsten)			

Little recrystallization (which reduces hardness and strength) occurs, despite use under high-temperature conditions.

③ Reductions in re-polishing margin in crack elimination process

In general, materials with superior hardness at high temperature are used to fuse materials like copper. However, in certain cases, high hardness may contribute to the development of cracks. Depending on the mode of crack elongation, this may require an increase in the machining margin for re-polishing. One way to avoid this problem is to suppress crack propagation by subjecting the material texture to recrystallization through thermal treatment.

* Certain restrictions apply to the dimensions of parts processed by thermal treatment. Please consult with us if you are considering thermal treatment.

Fibrous structured W

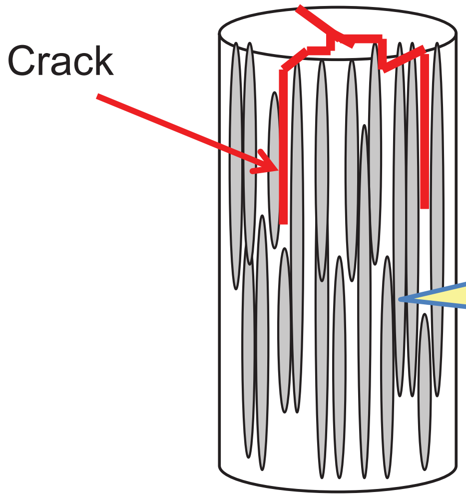
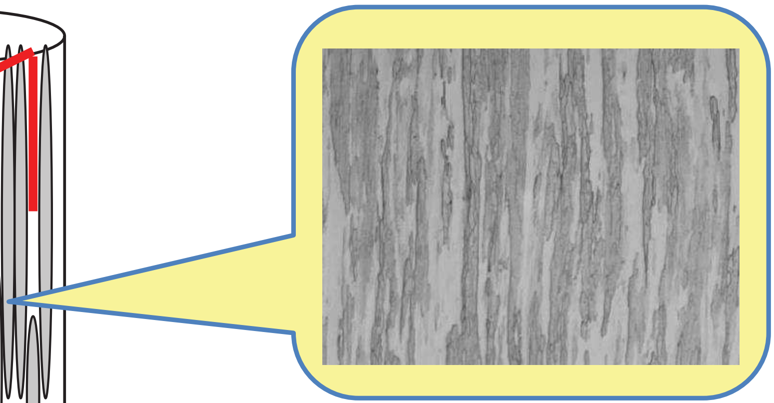


Photo of internal texture



Cracks tend to form along the direction of elongation of the fibrous structure (along the length axis of the rod)due to swaging.
This structure requires a large re-polishing margin to eliminate cracks.

Recrystallization by thermal treatment

Recrystalline structured W

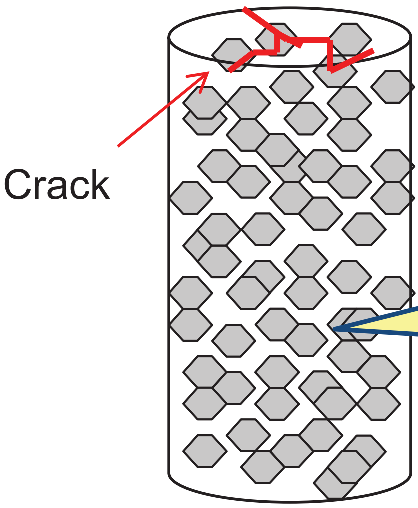
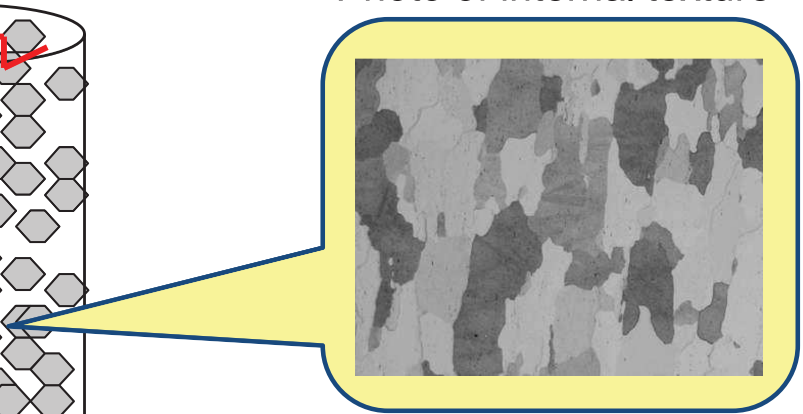


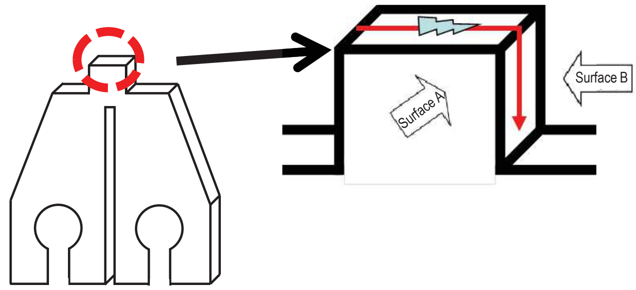
Photo of internal texture



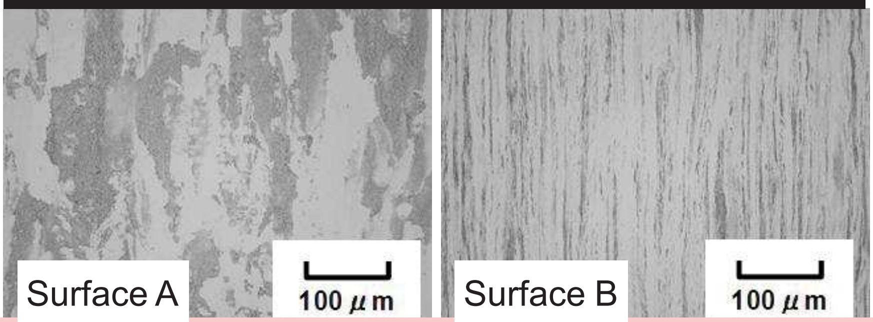
Recrystallization produces a stone-wall structure, which inhibits the formation of cracks along the direction of elongation.
This structure requires only a small re-polishing margin to eliminate cracks.

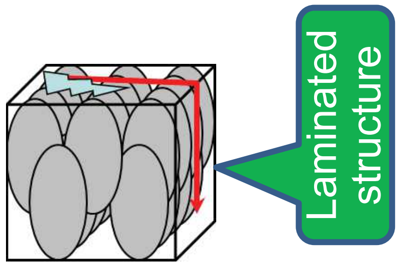
④ Countermeasures for fracture cracking of heater tips

If you're encountering the problem of shortened electrode life due to fracture cracking on the working surface of tungsten heater tips, we recommend the Heavy Alloy, our tungsten alloys. The Heavy Alloy features an isotropic structure that resists fracture cracking.



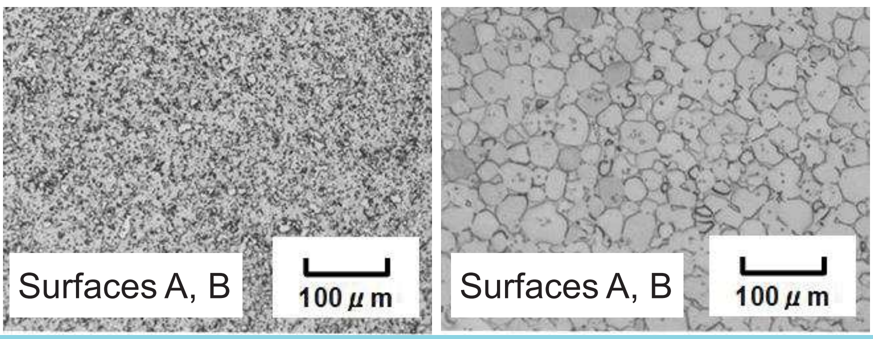
Tungsten (rolled)

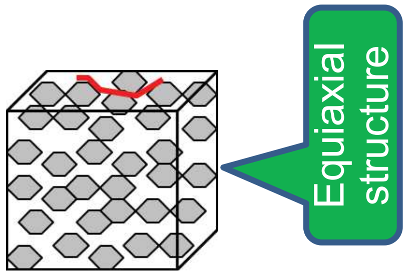




Since rolled tungsten has a laminated structure, it's susceptible to fracture crack formation along the plane of lamination during use.

Heavy Alloy HAF2 / Heavy Alloy HAC2





Since Heavy Alloys have an equiaxed structure, **they are unlikely to develop fractures**.

● Comparison of physical properties

Material		Composition	Specific gravity	Young's modulus (GPa)	Electrical conductivity (IACS%)	Thermal conductivity (W/m·K)
Heavy Alloy	HAF2	93W-5Ni-2Fe	17.6	350	—	90
	HAC2	94W-4Ni-2Cu	17.9	300	19	120
Conventional materials	W	W≥99.9%	19.3	345	31	165
	Mo	Mo≥99.9%	10.2	276	30	142

⑤ Longer cap tip electrode life for coated steel sheets

PAT. No 4683890 5083930 5127299

Corrosion-resistant coated steel sheets are used in various applications, including automobiles, housing construction, and home electronics. Spot welding is one of the most common bonding methods used for steel sheets. The materials generally selected for spot welding electrodes are copper alloys like chromium copper or alumina-dispersed copper.
In recent years, manufacturers have begun to produce new steel sheet products—for example, steel sheets featuring specialized surface finishes that enhance corrosion resistance, as with alloy coating materials, or chrome-free environmentally friendly steel sheets. However, conventional copper alloy electrodes appear to exhibit significantly shorter service life in spot welding of some of these special steel products, contributing to decreased production efficiency for those using these steel sheets. As a solution, we recommend our tungsten materials or direct-bonded (NDB) electrodes.

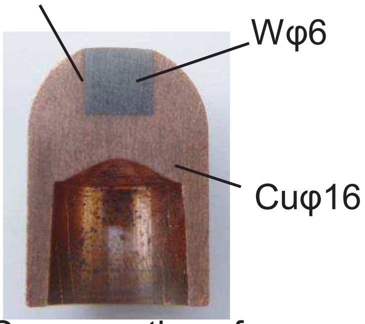
Electrode tip (core): W (tungsten) ⇒ Doesn't form alloy with Zn; offers superior hardness at high temperature.
Shank: Pure copper (oxygen-free copper) ⇒ Excellent cooling effects due to high thermal conductivity
Bond between core and shank: Pure copper materials are melted and hardened onto the tungsten to form a direct bond (NDB method).

● Welding test using ZAM® (comparison of life of CrCu electrode and NDB-W electrode)

Main test conditions

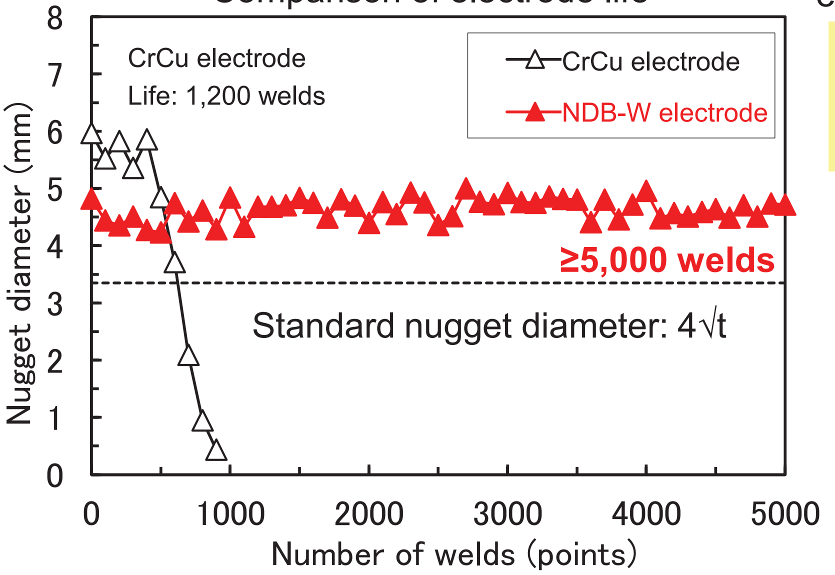
Specimen	ZAM60C 0.7 t /no treatment (MO)
Coating coverage on one side	60 g/m^2
Welding current	7.6 kA
Resistance welding time	12 cycles
Pressure	1.5 kN

NDB method



Cross-section of electrode

Comparison of electrode life



- W high hardness at high temperature
- W high alloying resistance
- Cooling effects due to NDB

The capacity to maintain electrode tip diameters enables longer electrode life.

* Dressing
Since W is extremely difficult to machine, dressing requires machining with cemented carbide tools.

"ZAM" is a registered trademark of Nisshin Steel Co., Ltd. for hot-dip zinc-aluminum-magnesium alloy coated steel sheets.

⑥ Developing electrodes for aluminum welding

In recent years, demand for lightweight design has grown for automobiles. More manufacturers are using aluminum as an alternative to copper. However, due to the low melting point of aluminum, a stable oxide layer often forms on surfaces, inhibiting bonding and making the material extremely difficult to join by resistance welding.
As a solution, our company has been working to develop a special electrode material designed specifically for aluminum welding. While the material is still in the development phase, we will introduce it below.

The concept underlying this material development involves a material that exhibits poor wettability (i.e., has a large contact angle) to aluminum in order to enhance adhesion resistance and alloying resistance. The material selected was TiN, and we created an alloy with W.

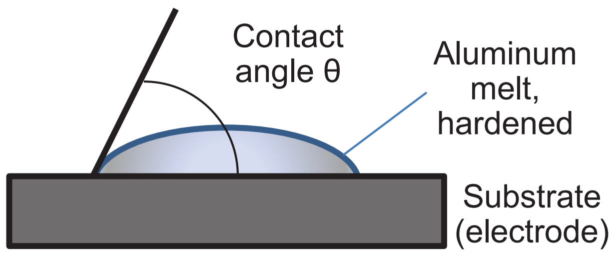
Overcoming the problem of adhesion between electrode and aluminum, a major problem in welding aluminum

- Selected TiN, a material that exhibits poor wettability to aluminum
- Maintaining electrical conductivity by alloying with W

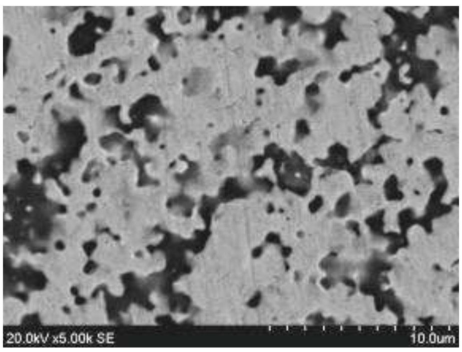
Produced W-TiN

Physical properties of various materials

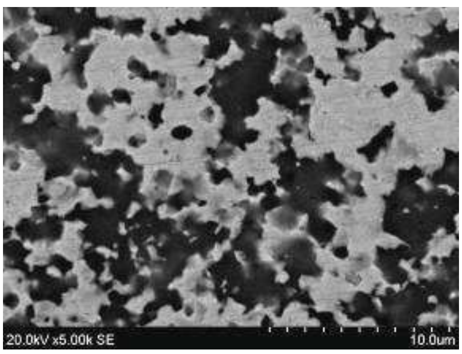
Materials	Electrical conductivity (IACS%)	Hardness (Hv)
W-25 TiN	20	680
W-50 TiN	13	810
W-75 TiN	8	1150
W (reference)	30	450
CrCu (reference)	80	120



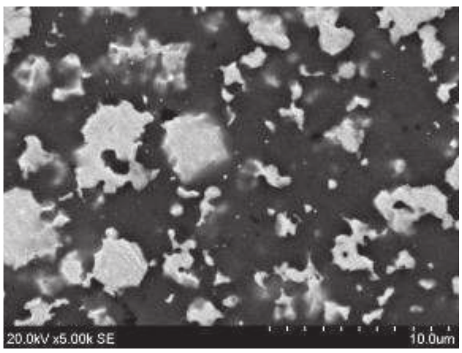
Schematic drawing of contact angle



Internal texture of W-25 TiN



Internal texture of W-50 TiN



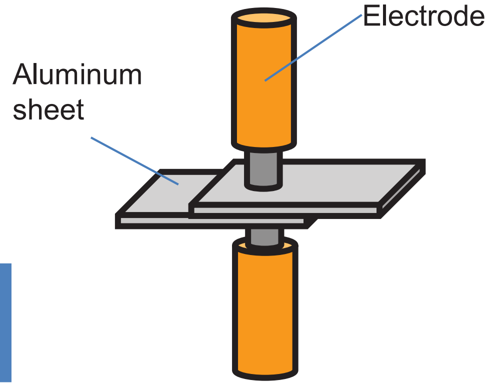
Internal texture of W-75 TiN

➢ Welding test using W-TiN material ①

Using W and W-TiN materials as electrodes, we performed a continuous point-welding test under welding conditions that allowed adjustment of workpiece bonding strength to a specific constant value. The tables below give the specifications for the workpiece and electrodes and the welding conditions for each electrode material after adjusting workpiece bonding strength to a constant value of approximately 80 N.

▪ Specifications for workpiece and electrodes

Workpiece	Aluminum (A1050-H24)
Workpiece dimension	0.5 × 20 × 40 mm
Electrode size	Tip: ϕ5; projection: 7 mm (bonded to shank)



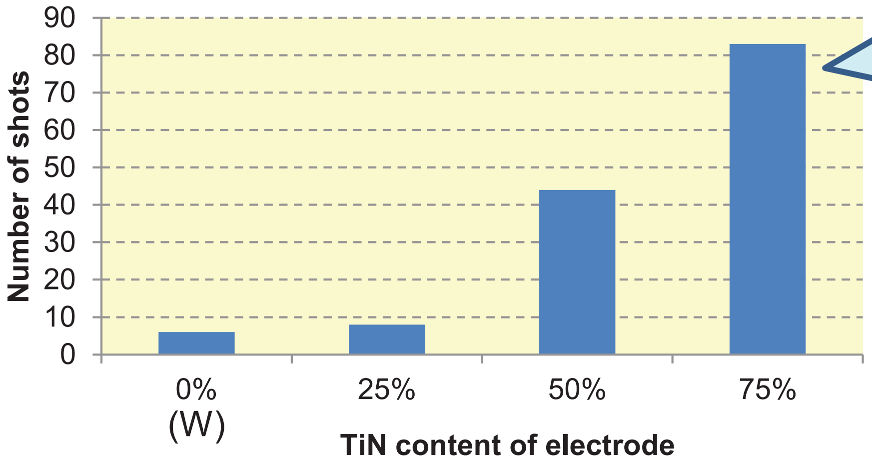
Schematic diagram of welding test

▪ Welding conditions for each electrode material
(workpiece bonding strength adjusted to approx. 80 N)

Electrode material	Welding current (kA)	Resistance welding time (ms)	Pressure (N)
W	3	100	90
W-25%TiN	2	300	90
W-50%TiN	2	300	90
W-75%TiN	2	200	90

The graph below compares the number of shots of continuous welding before adhesion, based on test results.

Number of shots of continuous welding before adhesion



The higher the electrode TiN content, the greater the number of shots of continuous welding that can be made before adhesion occurs.

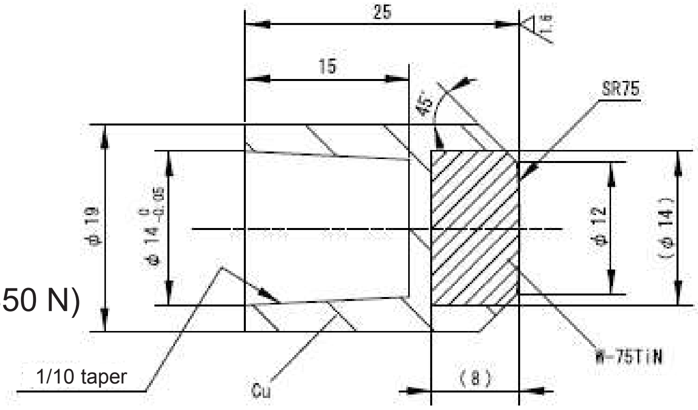
W-TiN materials exhibit better adhesion resistance compared to W to aluminum materials. Adhesion resistance improves with increasing TiN content.

➢ Welding test using W-TiN material ②

Using chromium copper and W-75TiN materials as electrodes, we performed a spot welding test on aluminum sheets and compared the state of transition of workpiece bonding strength in addition to the state of alloy formation between the electrode and the aluminum at the end of the test. The tables below give the specifications for the workpiece and electrodes and the welding conditions for each electrode material after adjusting workpiece bonding strength to a constant value of approximately 350 N.

▪ Specifications for workpiece and electrodes

Workpiece	Aluminum (A1050-H24)
Workpiece dimension	0.5×18×40 (mm)
Electrode size	ϕ19 cap tip; see figure on right.

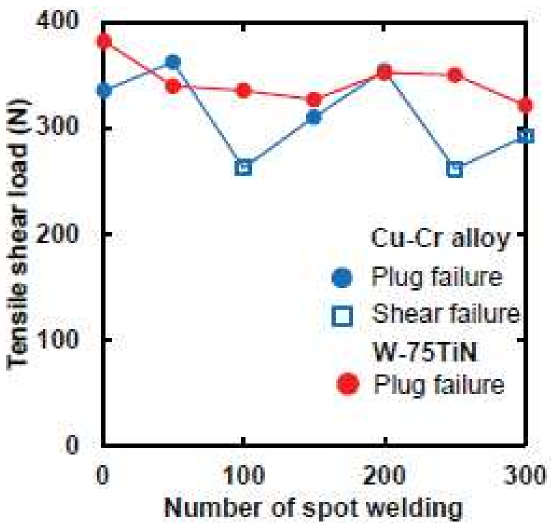


Drawing of W-75TiN electrode
(The chromium copper electrode has the same shape and is made of solid chromium copper.)

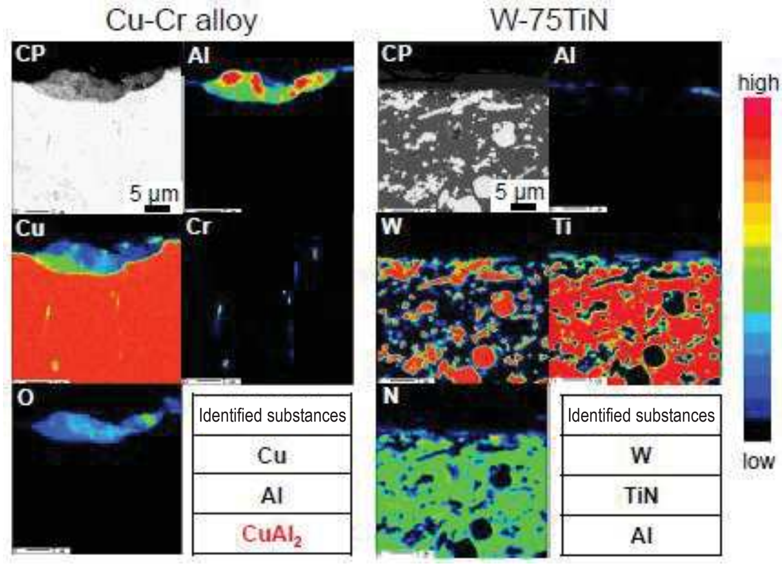
▪ Welding conditions for each electrode material
(workpiece bonding strength adjusted to approx. 350 N)

Electrode material	Welding current (kA)	Resistance welding time (ms)	Pressure (N)
Chromium copper	15	70	1.45
W-75%TiN	6	70	1.45

The test results are shown below as a graph showing the transition of workpiece bonding strength for welding up to 300 shots. Also shown here are images from EPMA analysis of the longitudinal sections of the electrode parts that came into contact with the workpiece at the end of the test.



Transition of workpiece bonding strength for each electrode



Mapping data for longitudinal sections of electrode tips after 300 shots of welding

➢ **Chromium copper electrode tips are alloyed with aluminum, resulting in progressive tip deformation. In contrast, no alloy layer is observed for the W-75TiN electrode. This absence appears to explain the lack of deformation.**

➢ **Workpiece bonding strength is a concern for chromium copper electrodes, which are susceptible to alloying and deformation. In contrast, alloying and deformation are suppressed in the W-75TiN electrodes, making it possible to achieve stable workpiece bonding strength.**

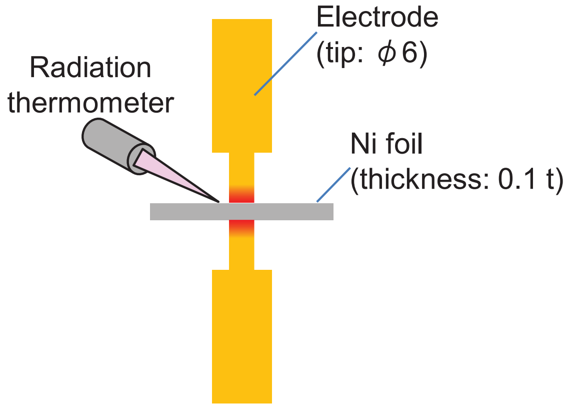
⑦ Electrode materials that do not readily react with nickel

Copper alloy electrodes are widely used in the nickel foil welding process in the production of secondary batteries. However, as more welding shots are made with the electrode, consumption of the tip progresses due to alloying of the tip material with nickel, resulting in less than satisfactory electrode life. We recommend silver tungsten alloys as electrode materials that do not readily react with nickel.

◆ Confirmation test involving applying pressure and electric current to nickel foil

We performed the following experiment: We sandwiched a piece of nickel foil between electrodes while varying the electrode material, then applied pressure and current repeatedly to compare reactions between nickel and the electrode.

We applied pressure and current to a piece of nickel foil measuring 0.1 mm in thickness and sandwiched between electrodes. For each electrode material, we adjusted the electric current while referring to a radiation thermometer to maintain constant temperature for the nickel foil.

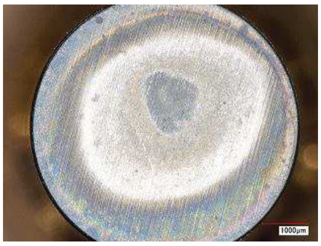
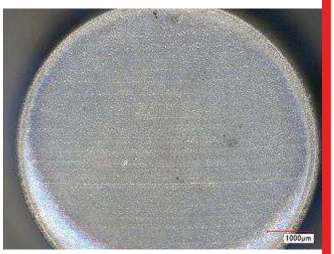
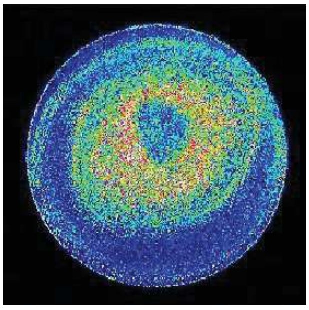
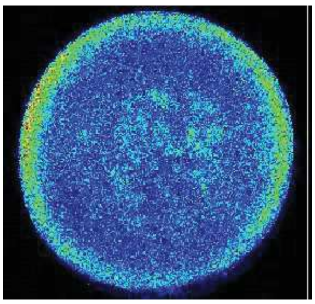
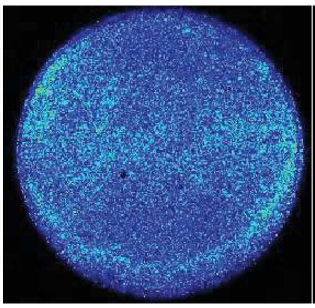
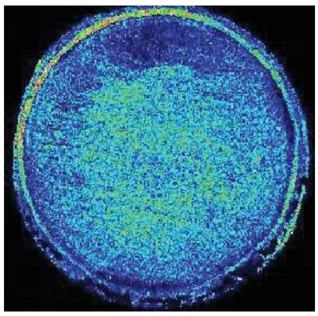


Schematic of experimental procedure

Electrode materials
① Tungsten (bonded to copper shank)
② Copper tungsten (30% Cu - 70% W)
③ Silver tungsten (35% Ag - 65% W)
④ Chromium copper alloy

The images below compare the external appearance and Ni mapping data obtained with EPMA analysis for each electrode after the completion of the experiment (after 100 shots).

◆ External appearance and Ni mapping data of used electrode surface for each electrode material

	①Tungsten	②30% Cu - 70% W	③35% Ag - 65% W	④Chromium copper
External appearance of used electrode surface				
Mapping (nickel)				

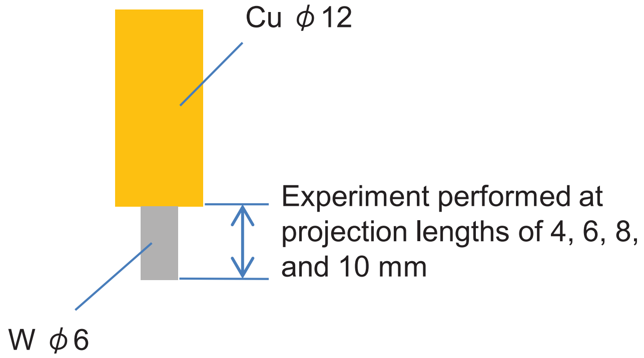
Silver tungsten alloys effectively extend the electrode life for Ni welding

⑧ Relationship between length of electrode tip projection and amount of heat generated

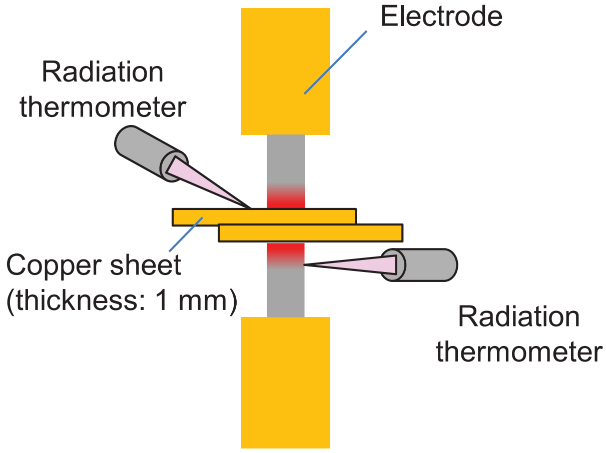
Tungsten electrodes are generally bonded with shanks made of copper or other materials. However, the length of the tungsten tip projection varies depending on the electrode. Here, for the sake of reference when designing an electrode, we investigated the relationship between the length of the tungsten tip projection and the amount of heat generated.

Overview of the experiment

- Using electrodes with workpiece tip projection lengths of 4, 6, 8, and 10 mm, we performed resistance welding under constant welding conditions (7 kA × 300 ms).
- Using a radiation thermometer, we measured the maximum temperatures reached by the electrode at a point 2 mm from its tip and by the workpiece at a point 5 mm from the contact with the electrode. We also measured the time required for the electrode to subsequently cool to 300°C.

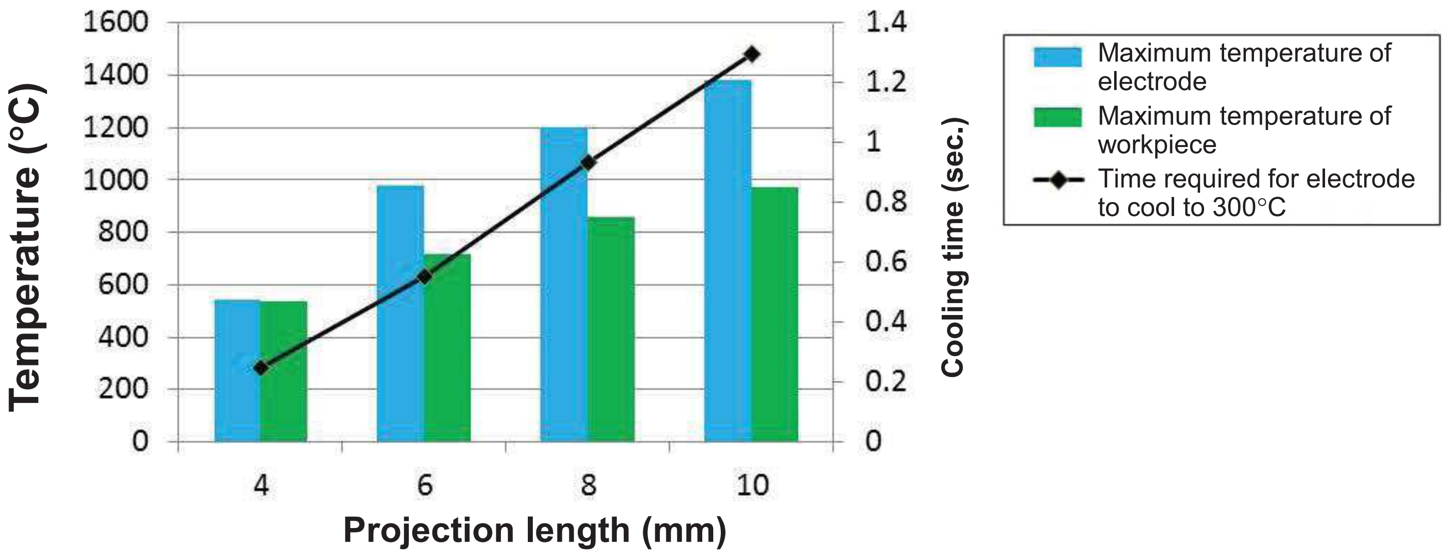


Electrode configuration



Schematic of experimental procedure

The graph below compares the maximum temperatures achieved by the electrodes and workpieces and the time required for the electrodes to cool to 300°C. The longer the projection, the greater the maximum temperatures of the electrode and the workpiece.



Besides welding conditions, the length of electrode tip projection can be adjusted to control the following factors:

- **Increase projection length to increase the heat generated at the bonding point.**
- **Reduce projection length to reduce the heat generated to prevent adhesion.**

● Compilation of Data for Reference

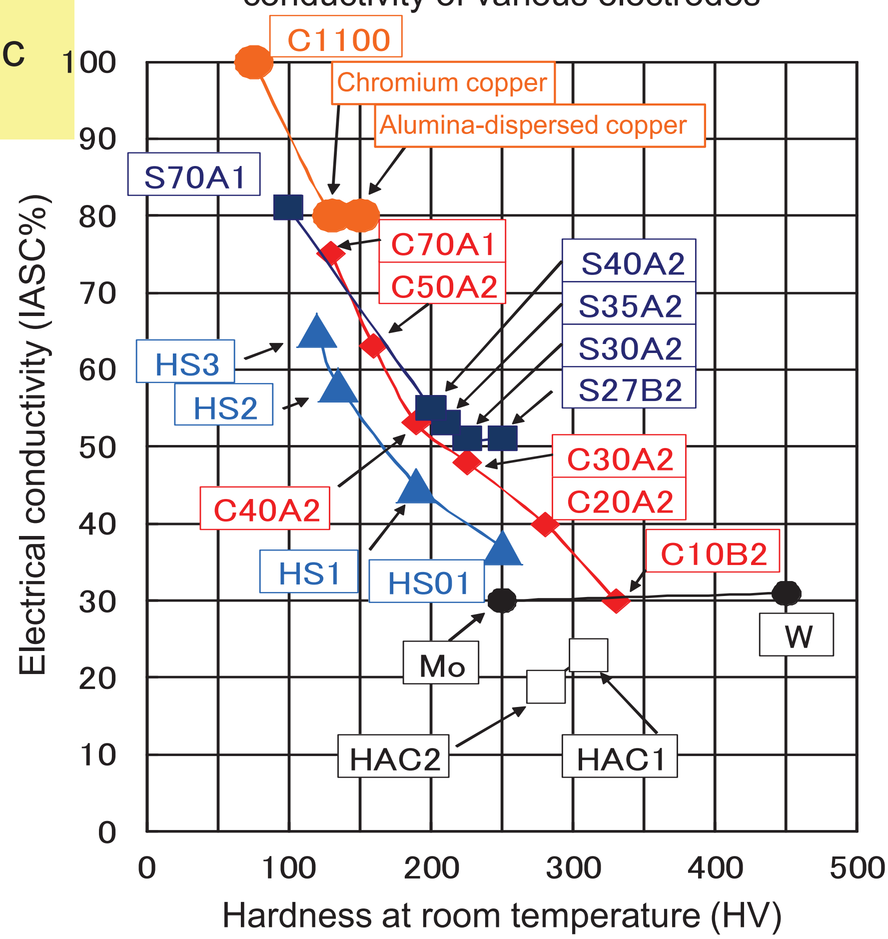
① Hardness at room temperature and electric conductivity IASC% of electrode materials

The graph on the right is a plot showing the relationship between hardness at room temperature and electric conductivity. We've added data for chromium copper, alumina-dispersed copper and tough-pitch copper for the sake of comparison.

As can be seen from the graph, hardness increases and electrical conductivity (IASC%) decreases with increasing content of tungsten, which exhibits high hardness and high electrical resistance.

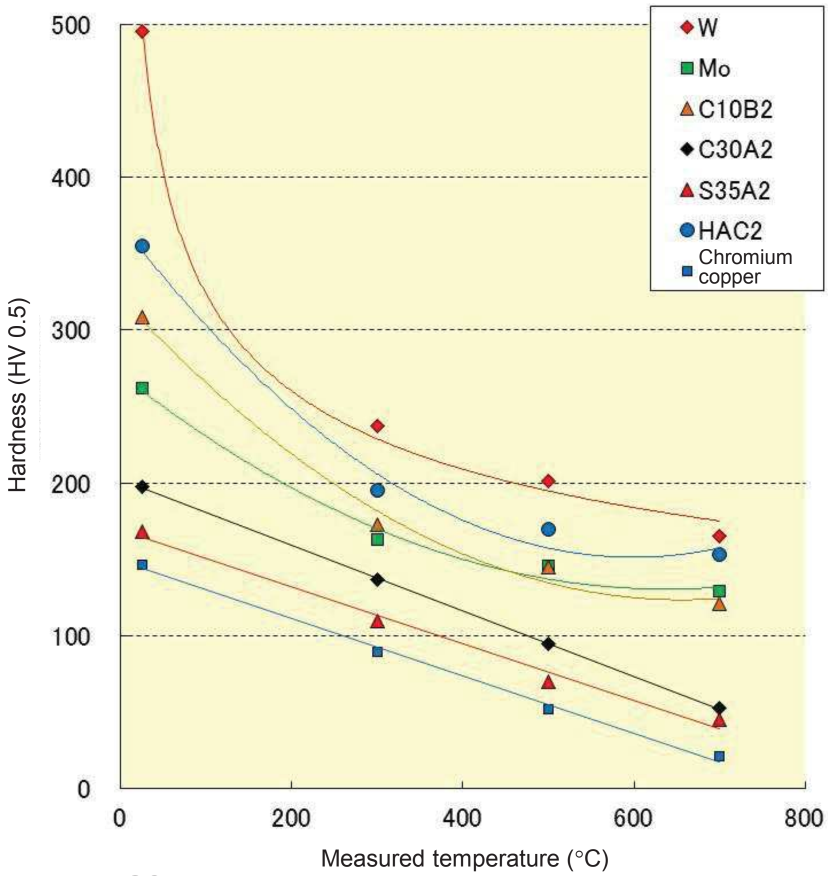
If welding conditions are identical, the amount of heat generated at the point of welding will vary with different electrode materials. This means the heat balance must be checked whenever changes are made in the electrode material.

Hardness at room temperature and electric conductivity of various electrodes



② Hardness of various electrode materials at high temperature

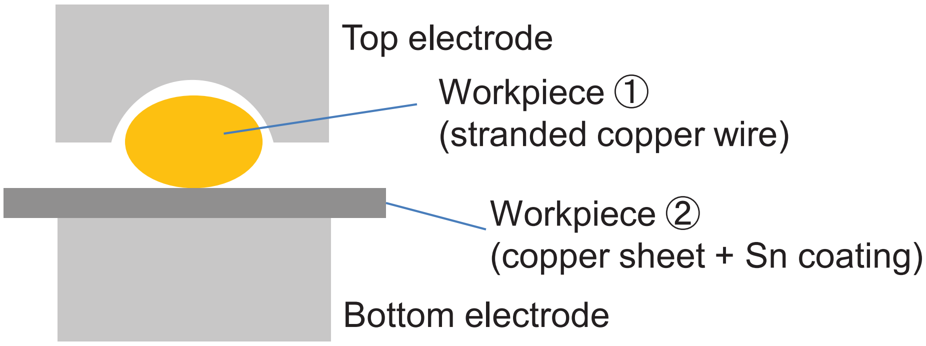
The graph on the right shows the hardness of our electrode materials at high temperatures. It can be seen that tungsten (W) has the highest hardness. When problems such as roughness of electrode surface are encountered, use the hardness at high temperature shown in this graph as a reference in identifying a solution.

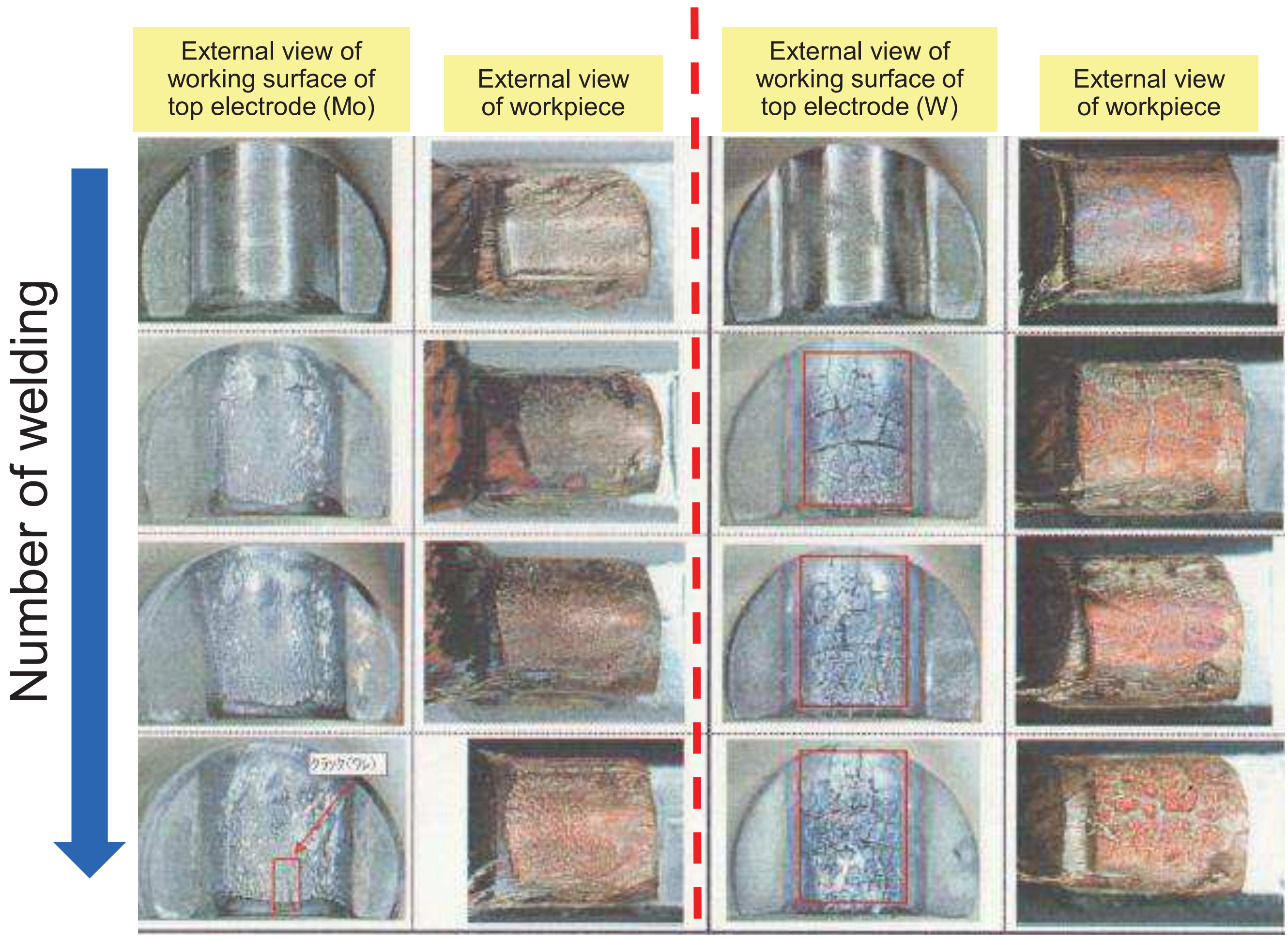


③ Crack resistance of W and Mo—comparison of case examples

The photos below show test specimens for comparing the crack resistance of tungsten and molybdenum. Crack formation in tungsten becomes more significant as the number of welds increases, and the cracks can even shift to the workpiece and become visible on external surfaces. In contrast, crack formation is less significant with molybdenum even with the same number of welds, and its effects are not apparent on the workpiece.

While tungsten offers superior hardness, it exhibits weaknesses against mechanical and thermal shock, posing the risk of crack formation when used as an electrode. In such cases, molybdenum may be a more suitable material, as shown in this example.





A higher number of cracks is confirmed in the working surface of tungsten than in molybdenum.

Since tungsten and molybdenum are both brittle materials, crack formation during use cannot be avoided. A recommended practice for achieving longer electrode life is to perform re-polishing in advance to eliminate cracks and to prevent crack propagation.

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