POLEMA

REFRACTORY METALS AND COMPOSITE MATERIALS

KOKS GROUP

POLEMA JSC

POLEMA JSC is the leading manufacturer of chromium, molybdenum, tungsten products, metal powders and composite materials.

The company is on the top positions of global markets of electrolytic refined chromium and high purity chromium sputtering targets, rolled metal and molybdenum and tungsten products, heavy-current contact materials. Since 1982 Russia's largest complex for production of metal powders with the capacity of 3,000 tons per year operates as part of the company. The enterprise produces more than 200 grade marks of powders based on nickel, cobalt, molybdenum, chromium, titanium, cuprum, zink, stannum, powdered alloy steels and alloys and powdered solder alloys, surfacing belts and wire.

POLEMA JSC was founded in 1961. In 2004 it became a part of Industrial Metallurgical Holding (IMH). Nowadays POLEMA successfully carries out different projects: reconstruction of electrolytic chromium manufacturing, mechanical processing of metals, production of new materials and extension of basic materials made of chromium, molybdenum, tungsten, nickel, nichromium, aluminum-titanium compositions and ceramics that are used for technologies of physical sedimentation (PVD) of hardsurfacing, protective, decorative, light-reflecting, resistive, commutative and transparent films and coatings.

Production volume of sputtering targets and evaporable cathodes made of high-purity chromium is about 30% of global market.

The company sells products at the home market, in China, Taiwan, Korea, USA, EEC countries, South America. It has representative offices in Europe and South East Asia.

Modern analytical equipment includes optical emissive and mass-spectrometers, Leco system instruments, electronic microscope Jeol JSM-6390, machines for mechanical testing of metals and etc. It guarantees perfect quality control of our products.

POLEMA JSC applies Quality Management System ISO 9001:2008 in its basic products manufacturing. It confirmed by an international certificate.

CONTENTS

CHROMIUM

Chromium is one of the most common elements found in nature thanks to its physical properties (it has a high melting point, inertness to the effects of harsh environments and is an oxygen-hungry metal). It has found wide practical application since the early 19th century.

POLEMA is a major global producer of unique pure electrolytic chromium used in heat-resistant superalloy metallurgy, in electronics (in conjuction with copper), in technologies for depositing thin films and functional coatings using PVD methods when producing electronic parts, large-format displays, tools, watch cases, household appliances, tinted glass, car parts and accessories, machines and instruments and for other purposes. In technologies for depositing thin films in vacuum using the thermal vaporization method,electrolytic refined chromium is used in lamellar form or in the form of grit; for spraying with an ion bombardment or arc vaporization, it is used in the form of compact parts of various shapes. To manufacture products using powder metallurgy (PM) methods, ERCr chromium in lamellar form is subjected to mechanical grinding into PM-ERCr powder.

The industrial production of electrolytic chromium, pioneered at Tulachermet in 1964, included the procedure of extracting the metal from a solution of chromium anhydride (electrolysis) followed by thermal cleansing in hydrogen of a cathode deposit known under the trademark ECr.

In 2006 chromium production was overhauled by moving the electrolysis unit to the outskirts of the industrial zone,into an environmentally purer area. The new electrolysis division is equipped with modern equipment, automated control and monitoring systems for all parameters of the technological process. The resulting primary product, ECr, has a purity of 99.992-99.996% for its basic element (not counting O, N, C, S, Cl, P, F, H).

Refining primary chromium in extremely pure hydrogen makes it possible to achieve unique pure industrial chromium, ERCr, in the form of thin flakes with a low content of gas-forming elements. The total content of impurities in 99.99 % ERCr chromium does not exceed 0.01% (not counting O,N,C,S,Cl,P,F,H).

The following chromium products are currently manufactured:

- unrefined electrolytic chromium ECr and refined chromium ERCr-0, ERCr-1,ERCr-2;
- powders and grit from ERCr chromium;

products made from ERCr-MP for sputtering targets and evaporable sources.

POWDER AND GRIT MADE OF ELECTROLYTIC CHROMIUM

JSC POLEMA produces powders and grit of electrolytic chromium with various chemical compositions and particle size.

Powders and grit are produced through mechanical grinding of refined electrolytic chromium material of the appropriate purity, with subsequent screening in order to achieve the needed particle size.

Powders made of refined electrolytic chromium are meant for use in manufacturing.

Grit made of refined electrolytic chromium is used as evaporable sources during vacuum application of chromium coatings.

Powder of high-purity refined electrolytic chromium containing the base element 99.99 % Cr and 99.98 % Cr

Grade	Cr,% (mass)*	Impurities, ppm, maximum				
		Total content of metallic impurities	C	N	O	S
					for fraction 56-280 microns	for fraction 56–160 microns	
MP-ERCr 99,99	99,99 min	100	50	40	120	130	20
MP-ERCr 99,98	99,98 min	200	70	50	140	150	20
*Metallic purity. The mass percentage of Cr is determined as the difference between 100% and the total content of metallic impurities determined using the ICP-MS method							

MP – Milled Powder

Particle size: 56-280, 56-160 microns with base fraction content of at least 93.5%. Other particle sizes are possible to be based on client request.

Powder of refined electrolytic chromium with a purity of 99.95 % Cr

Grade, fraction	Cr,% (mass)*	Impurities, ppm, maximum									
		Al	Fe	Cu	Ni	Si	C	N	O	S	Other
MP-ERCr-1 -280 microns (-50 mesh)	99,95 min	15	150	30	50	100	80	30	120	20	-
MP-ERCr-1 -150 microns (-100 mesh)	99,95 min	15	200	30	50	100	80	30	200	20	-
MP-ERCr-4 -150 microns (-100 mesh)	99,95 min	50	200	30	50	150	100	50	From 10000 to 30000**	80	P 20 Pb 10
*Metallic purity **In MP-ERCr-4 (oxidized) powder, oxygen is not classified among impurities, and its content in the amounts shown above is set based on individual contracts											

MP – Milled Powder

Powder of low-purity refined electrolytic chromium containing the base element 99.9 % Cr and 99.6 % Cr

Grade	Cr,%	Impurities, ppm, maximum**									
		Al	Fe	Cu	Ni	Si	Total content of metallic impurities	C	N	O	S
MP-ERCr 99,9	99,9 min	70	500	40	100	100	1000	200	100	350	30
MP-ERCr 99,6	99,6 min	70	1500	50	100	350	4000	200	100	1500	30
*Metallic purity ** Impurity norms are shown for powders MP-ERCr 99.9 of the fraction 56-280 microns (-50 mesh) and MP-ERCr 99.6 of the fraction 0-63 microns (-250 mesh). For powders of other fractions,impurity norms are determined in the specifications											

MP – Milled Powder

Particle size: 56-280 microns for the grade MP-ERCr 99.9 with base fraction particle content of at least 85 %; 0-63 microns for the grade MP-ERCr 99.6 with base fraction particle content of at least 95 %; other dimensions are possible at the client's request.

Grit from refined electrolytic chromium with a purity of 99.95% Cr and 99.9% Cr for evaporable sources

Grade	Cr,% (mass.)*	Impurities, ppm, maximum									
		Al	Fe	Cu	Ni	Si	Other impurities, total**	C	N	O	S
ERCr 99,95-PM	99,95 min	30	250	30	40	50	100	100	50	200	20
ERCr 99,9-PM	99,9 min	70	500	40	100	100	190	200	100	350	30

*Metallic purity
**K+Li+Mg+Mn+Mo+Na+V+W

Grit particle size: from 2.5 to 5.0 mm, with base fraction content of at least 88 %,as well as other sizes based on the client's request.

CHROMIUM SPUTTERING TARGET AND EVAPORABLE CATHODES

JSC POLEMA is a leading global producer of sputtering targets and evaporable sources (cathodes) made of refined electrolytic chromium. The company's share in this segment of the global market is approximately 30%.

Use

Products made of chromium are used in various technologies for the physical deposition of thin films and functional coatings (the PVD method) in the production of electronic components, displays and tools; in the vacuum chroming of watches, parts of household appliances, the working surfaces of hydro-pneumcylinders, slide valves, piston rods, tinted glass, mirrors, car parts and accessories and other machines and devices. When depositing strengthening coatings from ionized plasma using the method of vacuum-arc vaporization of a cathode or by magnetic target sputtering,chromium is used as an adhesive substratum and, in combination with other materials,is used for multi-layer and nanostructural multi-functional wear-resistant coatings. High-quality large-size planar targets made of electrolytic refined chromium (ERC) are used by leading manufacturers of plasma and liquid-crystal displays to deposit metallic conductors during the formation in monitor matrices of thin-film transistors (TFT technology).

Production

Production process:
Chromium ERCr flakes → powder → compact stock → ERCr-PM product.

The powder undergoes a special treatment that ensures material purity equal to that of the base ERCr chrome.

Compaction is done in the following manners:

- hot isostatic pressing (HIP);
- extrusion (HP);
- when necessary, rolling of sintered semi-finished products is performed (R).

Final tooling is done in accordance with the client's request.

Brands and guaranteed chemical composition of products made of ERCr chromium

Brands	Cr,%, mini-mum	Impurities, ppm, maximum								
		O	N	C	S	Fe	Si	Ni	Al	Cu
ERCr 99,9-PM	99,9	350	100	200	30	500	100	100	70	40
ERCr 99,95-PM	99,95	200	50	100	20	250	50	40	30	30
ERCr 99,97-PM	99,97	100	50	70	20	100	20	10	20	20
						∑ of metallic impurities Al, Fe, Cu, Ni, Si, Ca, K, Li, Mg, Mn, Mo, Na, Pb, Ti, W, Zn and others 300 ppm, maximum				
ERCr 99,99-PM	99,99	100	50	70	20	50	10	5	5	10
						∑ of metallic impurities Al, Fe, Cu, Ni, Si, Ca, K, Li, Mg, Mn, Mo, Na, Pb, Ti, W, Zn and others 100 ppm,maximum			

PM – Powder Metallurgy

Shape and dimensions of products made of chromium

Shape of treated product	Diameter, mm	Thickness, mm	Width, mm	Length, mm
Plate	-	From 5 to 50	Up to 1400	Up to 1700
Disc,ring	From 65 to 400	From 5 to 50	-	-
Rod,cylinder	From 15 to 65	-	-	Up to 600

The following tolerances for dimensions are applied, unless otherwise requested bythe client, in mm: diameter ±0.25; thickness ±0.2; length and width, up to 100 ±0.15; from 100 to 500 ±0.25; from 500 to 1000 ±0.4; more than 1000 ±1.0.

ELECTROLYTIC CHROMIUM FLAKES

Since 1964, POLEMA has been actively refining its production of electrolytic refined chromium. Developed as the leading method in 1854 by Bunsen, the electrolytic method now makes it possible to obtain high-grade chromium on an industrial scale.

JSC POLEMA's unique methods for refining electrolytic chromium allow it to eliminate any oxygen, sulphur, nitrogen and hydrogen contained in the «raw» product.

The product of electrolysis – primary ECr chromium – comes in thin layers of a dark gray color, flakey in shape, with a thickness of up to 2.5 mm. ECr contains 0.5-0.55% oxygen. High-temperature hydrogen processing of ECr produces refined ERCr chromium, primarily in the form of light gray, shiny layers (flakes) with extremely low amounts of interstitial impurities (C, O, N, S, H).

Use

Electrolytic refined chromium in the form of flakes is traditionally used in vacuum metallurgy when producing heat-resistant Ni-Cr superalloys. Flake chromium is widely used for other purposes as well: in electronics it is used for vaporizing and depositing thin films in units with involving electron-beam heating. Using thermal processing in a pure nitrogen atmosphere, flakey ERCr chromium can be turned into chromium nitride (Cr_2N) or nitrided products with other compositions for use in doping special steels and alloys.

Using mechanical grinding, electrolytic refined chromium flakes can be turned into powder and grit with various chemical compositions and dispersibility.

Powder made of pure electrolytic refined chromium is intended for use in manufacturing.

ECr electrolytic unrefined chromium

		Guaranteed chemical composition of ECr chromium									
Grade	Base	Impurities content, % (mass), maximum									
		O	N	C	S	Fe	Si	Ni	Al	Cu	Pb
ECr	Cr	0,55	0,013	0,01	0,02	0,008	0,01	0,005	0,006	0,003	0,001

ERCr electrolytic refined chromium

		Guaranteed chemical composition of refined chromium								
Grades	Cr, %, minimum	Impurities, ppm, maximum								
		O	N	C	S	Fe	Si	Ni	Al	Cu
ERCr-0	99,99*	50	50	80	20	∑ Ni, Mo, W, Al, Ca, Co, Cu, Fe, Mg, Mn, Si, Ti, V, K, Li, Na and others 100 ppm, maximum				
ERCr-1	99,95	50	50	80	20	80	100	50	60	30
ERCr-2	99,95	70	70	80	20	80	100	50	60	30

* Mass percentage of chromium, not including the gas-forming impurities C, O, N, S, H, F, Cl.

MOLYBDENUM

Molybdenum is a high-melting metal included among transitional elements with a body-centered cubic lattice; it has a strong interatomic bond, a high melting point of 2620 °C and a minimal expansion coefficient.

Some of molybdenum's important features in terms of its industrial application include its high heat resistance, electric conductivity and head conductivity, its relatively low thermal neutron capture cross-section, a volume weight almost two times lower than that of tungsten, etc. Molybdenum's resistance to creep and stress-rupture at high temperatures in vacuum and in a protective atmosphere (argon, hydrogen) is noticeably higher than the same properties of many metals used as the base for heat-resistant materials.

As a result of molybdenum's low temperature coefficient of linear expansion and its high melting point, it ensures the dependable functionality of structures made from molybdenum that operate at high temperatures.

Molybdenum's high thermal conductivity is several times greater than that of ordinarily used heat-resistant alloys, which prevents thermal stresses during rapid heating and cooling.

Molybdenum is resistant to the effects of acids, alkali and struts in many molten metals and liquid glasses.

JSC POLEMA makes sintered and deformed semi-finished products (rolled stock, rods), plates, electrodes for melting glass, sputtering targets and other products using oxide-restored molybdenum powder with purity of 99.95-99.97 % as the starting material.

Thanks to the low content of interstitial impurities and metallic impurities and the small-grain texture of the material, the finished products boast outstanding plastic properties.

Molybdenum products include the following:

- Molybdenum rolled stock and plates made from pure and lanthanum-oxide doped molybdenum
- Molybdenum boats
- Molybdenum rods, forgings
- Molybdenum sputtering targets
- Molybdenum alloys, such as MoW, MoLa and others
- Molybdenum crucibles and saucers
- Molybdenum screens
- Molybdenum electrodes for glass furnaces, from Mo 99.95%

MOLYBDENUM SHEETS, PLATES

Molybdenum products:

powders, sheets, plates, discs, sputtering targets, electrodes, rods, crucibles, pans, boats, screens.

The following grades of sheets and plates are produced:

1. sheets from Mo-PM grade alloy;
2. high-precision molybdenum rolled products.

Application:

- radiators, screens and boats for high-temperature ovens operating in vacuum, in hydrogen, or in an inert-gas atmosphere at temperatures of up to 2100 °C, as well as screens and other components for apparatuses used to grow sapphire monocrystals;
- substrata in the form of discs for silicon powder rectifiers;

- sputtering targets and components of magnetrons and other electric tubes.

Chemical composition Mo-PM

Contemporary powder metallurgy methods ensure a high level of molybdenum purity in terms of metallic interstitial impurities (C, N, O, H), a microstructure necessary for application in the electronics industry and as heat-resistant constructional material in electronics and other devices that operate under extremely high temperatures.

The chemical composition of stock-produced sheets meets or exceeds the norms established for raw molybdenum powder.

Since 2002, the company has been using Mo powder 99,95 to produce sheet products.

Guaranteed chemical composition of Mo powder 99,95 molybdenum powder.

Grade	Minimum Mo,%*	Chemical composition, ppm, maximum												
		Fe	Al	Ni	Si	Mg	Na	K	Ca	W	Mn	Zn	C	ΣMe**
Mo powder 99,95	99,95	100	30	50	50	20	30	80	40	130	10	5	40	500

*The weight percentage of Mo in Mo powder 99,95 is determined by subtracting from 100% the sum of all metallic impurities tested for using mass spectrometry with an inductively coupled plasma ICP-MS. The gas-forming impurities C, O, N, H, S, F, Cl are not included in calculations of molybdenum percentage.
** ∑Me – the sum of metallic impurities

Dimensions, mechanical and structural characteristics, surface quality.

Mo-PM rolled products are made:

- with finishing by pressure shaping: hot-rolled (HR) with a thickness of 1-45 mm and cold-rolled (CR) with a thickness of 0.3 (0.2)-0.9 mm;
- based on the degree of rolling accuracy: products of normal and enhanced accuracy;
- based on materials used, hot-rolled sheets – annealed or without annealing with a surface cleansed of oxides, based on the client's order;
- in moderate dimensions with scissor-trimmed edges, or a plate with a mechanically milled or grinded surface with a thickness of more than 5 mm;
- with monitoring of the surface condition, mechanical properties and microstructure.

Dimensions and mechanical properties of Mo-PM grade sheets and plates

Thickness, mm	Tolerances, mm	Width, mm	Length, mm	σв, H/ mm² (kgf/ mm²), minimum	δ, %, minimum
0,2–0,4	±0,05 (0,03)	50–300	150–1000	*	*
0,5–0,7	±0,05	50–500	150–1350	*	*
0,8–0,9	±0,08	50–500	150–1350	690 (70)	8
1,0–2,0	+0,20–0,15	50–600	150–1600	690 (70)	8
2,2–4,0	+0,25–0,15	50–600	150–1250	690 (70)	10
4,5–6,0	+0,30–0,20	50–600	150–1000	640 (65)	8
6,5–10,0	±0,40	100–600	>150	**	**
10,5–20,0	±1,0	100–400	>150	**	**
20,5–30,0	±1,5	100–400	>150	**	**
>30 to 45	In accordance with plans agreed upon with the client				

* Sheets with a thickness of 0.7 and more are tangent bending-tested for parallelness with the following thicknesses in mm:
5 – for sheets with a thickness of > 0.2 to 0.5 mm;
8 – for sheets with a thickness of > 0.5 to 0.7 mm, inclusive.
** Mechanical properties of sheets (plates) with a thickness of more than 6 mm are determined at the client's request.
Norms are set based on agreement with the client.

Upon agreement with the client, sheets are delivered without determining their mechanical properties. In this case, the manufacturer guarantees mechanical properties in keeping with the standard.

Non-flatness:

- of sheets with a thickness of 1-3 mm does not exceed 2 mm per 100 mm of length;
- of sheets with a thickness of over 3 mm does not exceed 1 mm per 100 mm of length.

Surface condition:

rolled stock is delivered without cracks, slivers, backfins, rolled-in foreign particles, blemishes or edge lamination.

Annealing to remove internal stress:

hot-rolled sheets are manufactured with annealing to remove internal stress, or without annealing (based on the client's order) with a surface cleansed from oxides.

Microstructure:
in sheets (with a thickness of 1-6 mm) a full recrystalliation structure, lamination and foreign particles, tested for using supersonic defectoscopy, are not allowed.

Samples of the microstructure and mechanical properties of a Mo-PM sheet, annealed to remove internal stress:

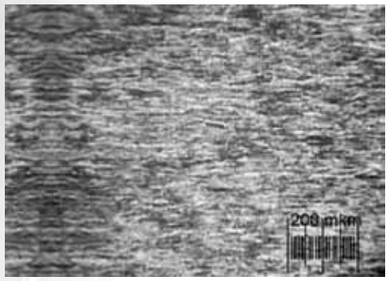


fig.1

fig.2

*Fig.1: A Mo-PM sheet with a thickness of 2 mm. Microstructure x100, transverse rolling.
*Fig.2: A Mo-PM sheet with a thickness of 5.4 mm. Microstructure x100, transverse rolling.

Chemical composition Mo99.95-PM.
High-quality raw materials – molybdenum powder with a purity of Mo 99.95-99.98% - are used to make the sintered semifinished products from which sheets are produced.

Chemical composition of Mo99.95-PM rolled stock

Mo 99.95-PM	Mo, %, minimum *	Maximum impurities, ppm									
		O	N	C	Fe	Al	Ni	Si	Mg	Ca	Σ Me**
Guaranteed composition	99,95	70	50	100	100	50	50	100	30	70	500
Typical values	>99,97	40-70	20-30	15-30	37-45	<10	<10	<10	<10	<10	<300

* Content of the base metal, not including gas-forming elements.
** Σ Me - total metallic impurities.
PM – Powder Metallurgy

Dimensions, mechanical and structural properties and surface quality
Mo 99,95-PM rolled stock is produced:
- based on finishing by pressure treatment – hot-rolled and cold-rolled;
- based on the condition of the material – thermally treated, with annealment to remove internal stress, unless the client makes other requests;
- based on the client's request – with an untreated surface following rolling, or with a mechanically or chemically cleansed surface, or with a surface treated mechanically with milling or grinding;
- based on the condition of the edges – with trimmed edges and ends or, at the client's request, with mechanically treated edges and ends.

Rolled stock dimensions and norms for maximum dimension deviations meet ASTM B 386 standards.

Maximum deviations for thickness of Mo99.95-PM grade rolled stock

Width, mm	Thickness, mm	Maximum thickness deviation
305 or less	from 0.3 to 0.51	±0,05 mm
	> 0,51	±10 %
from 305 to 610	> 0,64	±10 %

The thickness of rolled stock ranges from 0.3 (0.2) to 45 mm. Maximum width deviations are set based on agreement with the consumer, but do not exceed ±1.6 mm for trimmed sheets and ±0.8 mm for sheets with milled edges.

Maximum widths and lengths of thick sheets and mechanically treated plates prepared from them with a thickness of between 6 and 45 mm are set based on an agreement with the client, depending on his requests (drawing).

Sample dimensions for Mo99.95-PM large-size plates and sheets:
- 8x127x1575 mm;
- 8x400x800 mm;
- 10x305x1000 mm;
- 12x609x609 mm;
- 12x190x1470 mm;
- 16x610x710 mm;
- 18x244x1010 mm;
- 42x83x107 mm;
- 45x95x110 mm.

Maximum length and camber deviations do not exceed ±1.6 mm for a length of 304.8 mm, unless otherwise requested.

Maximum flatness (waviness) deviations for Mo99.95-PM rolled stock:
- < 4% for thicknesses from 0.3 to 4.75 mm;
- < 5% for thicknesses from 4.75 to 12.7 mm;
- < 8% for thicknesses from 12.7 mm of raw plates.

Surface condition: rolled stock is delivered without cracks, slivers, backfins, rolled-in foreign particles or blemishes.

Guaranteed mechanical properties of Mo99.95-PM rolled stock*

Thickness, mm	Tensile strength $\sigma_в$, N/mm² (kgf/mm²)	Relative elongation δ, %
	At least	
from 0.33 to 0.5	760 (77)	6
from 0.5 to 1.5	725 (74)	10
from 1.5 to 2.5	690 (70)	14
from 2.5 to 4.75	690 (70)	18
from 4.75 to 12.7	690 (70)	10
from 12.7 to 25.4	655 (67)	2**
from 25.4 to 38	655 (67)	1**

*property norms are established for materials after annealment in a protective atmosphere at a temperature of 900 °C during a 30 minute period
**parameters are determined using samples transverse to the direction of the rolling

Thin sheets with a thickness of less than 1 mm should withstand a bending test to an ordered angle of at least 90°.

Sample values for mechanical properties of molybdenum rolling stock

Thickness, mm	Tensile strength $\sigma_в$, N/mm² (kgf/ mm²)	Relative elongation δ, %	Hardness HB
1,0–1,3	78–85	13–16	217–240
1,9–2,5	79–88	18–21	229–240
3,0–5,4	75–82	18–25	210–229

Microstructure

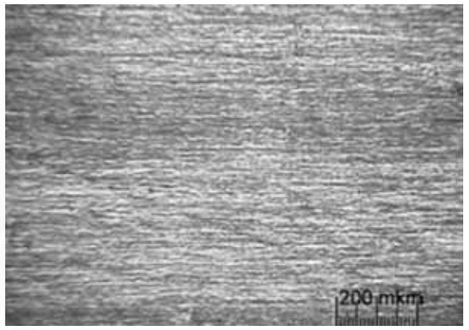


fig.3

*Fig.3: Sample structure of molybdenum sheet with a thicknes of 0.5 mm, transverse x100, following bending tests.

The manufacturer monitors the microstructure of rolled sheets. In thin sheets (less than 4.75 mm) no full recrystallization structure is permitted, unless otherwise requested by the client.

MOLYBDENUM BOATS

JSC POLEMA manufactures molybdenum boats in various shapes and dimensions for use in high-temperature devices in vacuum or in protective atmospheres for sintering products, reducing metal oxides, growing monocrystals, producing nuclear fuel, etc.

Boats are made from Mo-PM or Mo 99,95-PM sheet molybdenum by bending structural components and staves of units. The shape and dimensions of the boats depend on the client's request.

MOLYBDENUM RODS, FORGED PRODUCTS

Rods of the following grades are produced:
1. Mo-PM molybdenum rods and forged products;
2. Mo99.95-PM super-thin molybdenum rods.

Application.

Mo-PM and Mo 99.95-PM rods and forged products are used to make components of high-temperature vacuum and hydrogen furnaces, hot zones of sapphire smelting units, components of gas turbines, heat exchangers, eletrodes for smelting glass and basalt, etc. The thermionic properties of molybdenum are as follows: electronic work function of 4.29 eV, low vacuum evaporation speed and vapor pressure at 1000-2000 °C, allowing the metal to be used widely in various structures of electrovacuum devices and as thermoelectric energy converters. Pure unalloyed molybdenum prepared using the method of PM-Mo powder metallurgy (POLEMA analogues include Mo-PM, Mo 99.95-PM) is marked by good plastic characteristics after annealment for internal stress removal (ISR). The fraility threshold of Tx is in a temperature range well below room temperature. The σ_B PM tensile strength of ISR molybdenum in the range of high temperatures drops monotonically: 95-100 Mpa at T=1200 ^{0}C, 75-80 MPa at T=1400 ^{0}C, and approximately 50-40 Mpa at T=1600-1800 ^{0}C. The useful life of molybdenum products is affected by the metal's creep and vaporization in avacuum. The speed of molybdenum's vaporization is $2.07 \cdot 10^{-9}$ g/ cm^2 · sec at T=1727 ^{0}C; $7.3 \cdot 10^{-8}$ g/ cm^2 · sec at T=1927 ^{0}C; $5.03 \cdot 10^{-6}$ g cm^2 · sec at T=2227 ^{0}C. Nevertheless, in structures operating in static conditions (screens of vacuum furnaces) — sheets and rods made of molybdenum M-MP and M99.95MP that are used, for example, to outfit hot zones for growing sapphire monocrystals, function under working temperatures of 2000-2100 ^{0}C.

The temperatures of recrystallization of molybdenum are as follows: initiation at 900 ^{0}C, with full recrystallization commencing at 1100 ^{0}C (annealment within 1 hr). Once recrystallized, molybdenum is fragile at room temperature. In open air, molydbenum begins to oxidize at T=400 ^{0}C, while the speed of oxidation accelerates significantly at T > 600 ^{0}C.

These properties of pure unalloyed molybdenum determine the sphere of its application as a heat-resistant material.

1. Mo-PM MOLYBDENUM RODS AND FORGED PRODUCTS

Chemical composition

Current powder metallurgy methods ensure a high level of purity of molybdenum in terms of metallic interstitial impurities (C, N, O, H), the necessary microstructure for use as a heat-resistant construction material in electronics and other devices functioning in extremely high temperatures. The chemical composition of rods and forged products is ensured to meet or surpass the norms set for pristine molybdenum powder. Since 2002, the company has primarily used Mo powder 99,95 molydbenum powder in its products.

By virtue of its low content of interstitial impurities and metallic impurities, as well as its small-grain structure, finished products are distinguished by outstanding plastic characteristics.

Guaranteed chemical composition of Mo powder 99.95

Grade	Mo,% minimum*	Chemical composition,ppm,maximum												
		Fe	Al	Ni	Si	Mg	Na	K	Ca	W	Mn	Zn	C	∑Me**
Mo powder 99.95	99,95	100	30	50	50	20	30	80	40	130	10	5	40	500

*The weight percentage of Mo in Mo powder 99.95 is determined by subtracting the sum of all metallic impurities controlled for using mass-spectrometry with ICP-MS inductively coupled plasma. The gas-forming impurities C,O,N,H,S,F,and Cl are not included when calculing the share of molybdenum.
** ∑Me – total metallic impurities.

Dimensions of Mo-PM rods and forged products
Hot-rolled rods are produced with diameters of between 10 to 40 mm, and forged products (forged rods, cylinders, cubes, parallelipeds and sheets) with a diameter or rectangular edge of 30-300 mm to 1500 mm in length with a surface cleansed from oxides or tooled.

Annealment
At the client's request, products are manufactured with annealment for internal stress removal.

Tooling
At the client's request, rods and forged products are delivered with ground, turned or milled (for flat forged products) surfaces, whose dimensions and tolerances are determined by the consumer's drawings or order.

Microstructure
Microstructure is controlled in rods with a diameter of 30 mm or less. A full recrystallization structure is not permitted, unless otherwise requested by the client.

Guaranteed mechanical properties of hot-rolled rods Mo-PM

Diameter, mm	Tensile strength $\sigma_в$, N/mm^2 (kgf/ mm^2)	Relative elongation, δ %
	Minimum	
14,5–29	640 (65)	20
30–40	590 (60)	15

Upon agreement with the client, rods are delivered without any set mechanical properties with a guarantee that they meet the parameters established by the standard.

2. HIGH PRECISION Mo 99.95-PM MOLYBDENUM RODS

Guaranteed chemical composition

Grade	Mo,%, minimum*	Impurities, ppm, maximum											
		O	N	C	Fe	Al	Ni	Si	Mg	Na	K	Ca	Na	W
Mo99.95-PM	99,95	70	50	100	100	30	50	50	20	30	80	40	30	130
		Total content of metallic impurities < 500 ppm												

* The weight percentage Mo is determined by subtracting from 100% the total content of metallic impurities (without including gas-forming elements)

The share of molybdenum and the total content of metallic impurities is guaranteed and is set according to the client's request.

Sample chemical composition of 20 mm diameter rods*

Grade	Mo,%	Impurities, ppm, maximum												
		O	N	C	Fe	Al	Ni	Si	Mg	Na	K	Ca	Na	W
Mo99,95-PM	99,97	70	20	25	35	1	8	6	0,3	2,5	<10	40	30	130
		Total content of impurities 275 mcg/g not including H, C, N, O, F, P, S,Cl												

* The full analysis of the chemical composition is determined using inductively coupled plasma mass spectrometry (ICP-MS).

Deformation method
Hot rolling, extrusion, forging or cobbing.

Shapes of rods and forged products
Round, rectangular, or other cuts.

Surface finish
Rods are produced chemically cleansed of oxides or machined: tooled or ground. Local defects (with the exception of cracks, backfins and blemishes) on the surface of oxide-cleansed rods that do not cause the rods to exceed the maximum dimensions are permitted.

Roughness requirements for tooled rods are set based on the client's requests. Unless otherwise requested, the roughness of tooled rods is set at Ra 2.5 maximum and the roughness of ground rods at Ra 1.25 maximum.

Dimensions and tolerances for dimensions of round Mo 99.95-PM rods

Type	Diameter, mm	Diameter tolerances, mm	Ovality, mm, maximum
Ground	3,18 -12,7	±0,05	-
	> 12,7	±0,08	-
Turned	> 6–10	±0,18	-
	> 10–18	±0,21	-
	> 18–30	±0,26	-
	> 30–50	±0,31	-
	> 50–80	±0,37	-
	> 80*	±0,44	-
Without mechanical treatment, cleansed of oxides	3,18–7,14	±0,05	0,1
	>7,14–10,32	+0,25/-0,13	0,2
	>10,32–15,9	+0,25/-0,13	0,3
	>15,9–22,2	+0,38/-0,13	0,38
	>22,2–25,4	+0,51/-0,13	0,38
	>25,4–34,9	+0,51/-0,25	0,46
	>34,9–38,1	+0,51/-0,38	0,51
	>38,1–41,3	+0,64/-0,38	0,51
	>41,3–50,8	+0,76/-0,51	0,64
	>50,8–63,5	±0,81	0,64
	>63,5–82,6	±0,81	0,69
	>82,6–88,9	±1,14	1,02

* Maximum dimensions of turned rods with a diameter of more than 80 mm are determined based on agreement with the client.

Dimension intervals and maximum deviations of rod dimensions are set in accordance with the ASTM B 387 standard.

Rod length is established in accordance with the client's request.

Length tolerances are < ±6.35 mm.

Curvature < 1.27 mm for 305 mm of length.

Acceptable deviations for rod dimensions of rectangular or other cuts other than round cuts are established based on client request.

Guaranteed mechanical properties of Mo 99.95-PM rods

Diameter, mm	Tensile strength $\sigma_в$, N/mm² (kgf/ mm²)	Relative elongation δ, %	Vickers hardness HV10
	Minimum		
3,18 −10,32	515	15	Not specified
> 10,32 −22,2	620	18	230-280
> 22,2 −28,6	585	15	225-270
> 28,6 −47,6	515	10	215-260
> 47,6 -73	480	10	210-250
> 73 −88,9	450	10	205-240

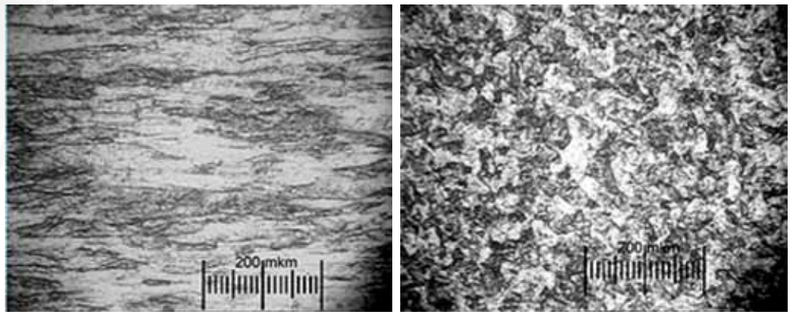
Norms of mechanical properties are set for material following annealment at 900 ^{0}C over the course of 0.5 hrs.

Thermal treatment and microstructure

Rods are thermally treated, with annealment for internal stress removal, unless otherwise requested by the client.

In the microstructure of rods with a diameter of 40 mm or less, full recrystallization structure is not permitted, unless otherwise requested by the client, and special requests regarding recrystallization annealing or structure parameters are agreed to.

Sample structures and mechanical properties of Mo 99.95-PM rods with a 20 mm diameter



Microstructure in longitudinal and transverse x 200
After annealing (for internal stress removal)
Average grain size is 20-30 μm.
Hardness HV10 230 kgf/mm²
Short-term strength at room temperature $\sigma_в$ 690 N/mm²
Relative elongation δ 33%.
Ultimate strength at 1800 °C $\sigma_в$ 40 N/mm², relative elongation δ 17%

MOLYBDENUM SPUTTERING TARGETS

Application:

Sputtering targets made from high-purity molybdenum are used in physical vacuum deposition technologies (PVD methods) for thin films and functional coatings in the production of solar battaries and integral circuits, in forming TFT-matrices of large-format LCD displays and in other technical spheres.

Guaranteed chemical composition of molybdenum products for sputtering targets

Grade	Mo,%*	Impurities, ppm, maximum							
		Fe	Al	Ni	Si	C	O	N	∑Me**
M99,95-PM	>99,95	100	50	50	100	100	70	50	<500

* Typical content of the base element Mo 99.97%
** Sum of metallic impurities

Product shape

Sheets, discs and rings, tooled in accordance with the product design.

Sheet dimensions

- thickness from 5 to 32 mm;
- width up to 550 mm;
- length up to 1500 mm.

Targets can be produced in the form of a set of end-joined parts of any width and any total set length.

Tolerances for dimensions and roughness are established based on the client's requests.

MOLYBDENUM CRUCIBLES AND PANS

Products made from molybdenum in the form of crucibles, pans and other shapes are meant for use in processes of sintering, vaporization of metals, smelting of oxide ceramics and growing of monocrystals.

Grades: Mo-PM base metal purity of at least 99.9 % Mo; Mo99.95-PM with a purity of at least 99.95 % Mo.

The density of sintered product material is at least 9.6 g/cm³; while deformed (forged) material is at least 9.9 g/cm³.

The shape and dimensions of products and requirements for the purity of surface treatment are based on the client's individual drawings.

MOLYBDENUM SCREENS

JSC POLEMA makes products from molybdenum and its alloys of various shapes and dimensions, used to equip high-temperature installations with hydrogen or vacuum atmospheres for processes of sintering, annealing, growing of monocrystals, etc.

Products: thermal screens, radiators, hot zones, etc. Depending on their construction, products are made using sheet materials made from molybdenum, and also from alloys based on molybdenum and other metals, fastening details made from molybdenum, and high-melting fillers (Mo, W, Mo-W).

Products are made based on the client's individual drawings.

MOLYBDENUM ELECTRODES

The glass industry is a major consumer of metallic molybdenum. Experience has shown molybdenum to be a superior material for electric heating during smelting of glass and basalt. This industry's use of molybdenum in the form of electrodes is conditioned by the following characteristics of the material:

- high elasticity modulus, resistance to plastic deformation and sufficient tensile strength at the melting temperatures of glass and basalt;
- good heat conductivity;
- a low coefficient of heat expansion;
- resistance to corrosion in molten solutions;
- no influence on the color or transparency of glass;
- good machinability.

Mo 99.95-PM electrodes are used in electric furnaces to smelt container and flat glass, technical glass and basalt. Smelting glass and basalt in electric furnaces makes it possible to conduct the boiling process with greater productivity.

The chemical purity of electrode material (99.95% Mo) and the special program of temperature-deformation processing of stock used at JSC POLEMA allows to get products with high density and resistance to creeping (deformation) at the working temperatures for glass boiling.

Characteristics

Electrodes are delivered in annealed condition in the form of tooled rods or plates based on drawings agreed upon with the client.

Based on the order, electrodes can be produced with connective cuts.

Electrode density is >99%, and Vickers hardness HV 10 ranges from 160 to 210.

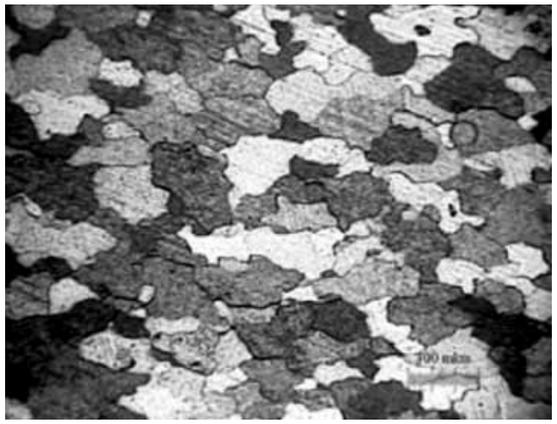
To increase resistance to creeping (bending, deformation), the average grain size of the microstructure of electrodes upon delivery is set within the range from 50 to 300 microns.

Dimensions of Mo 99,95-PM electrodes				
Electrode type	Diameter, mm	Tolerances, mm	Roughness	Length tolerances, mm
Turned	From 25 to 30	±0,26	2,5	<±6,35
	> 35 до 50	±0,31	2,5	
	> 50 до 80	±0,37	2,5	
Grinded	From 25 and more	±0,08	1,25	

Electrode lengths and diameters of more than 80 mm are set based on client's request.

Guaranteed chemical composition of Mo99,95-PM electrodes													
Grade	Mo,%	Impurities, ppm, maximum											
		O	N	C	Fe	Al	Ni	Si	Mg	Na	K	Ca	W
M 99,95-PM	>99,95	70	50	100	100	30	50	50	20	30	80	40	130
		∑Fe, Si, Ni, Al, W, Mg, Na, K, Ca <400											
		Total content of metallic impurities <500											

Sample chemical composition of Mo99.95-PM electrodes of various diameters													
Electrode dimensions	Mo, %	Impurities, ppm											
		O	N	C	Fe	Al	Ni	Si	Mg	Na	K	Ca	W
Ø48x1000	>99,95	60	20	27	44	10	10	10	10	10	30	10	130
Ø50,8x631		40	20	50	43	10	10	10	10	10	20	10	115
Ø63x1000		70	20	14	37	10	10	10	10	10	30	10	130



The structure of a Mo 99.95-PM large-grain electrode, which ensures high resistance to creeping

Advantages:

- high purity of the material;
- minimal content of interstitial impurities;
- maximal density;
- homogenous structure throughout the entire length;
- high tensile strength and operating endurance;
- lack of effect on the color and transparency of glass;
- good machinability.

MOLYBDENUM ALLOYS MoW, MoLa AND OTHERS

Some properties of molybdenum that are important for industrial use include its high melting point, high elasticity modulus, low temperature linear expansion

coefficient, good plasticity at low and room temperatures, heat-resistance, high electric and heat conductivity, relatively small capture cross-section of thermal neutrons and almost half the density of tungsten.

Some drawbacks of molybdenum as a construction metal are its susceptibility to oxidation at temperatures higher than 500-700 °C and the fact that it is not sufficiently heat resistant to be used in conditions of extremely high temperatures and lengthy loads. Alloying of molybdenum has practically no effect in terms of eliminating the first drawback, but does make it possible to significantly raise the recrystallization temperature, tensile strength and creep resistance at high temperatures, and, for dispersive hardening — for example, using lanthanium oxide — to increase heat resistance and improve plastic properties (lower the frailty threshold).

Below is the list of products made from alloyed molybdenum:

1. **Hot-rolled sheet from molybdenum-tungsten alloy MoW-PM.**
2. **Extruded and tooled products from molybdenum-tungsten alloy MoW-2-PM.**
3. **Crucibles from molybdenum-tungsten alloy.**
4. **Products from molybdenum, tungsten and their alloys for high-temperature furnaces.**
5. **Products from the molybdenum-tungsten alloy MoW10-PM for sputtering targets.**
6. **Rolled stock and products from lanthanium-treated molybdenum MoLa-PM.**
7. **Stock materials made from MoWCu-PM.**
8. **Tooled stock materials made from MoY-PM molybdenum alloy.**

1. HOT-ROLLED SHEETS FROM MoW-PM MOLYBDENUM- TUNGSTEN ALLOY

Use

The molybdenum alloy MoW, strengthened by forming a solid solution with tungsten (nominal composition by mass percentage: Mo 70%, W 30%, content of alloying component ±2%), boasts a higher recrystallization temperature than molybdenum (as high as 1200 °C with a deformation ratio of 90%), resistance to high temperatures, resistance to corrosion and creep (creeping at high temperatures).

Rolled stock made from MoW alloy is used to make components for high-temperature furnaces, electrodes for power semiconductors and other purposes.

Dimensions of sheets made from MoW-PM alloy		
Thickness, mm	Width, mm	Length, mm
0,8–0,9	From 30 to 300	From 80 to 1000
1,0–3,0	Up to 500	Up to 1000
3,1–15	Up to 500	Up to 1000

Sheets are delivered annealed for internal stress removal and with tested microstructure.

Guaranteed mechanical properties of sheets at room temperature		
Sheet thickness, mm	Tensile strength $\sigma_в$, N/mm² (kgf/ mm²), minimum	δ, %, minimum
	Sheet properties, transversal direction	
0,8–0,9	830 (85)	8
1,0–3,0	780 (80)	8
3,1–6,0	780 (80)	6

Mechanical properties of small-scale sheets (thickness of up to 110 mm, length up to 250 mm) are set based on the client's request.

2. EXTRUDED STOCK FROM MoW-2-PM ALLOY

Use

Products made from strengthened MoW-2-PM molybdenum-tungsten alloy are used to produce components operating in difficult, stressed environments at increased temperatures (up to 2100 °C).
Stock is produced using powder metallurgy, with technical support from specialists at the Central Science and Research Institute for Materials (OAO CSRIM) and the Powder Metallurgy Institute at the Central Science and Research Institute for Iron Metallurgy (PMI FGUP named after I.P. Bardin "CSRIIM").

Stock dimensions

Tooled stock is produced in the following dimensions:

- round, with diameters of Ø 36, 53;
- rectangular, cut to 64x46, with a length of at least 350 mm.

The surface roughness of tooled products does not exceed 6.3 microns.

At the client's request, products with other dimensions can be produced.

Stock is delivered having undergone thermal treatment and with testing for microstructure and mechanical properties.

Guaranteed mechanical properties of MoW-2-PM extruded stock								
Dimensions, shape, mm	Thermal treatment variant *	Specimen type**	Mechanical properties (minimum) at testing temperature					
			20 °C		150 °C		1800 °C	
			$\sigma_в$, MPa	δ,%	$\sigma_в$, MPa	δ,%	$\sigma_в$, MPa	δ,%
64x46	A	lengthwise	650	5,0	n/a	n/a	50	5,0
		transverse	500	1,0	500	2,0	50	5,0
	B	lengthwise	500	5,0	n/a	n/a	45	5,0
		transverse	450	2,0	450	2,0	45	5,0
Ø 53	A	lengthwise	650	5,0	n/a	n/a	50	5,0
		transverse	500	0	500***	2,0***	50***	5,0***
Ø 36	B	lengthwise	500	5,0	n/a	n/a	45	5,0
		transverse	450	0	450***	2,0***	45***	5,0***

Notes:
* Thermal treatment variant
A – at 1300 °C
B – at 1400 °C
** Specimen type:
lengthwise, transverse – direction of the specimen's cut with regard to the direction of extrusion.
*** properties not determined, guaranteed by the technology
n/a – properties not determined

With a relative elongation of δ ≥ 2%, a conditional yield limit of $\sigma_{0,2}$ is achieved. Typical values for mechanical properties exceed the guaranteed parameters by 15-35 %.

Sample actual characteristics of extruded and annealed (for internal stress removal) rods from MoW-2-PM alloy at room temperature and at 1800 °C					
d ,мм *	ε ,% **	$\sigma_в$, MPa	δ,%	$\sigma_в$, MPa	δ,%
		20 °C		1800 °C	
53	75	760	11,8	57,6 / 54,8	22,6 / 14,0
36	79	790	16,0	62,0 / 61,2	24,0 / 14,0
Note: * rod diameter ** deformation ratio					

Figures including fractions (/): the numerator indicates data obtained during testing of lengthwise specimens, and the denominator indicates data for transverse specimens.

3. MoW30-PM CRUCIBLES FROM MOLYBDENUM – TUNGSTEN ALLOY

Use

MoW30 molybdenum-tungsten alloy, strengthened with a solid solution of tungsten, features temperature resistance and creeping resistance that is higher than molybdenum, and higher machinability than tungsten.

MoW30-PM crucibles made from sintered and forged molybdenum-tungsten alloy are used primarily to melt corundum in technologies for growing extremely pure sapphire monocrystals.

Chemical composition of crucibles

Molybdenum is the base, with 28-32% tungsten. The alloy may be additionally strenghened with admixtures of B, Hf, Y, Zr, C.

Shape and dimensions

Crucibles are produced in accordance with drawings. The shape and dimensions are agreed upon with the client. Surface roughness of tooled crucibles does not exceed Rz 6.3.

Crucible density:

Sintered MoW30-PM crucibles – at least 10.9 g/cm^3
Forged MoW30-PM crucibles – at least 11.2 g/cm^3

Recommendations on crucible storage and use.

Recommendations on the use, transport and storage of crucibles can be found in the section entitled “Tungsten. Tungsten Crucibles”.

4. PRODUCTS MADE FROM MOLYBDENUM, TUNGSTEN AND THEIR ALLOYS FOR USE IN HIGH-TEMPERATURE FURNACES

Use

Products made from molybdenum, tungsten V-MP, and the molybdenum alloys MoW30-PM (MoW30), MoLa-PM are used to outfit vacuum and hydrogen furnaces, the heat zones of units for smelting quartz glass and growing sapphire monocrystals, furnaces for the annealment of uranium fuel in the manufacture of fuel rods and for the production of components for high-temperature heat exchangers, thermoelectric converters and other devices that operate at high temperatures.

Shape and manner of production

Products are made in sintered form or from deformed (by forging or rolling) stock (sheets, plates, forced products, rods) according to the client's drawings or according to a manner of production, geometric dimensions and tolerances for dimensions and surface roughness submitted by the client.

Products are made in simple shapes: tooled discs, slabs, rings, plates, substrata, bearing plates, rods, or electrodes; or in complex shapes: thermal screens, radiators, boats, fastening details, etc. Additional requirements regarding product specifications are set based on the client's request.

Recommendations on use

Before use, thermal screens and other products used in acustomer's vacuum furnaces should be annealed in a vacuum of p<10^{-4} mmhg (torus) in the following manner:

- heat to 1000 °C for over a period of at least 3 hours,
- hold at approximately 1000 °C for at least 1 hour,
- heat to 1400-1500 °C over a period of at least 1 hour,
- hold at approximately 1400-1500 °C for at least 1 hour,
- heat to 2000-2200 °C over aperiod of at least 1 hour,
- hold at approximately 2000-2200 °C for at least 1 hour,
- cool the products in the furnace.

During use, the products should not be subjected to shocks.

5. PRODUCTS FROM MOLYBDENUM-TUNGSTEN ALLOY MoW10-PM FOR SPUTTERING TARGETS

Use

Products made from MoW30-PM (MoW10) molybdenum-tungsten alloy are used as sputtering targets in technologies of thin films to produce electronic components and other functional coatings, as well as to produce components for high-temperature vacuum and hydrogen furnaces.

Guaranteed chemical composition of MoW10-PM 99.95% products	
Element	Mass percentage
Mo+W	99.95% minimum
W	(10,0±1,0) %
Impurities, ppm, maximum	
Fe	100
Al	50
Ni	50
Si	100
Total metallic impurities	500
C	100
O	70
N	50

Other requirements for the products' chemical composition may be agreed upon based on the client's requests.

Product shape and dimensions

Products are made in the form of tooled plates, discs, rings, cylinders (rods) and in simple and complex shapes.

The shape and dimensions of products and surface characteristics are determined based on drawings agreed upon with the client.

6. ROLLED STOCK AND PRODUCTS MADE FROM MoLa-PM LANTHANUM-TREATED MOLYBDENUM

Use

In the late 1990's, a molybdenum alloy dispersion-strengthened with lanthanum oxide — so-called ODS-Mo — won widespread recognition and use abroad. POLEMA produces an alloy of this kind, under the brand MoLa-PM (lanthanum-treated molybdenum).

ODS-Mo is recommended as a more stable material for replacing other molybdenum alloys in a number of spheres for use in high (1600-1800 °C and higher) temperatures:

- electric engineering: radiators, thermal screens, circuit breaker parts and

incandescent lamp parts;

· atomic energy and power systems: creep-resistant boats for smelting nuclear fuel, high-temperature springs, high-temperature convertors, vanes and tracks for cyclical turbines;

· the space and rocket industry: parts for jet apparatuses, high speed engines, and rocket combustion chambers;

and other industries.

Lanthanum oxide, introduced into the system and enveloping molybdenum grains, serves as a displacement barrier to dislocations during the deformation process, which allows the alloy structure to stabilize; with small grain sizes, it ensures ultimate strength and resistance to creep at high temperatures. Other well-known industrial alloys — for example, stabilized with carbides of titanium and zirconium — of the type Mo-TZM (Mo-0,5Ti-0,08Zr, 0,01-0,04C mass %) и Mo-TZC (Mo-1,2Ti-0,3Zr, 0,25C mass %), are less stable, since at high temperatures the carbide constituent becomes coarse or dissolves within the molybdenum matrix.

Molybdenum alloy that has been dispersion-reinforced with lanthanum oxide has the following advantages over molybdenum: a significantly lower cold shearing threshold following annealment (with internal stress removal), higher tensile strength at room temperature,high plasticityin arecrystallized state,more than 1.6 times greater tensile strength at 1600 °C, and significantly higher (an order of magnitude greater) resistance to deformation during tests for long-term tensile strength at 1800 °C when compared with unalloyed molybdenum obtained through arc melting or the PM method.

Guaranteed chemical composition of rolled stock and products made from lanthanum-treated MoLa-PM brand molybdenum

Element	Mass percentage
Mo	basis
La	0,40±0,07 %
Impurities, ppm, maximum	
Fe	100
Al	30
Ni	50
Si	50
Mg	20
Na	30
K	80
Ca	40
W	130
Total metallic impurities	500
C	100

Product shape and dimensions

Products made from MoLa-PM are produced in the form of rolled sheets, slabs, plates, discs, forged rods, boats, screens, and radiator components.

Sheet it produced with thickness of 0.5 mm or greater.

Below are the guaranteed tolerances for dimensions and surface quality of rolled stock:

thickness ±0.10 %;

width ±0.8 mm;

length ±1,6 mm per 304,8 mm of length;

roughness of a milled or ground surfaces shall not exceed 40 Rz.

Concrete dimensions and tolerances for thickness, width and length of rolled stock, forged stock or tooled products, including requirements for surface roughness, are set in accordance with client requests. Unless otherwise specified, the roughness of a milled or ground surface does not exceed Rz40.

Products with complex shapes are produced based on plans.

Mechanical properties of MoLa-PM rolled stock

Width, mm	Tensile strength $\sigma_в$,N/mm² (kgf/mm²)	Relative elongation δ, %
	Minimum	
From 1.0 to 2.0 mm inclusive	690 (70)	5
> 2.0 to 4.0 mm inclusive	690 (70)	10
> 4.0 to 6.0 mm inclusive	640 (65)	8

Sheets with a thickness of less than 1 mm undergo bend testing with a bending angle of at least 90°.

Sample actual characteristics of MoLa-PM rolled sheet and forged rods

Material	Test temperature, °C	Tensile strength $\sigma_в$, kgf/mm²	Relative elongation δ, %
Sheet Mo-La-PM 2.0-3.0	20	88-98	10-12
Rod Mo-La-PM Ø 9.5	20	74-75	30-35
Rod Mo-La-PM Ø 20	1400	8,2-9,0	31-39
	1800	6,3	9,2

Mo-La-PM material dispersion-strengthened with lanthanum oxide shows excellent resistance to creeping. Its operational life in the form of screens and radiators in resistance furnaces is more than twice the useful life of components made of pure molybdenum. The material maintains its fibrous structure throughout extended operation at high temperatures. Moreover, radiator and screen components made of 0.4-0.5 mm maintain plasticity at room temperature in a recrystallized state.

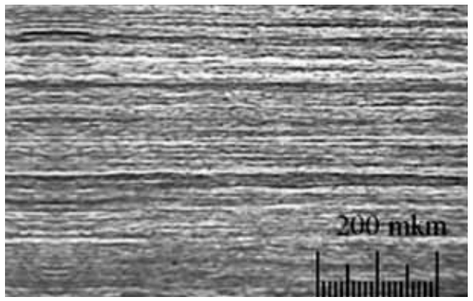


fig.2
Microstructure of MoLa-PM sheet with a thickness of 1 mm
Distribution of lanthanum in the structure of dispersion-strengthened molybdenum MoLa-PM

7. STOCK MADE FROM MoWCu-2-PM MATERIAL

Stock is produced using powder metallurgy with technological support from specialists at the Institute of Powder Metallurgy at the Central Science and Research Institute for Iron Metallurgy (IPM FGUP “CSRIIM” named after I.P. Bardin).

Use

Compositional material based on molybdenum-tungsten alloy infiltrated with copper shows tensile strength at high temperatures and resistance to gas erosion. It is used to make parts for new equipment operating at high temperatures and with dynamic loads.

Material characteristics

Currently, MoWCu-2-PM material is used to produce tooled stock in cylindrical form with a diameter of 50 or 70 mm. At the client's request, products of other shapes and dimensions can be produced.

The stock's density following infiltration of the sintered frame is at least 11.0 g/cm^3.

8. STOCK MADE FROM MoY-PM MOLYBDENUM ALLOY

Stock is produced using powder metallurgy with technological support from specialists at the Institute of Powder Metallurgy at the Central Science and Research Institute for Iron Metallurgy (IPM FGUP "CSRIIM" named after I.P. Bardin).

Use

Dispersion-strengthened deformed MoY-PM molybdenum alloy is intended for use in preparing parts capable of working for extended periods at high temperatures.

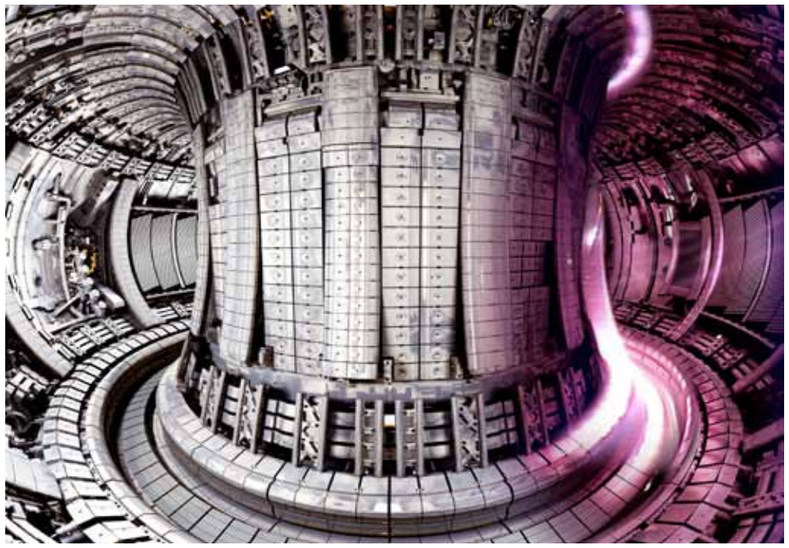
Material characteristics

Currently, tooled stock made from MoY-PM alloy is produced in the form of rods with a diameter of 66 mm and a length of no less than 310 mm, and with a diameter of 90 mm and a length of no less than 230 mm. Surface roughness does not exceed 6.3 microns. At the client's request, products of other dimensions can be made according to drawings.

Product microstructure is monitored using an optical microscope, while the absence of internal flaws is checked for using ultrasound.

Guaranteed product mechanical features				
Material	Minimal mechanical properties of semifinished products in end-fire direction based on temperature,°C			
	20		1800	
	$\sigma_в$, N/mm^2 (kgf/ mm^2)	δ,%	σв, N/mm^2 (kgf/ mm^2)	δ,%
MoY-PM	500 (51)	8,0	27,0 (2,75)	20

TUNGSTEN



Thanks to its exceptional refractory property and high structural behaviors, tungsten is the most promising base for materials and products that operate under high temperatures and radiation levels.

Tungsten in the VI A group is marked by maximal interatomic bond strength, a melting temperature (3420 °C) that is the highest among high-melting metals, a high density of 19.3 g/cm^3, high tensile strength, head conductivity, hardness (HV30 >460), resistance to creep and stress rupture (significantly higher than molybdenum, tantalum or niobium at a temperature, for example, of 1100 °C). Compared to molybdenum, pure tungsten has a higher recrystallization temperature of approximately 1350 °C, a vapor pressure and vaporization rate of 4-5 times less, a lower thermal expansion coefficient ($4.2 \cdot 10^{-6}$ at 20 °C) and a low electric resistance ($0.05 \cdot 10^{-6}$ Om·m).

Since 1965, JSC POLEMA has been actively developing production of high-purity tungsten powder and rolled stock, as well as tungsten-based composite materials.

The cutting-edge powder metallurgy technologies used at JSC POLEMA ensure that our tungsten is largely free from metallic interstitial impurities (C, N, O, H) and has the small-grained structure necessary for application in the electronics industry and as a heat-resistant construction material in electronics and other devices that work at extremely high temperatures.

JSC POLEMA produces a wide range of tungsten products that boast outstanding properties and meet the most stringent requirements.

Our tungsten products are made from tungsten powder manufactured in-house.

Tungsten oxide with a mass fraction of WO_3 99.99 % is used as the starting material, which guarantees a high level of purity in the resulting powder and, as a result, high purity in the products made from it.

Tungsten-based products include the following:

- Tungsten powder
- Tungsten sheets, plates and sputtering targets
- Tungsten crucibles
- Tungsten-based composites W-Cu, W-Ni-Cu

Typical chemical composition of tungsten powder PW 99.95 used in production					
Element	Ppm	Element	Ppm	Element	Ppm
Li	< 0,01	Cr	≤ 2	Ru	< 0,01
Be	< 0,01	Mn	≤ 0,1	Cd	< 0,1
B	< 0,1	Fe	≤ 15	In	< 0,01
C	≤ 30	Co	< 0,2	Sn	< 0,2
N	≤ 11	Ni	≤ 12	Sb	≤ 1,6
O	≤ 170	Cu	≤ 1	Cs	< 0,1
Na	≤ 6	Zn	< 0,1	Ba	< 0,1
Mg	≤ 0,3	Ge	< 0,01	Ta	≤ 4
Al	≤ 7	As	≤ 7	W	matrix
Si	< 5	Se	< 0,1	Pt	< 0,1
P	< 10	Rb	< 0,1	Tl	< 0,1
K	≤ 10	Sr	< 0,1	Pb	≤ 0,3
Ca	≤ 6	Y	< 0,01	Bi	< 0,1
Sc	≤ 0,1	Nb	≤ 1	U	≤ 2,2
Ti	≤ 0,6	Mo	≤ 38	S	≤ 30
V	≤ 0,3	Rh	< 0,01		
Ga, Zr, Pd, Ag, Te,La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Re, Ir, Au, Th in each					<0,05

Various equipment for high-temperature vacuum and hydrogen furnaces (heat screens, heaters, trays, racks, and other fastening components) are made from pure tungsten, as are crucibles for melting corundum in sapphire growing technologies, crucibles for thermal vaporization of substances in technologies for vacuum deposition of thin films, plasmatron electrodes, igniter systems in internal combustion engines and devices for measuring the concentration of acid solutions in electrochemical processes.

Tungsten sputtering targets made from high-grade tungsten are used to deposit thin barrier films during the metallization of semiconducting components of integrated circuits.

Heat-resistant rocket parts operating under extremely high temperatures and intense gas erosion are made from tungsten and its alloys.

Tungsten's low vapor pressure allows it to be used at high temperatures (up to 2300 °C) as an electron emitter in thermoionic convertors.

In the nuclear power industry, tungsten is used in the form of screens for weakening the flow of radiation, ensuring the functionality of elements facing the plasma under high radiation and thermal-cycle stresses (the divertor in a thermonuclear reactor).

Porous, sintered tungsten is a promising material for use in ionizers in plasma-ion engines.

TUNGSTEN SHEETS, PLATES, SPUTTERING TARGETS

Use

Tungsten sheets and plates are used in high and extremely high temperatures, as equipment for high-temperature furnaces (heat screens, supports and other reinforcing elements) and also in the aerospace industry.

Thanks to its high absorbency of X- and gamma-rays, tungsten is widely used in the form of screens for weakening the flow of nuclear radiation in the nuclear power industry, in collimators and in radiotherapy.

Tungsten sputtering targets made in the form of plates are used to deposit thin barrier films during the metallization of semiconducting components of integrated circuits.

Sheets from W-PM tungsten

Chemical composition

Sheets are made from tungsten powder reduced with hydrogen from tungsten oxide. Tungsten oxide with a mass percentage of WO_3 99.98 % (the typical value is 99.99 % WO_3 without including gas-forming elements) is used as raw material.

An example of the chemical composition of tungsten powder PW1, PW2

Grade	W,%	Element contents, ppm											
		Na	Al	Si	P	K	Ca	Ti	V	Fe	Ni	Mo	∑As,Cd, Sn,Sb,Pb, Bi
PW1	>99,98	6	7	<5	10	10	6	0,6	0,3	15	12	38	<9,5
		∑ of impurities, not including C, N, O, H, F, P, S, Cl < 122											
PW2	>99,98	0,5	1	6	6	50	10	0,1	2	10	5	55	<3
		∑ of impurities, not including C, N, O, H, F, P, S, Cl < 160											

Dimensions and surface condition

W-PM sheets and plates are made with a thickness of between 0.5 and 45 mm, with trimmed edges, or tooled in accordance with the client's needs.

The roughness of tooled surfaces is set at Ra < 10 microns.

Thickness, mm	Width, mm	Length, mm
From 0,5 to 0,7	From 20 to 250	From 50 to 1000
> 0,7 to 5,0	From 30 to 310	From 50 to 1000
> 5,0 to 7,0	From 30 to 320	From 50 to 700
> 7,0 to 15,0	From 30 to 305	From 50 to 350
> 15,0 to 20,0	From 30 to 250	From100 to 300
> 20 to 45	Up to 150*	Up to 250*
*Width and length are set depending on the plate's thickness.		

Sheets and plates may be made with other maximum dimensions for width, length and thickness — for example, with a thickness starting at 0.3 mm — based on the client's request.

Nonflatness

The nonflatness of thin sheets with a thickness of up to 3 mm is as follows: < 2 mm per 100 mm of length; and, for sheets with a thickness of more than 3 mm with no tooling: < 1 mm per 100 mm of length.

At the client's request, sheets are produced with more rigorous nonflatness requirements.

Lack of internal defects, microstrucure, density

At the client's request, sheets and plates are delivered with control for micro- and macro-structure, mechanical properties and density.

Sample microstructures of tungsten sheets with controlled parameters

fig.1 fig.2 fig.3

*Fig.1: W-PM sheet, thickness 1 mm, x100, density of material 19.21 g/cm^3, hardness HRC 46

*Fig.2: W-PM sheet, thickness 5 mm, x100, density of material 19.25 g/cm^3, hardness HRC 44

*Fig.3: W-PM plate, thickness 8 mm, x100, density of material 19.25 g/cm^3, hardness HRC 43

Rolling of precision sheet W99,95-PM

Requirements for the chemical composition and dimensions of W99.95-PM rolled stock are set that meet the ASTM B760 standard, along with heightened surface quality requirements with respect to State Standard 23922 for W-PM sheet.

Dimensions, surface condition

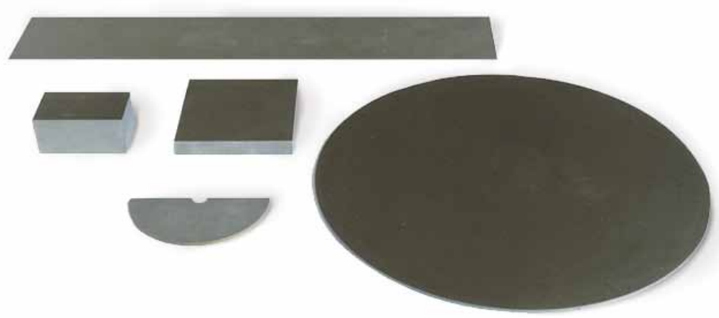
Thickness, mm	Thickness tolerances, % maximum	Width, mm	Length, mm
From 0,5 to 1,0	±10	From 10 to 200	From 50 to 1000
> 1,0 to 15,0	±10	From 10 to 310	From 50 to 1000
> 15,0 to 40,0	±10	From 10 to 310	From 50 to 600

Maximum deviations for rolled stock width

Thin sheet from 0.5 mm to 4.75 mm is made with trimmed edges (ends), with a width tolerance of ± 1.6, or with tooled ends with a width tolerance of ± 0.8 mm, unless otherwise requested by the client.

Maximum rolled stock length deviations do not exceed ± 1.6 mm per 304.8 mm of length, and camber is no more than 1.6 mm per 304.8 mm of length, unless otherwise requested by the client.

Deviations from flatness (undulation) depending on the thickness of rolled stock	
Thickness, mm	Flatness deviation, %, maximum
From 0.5 to 4.75	4



Surface roughness of tooled rolled stock

The parameter for roughness of a milled surface is no more than Rz 40; the parameter for roughness of a ground surface is no more than Ra 1.6.

Thermal treatment

Following pressure treatment, rolled stock is annealed for internal stress removal, unless the client has other needs regarding the condition of the material.

Chemical composition of W99.95-PM rolled stock

W99.95-PM is made from the same reduced tungsten powder as W-PM grade rolled stock (see above).

Guaranteed chemical composition of W99.95-PM rolled stock								
Grade	W,% minimum*	Impurities content, ppm, maximum						
		Fe	Al	Ni	Si	C	O	N
W99.95-PM	99,95	80	50	50	50	50	100	100
* the mass percentage of tungsten is determined by subtracting from 100% the total of controlled metallic admixtures,without including the gas-forming elements C,O, N,S,H,F,Cl.								

Sample chemical composition of W99,95-PM sheet 3.5 mm														
Grade	W,%	Impurities content, ppm *												
		C	O	N	Fe	Al	Ni	Si	Ca	Na	K	Mo	P	S	As
W99.95-PM	99,986	15	40	20	13	2	15	6	6	6	20	45	<1	10	1
* the total content of metallic impurities, determined using mass-spectrometry with inductively couple plasma(ICP-MS), does not exceed 0.0138 % (138 ppm).														

Tungsten sputtering targets W99.95-PM

Tungsten sputtering targets are made in the form of tooled plates and discs with dimensions and surface conditions set according to the drawings agreed upon with the client.

Guaranteed chemical composition of W99.95-PM sputtering targets								
Grade	W,%, minimum*	Impurities content, ppm, maximum						
		Fe	Al	Ni	Si	C	O	N
W99.95-PM	99,95	80	50	50	50	100	100	100
		∑ of metallic impurities < 500 **						
* the mass percentage of tungsten is determined by subtracting from 100% the total of controlled metallic impurities without including the gas-forming elements C, O, N, S, H, F, Cl. ** metallic impurities are determined using mass-spectrometry with inductively coupled plasma (ICP-MS).								

Advantages:

- the chemical purity of products from metallic impurities and harmful interstitial impurities ensures better mechanical characteristics of the material and operating properties of the products when working at high temperatures or with radioactive loads
- it is possible to deliver rolled stock and products ranging from thin sheets to large-size plates tooled according to the client's plans
- homogenous microstructure
- varied product design to satisfy the client's individual needs

TUNGSTEN CRUCIBLES

Use

Tungsten crucibles, thanks to their resistance to certain molten metals and metal oxides, have found wide use in technologies for growing monocrystals from molten corundum, as well as in electronics and technologies for thermal vaporization-deposition of various substances.

Chemical composition

Guaranteed chemical composition of the material in tungsten crucibles W-PM										
Grade	W,%, minimum	Impurities, ppm, maximum								
		Fe	Ni	Al	Mo	Si	K	Na	Ca	As
Cru-cible W-PM	99,0	80	50	10	400	30	200	150	50	50

Upon agreement with the client, crucibles can be prepared with additions of molybdenum of up to 0.9%, and with other requirements regarding the material's chemical composition.

Shapes, dimensions and surface condition of W-PM crucibles

Crucibles are made in accordance with drawings. The shape and dimensions are agreed upon with the client. The surface roughness of tooled crucibles does not exceed Rz 6.3.

Sample dimensions of sintered tungsten crucibles W-PM, diameter Ø x height, mm:

- Ø130x150;
- Ø200x240;
- Ø240x300;
- Ø250x350-400;
- Ø330x350;
- Ø330x450;
- Ø338x460;
- Ø350x460
- Ø350x495
- Ø380x530

Modestly sized crucibles made form tungsten — for example, with diameters of 40-50mm — can be produced based on drawings agreed to with the client.

Crucible density:

- Sintered crucibles W-PM – at least 17.8 g/cm^3;

Advantages:

- the products' fairly high chemical purity, which ensures sapphire monocrystals free from impurities;
- a fairly wide selection of standard product sizes, to quickly fulfill consumers' order;
- the ability to develop products with new sizes based on the client's individual needs.

Recommendations on using and storing crucibles

Before use, it is recommended that the consumer anneal (de-gas) crucibles in a vacuum without batch charging.

In a furnace, the annealment process should be supported with a vacuum at $P < 10^{-4}$ mmhg.

Heating and cooling technique:

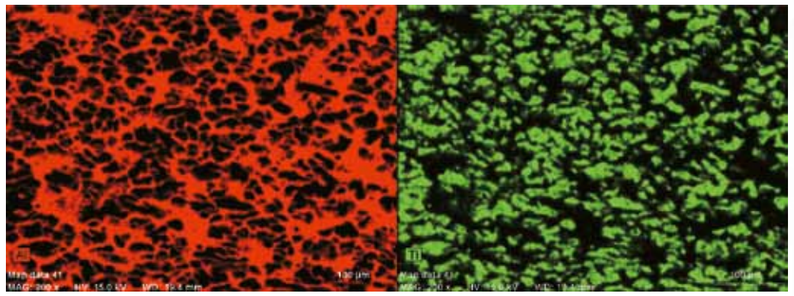
1. raise temperature (T) to 1000 °C over a period of 3 hrs;
2. hold at T=1000 °C for at least 1 hr;
3. raise to T=1400-1500 °C for at least 1 hr;
4. hold at T=1400-1500 °C for at least 1 hr;
5. raise to T=2000-2200 °C for at least 1 hr;
6. hold at T=2000-2200 °C for at least 1 hr;
7. cool crucibles in furnace.

When preparing a crucible for work, the consumer should not allow a sharp rise or fall in temperature or abbreviate the recommended time periods for holding temperatures.

While preparing the crucible for work and during operation, it should not be subjected to shocks.

The manufacturer packs crucibles into wooden packaging (crates) with crash pads. During transport and storage, the crucibles are not submitted to sharp jolts or shocks. They are stored in the manufacturer's packaging in closed, dry and heated warehouses.

ALUMINUM-TITANIUM, CHROMIUM, ALUMINUM-CHROMIUM SPUTTERING TARGETS, EVAPORABLE CATHODES



POLEMA sputtering targets and evaporable cathodes are produced from various Al-Ti, Al-Ti-Si, Cr and Al-Cr compositions

Sputtering targets and evaporable cathodes made from Al-Ti composites:

Grade, nominal composition, mass %	Com-position, atomic %	Chemical composition, maximum mass %								minimum density, g/cm³
		C	N	O	S	Mg	Fe	Ni	Si	
Ti37Al63-PM	Ti /Al 25/75	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,11
Ti43Al57-PM	Ti /Al 30/70	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,20
Ti47Al53-PM	Ti/Al 33/67	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,26
Ti54Al46-PM	Ti/Al 40/60	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,38
Ti59Al41-PM	Ti/Al 45/55	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,46
Ti64Al36-PM	Ti/Al 50/50	0,1	0,1	0,5	0,01	0,005	0,12	0,1	0,1	3,55
TI43AL49SI8-PM	TI/AL/SI/ 30/60/10	0,1	0,1	0,5	0,01	0,005	0,15	0,1	8±1	3,14

PM – Powder Metallurgy

The other composites from other components can be created at the client's request.

Modern materials for multi-functional hardsurfacing coatings

Our materials for applying hardsurfacing coatings using physical vacuum deposition (PVD) methods are oriented toward the synthesis of multi-functional coatings which, along with extreme hardness, boast a low friction constant, high tenacity, heat resistance, corrosion resistance, chemical inertness with respect to working material and high resistance to plastic deformation and abrasive wear.

Some advantages of POLEMA materials for hardsurfacing coatings:

- The materials reflect current trends in the creation of multi-functional hardsurfacing coatings in metalworking, the aviation industry and power engineering.
- The coatings make it possible to dramatically increase the strength of cutting and stamping instruments, to perform high-speed metalworking without metal-working oil, to increase erosion resistance and the endurance strength of machine parts.
- A wide selection of compositions makes it possible to control the chemical composition and structure of the coatings, synthesize multi-layer nitride, gradient and nano-structured hardsurfacing coatings for application in various spheres of metalworking, including under conditions of cyclical thermo-mechanical stress.
- The design of sputtering targets and evaporable cathodes is aimed at various types of vacuum units and various kinds of ion-assisted coating deposition.
- All products are made based on the customer's specifications. The materials used are marked by a homogenous microstructure and vacuum tightness.

Product form and dimensions

Shape of machine-finished products	Diameter, mm	Thickness, mm	Width, mm	Length, mm
Plate	-	6 to 20	Up to 250	Up to 1700
Disc, cylinder, cone	60 to 200	15 to 35	-	-

Chromium sputtering plates and evaporable cathodes ERCr 99,9-PM (Cr 99,9% min), ERCr 99,95-PM (Cr 99,95% min), ERCr 99,97-PM (Cr 99,97% min), ERCr 99,99-PM (Cr 99,99% min)

Shape of machine-finished products	Diameter, mm	Thickness, mm	Width, mm	Length, mm
Plate	-	5 to 50	Up to 1400	Up to 1700
Disc, ring, cone	50 to 400	5 to 50	-	-
Rod, cylinder	15 to 65	-	-	Up to 600

Products made from Cr-Al composites are made in the form of disks with diameters of up to 105 mm, depending on the client's wishes

Cr-Cu, W-Cu CONTACTS

JSC POLEMA is Russia's largest manufacturer of composite chromium-copper and tungsten-copper materials for high-current contacts in vacuum arc-quenching chambers.

Application

Cr-Cu contacts are used in the vacuum arc-quenching chambers (VACs) of highly dependable, quick-acting vacuum circuit breakers capable of breaking large currents in high-voltage 6-35 kW electrical networks. Contacts are a key element in commutation switches (circuit breakers). Currently, the most common material used in contact pairs in VACs are Cr-(50-75%) Cu composites.

Contacts are subjected to the effects of short-circuit currents and fusing metals in various points of the surface due to the high density of the current in them; as a result, welding joints form in these zones. This problem was one reason that delayed the development of vacuum commutation technology for more than twenty years. The resistance of a VAC's contacts to welding is one of its key characteristics. The problem of welding was solved by developing special contact plates made of chromium-copper composites, which provided a high breaking capacity for circuit breakers in commutation networks, wear-resistance and resistance of contact pairs to welding.

W-Cu contacts are used in VACs of vacuum contactors with a nominal voltage of 1.14 kW and higher in systems for remote control of electric drivers. The contacts are a long-lasting means of switching contactors in electric circuits on and off and ensure allow cut-off current in the system.

1. CHARACTERISTICS OF FABRICATED PARTS FROM CHROMIUM-COPPER MATERIALS

2 types of products are manufactured: disks made from a composite chromium-copper material and complex parts consisting of a contact chromium-copper layer and a copper substratum. High-quality POLEMA-produced electrolytic refined ERC99.95 chromium is used in making these parts. The contact material is distinguished by high purity in terms of gas-forming and metallic impurity content, outstanding phsyical and mechanical characteristics.

Grades, structure and chemical composition

Grade, standard	Form and structure		Chemical composition, mass %				
			Cr	Cu	O max	N max	S max
ERCr25Cu75-PM	Single-layer chromium-copper disks		24-27	Base	0,07	0,005	ND
ERCr50Cu50-PM	Single-layer chromium-copper disks		Balance	48-53	0,07	0,005	ND
ERCr35Cu65-PM	Single-layer chromium-copper disks		33-37	Base	0,07	0,005	ND
ERCr30Cu70-PM	Two-layer disks: Cr-Cu and Cu	Contact layer	27-33	Balance	0,05	0,005	0,007
		Copper layer	<1,0	Base	0,02	0,005	0,007
ERCr50Cu50-PM		Contact layer	48-53	Balance	0,05	0,005	0,007
		Copper layer	<1,0	Base	0,02	0,005	0,007

PM – Powder Metallurgy

Dimensions

Grade	Nominal dimensions, mm			
	Diameter	Thickness		
		Disc	Contact layer	Copper layer
ERCr25Cu75-PM single-layer discs	90	8.0 to 20.0	-	
ERCr50Cu50-PM single-layer discs	48,56,66,70,80	8.0 TO 20.0	-	
ERCr35Cu65-PM single-layer discs	42,0 TO 90,0	7.0 TO 13.0	-	
ERCr30Cu70-PM two-layer discs	32	4,0	2±0,5	2±0,5
	48,56,60,66,80	6,0	3±0,5	3±0,5
ERCr50Cu50-PM two-layer discs	32	4,0	2±0,5	2±0,5
	48,56,60,66,80	6,0	3±0,5	3±0,5

At the client's request, contact parts of other dimensions can be produced.

Physical and mechanical characteristics

Grade	Minimum density, g/cm³	Minimum hardness HB*	Minimum conductivity %**
ERCr25Cu75-PM single-layer discs	8,2	65,0	55,0
ERCr50Cu50-PM single-layer discs	7,8	90,0	40,0
ERCr35Cu65-PM single-layer discs	8,0	72,0	45,0
ERCr30Cu70-PM two-layer discs	8,35	70	55
ERCr50Cu50-PM two-layer discs	8,35	85	40

* Contact layer Brinell hardness HB 5/250
**Conductivity of the contact layer in % of standard copper.

Other types of contact parts

1. **ERCr30Cu70-PM** made from Cr30Cu70 material. Single-layer disks with the dimensions: Ø 50x16,70x22 mm.
2. **ERCr30Cu70-PM** and **ERCr50Cu50-PM** Bimetallic disks with a contact layer made from Cr30Cu70 or Cr50Cu50 material and copper substrata.

Nominal product dimensions, mm: diameter 48, 56, 66, 80, thickness (height) 10. Thickness of contact layer 4.5±0.5 mm.

Contact parts with other dimensions can be produced at the client's request.

Controlled parameters: chemical composition, dimensions, density, hardness and conductivity.

Sample actual specifications of contact parts

Part		Chemical composition,%					ρ, g/cm³*	HB**	σ, %***
		Cr	Cu	O max	N max	S			
ERCr30Cu70-PM Two-layer disk Ø48x10	Contact layer	30,69	Rem.	0,025	0,002	0,001	8,59	79	59,7
	Copper substratum	<0,05	Base	0,009	0,002	0,001	-	-	-
ERCr30Cu70-PM Two-layer disk Ø56x6	Contact layer	30,16	Rem.	0,026	0,002	0,002	8,54	77,1	58,7
	Copper substratum	<0,05	Base	0,01	0,002	0,001	-	-	-
ERCr50Cu50-PM Two-layer disk Ø66x6	Contact layer	50,3	Rem.	0,042	0,002	0,002	8,4	106	41,1
	Copper substratum	<0,05	Base	0,008	0,002	0,001	-	-	-

* ρ - part density
** HB - Contact layer Brinell hardness HB 5/250
*** σ - contact layer conductivity in % of standard copper.

Microstructure

In complex parts, material microstructure is monitored to prevent defects, and the thicknesses of the contact layer and substratum are checked, along with the quality of the composite's transition layer.

Sample structures of complex contacts

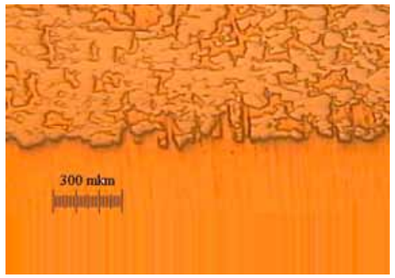


fig.1

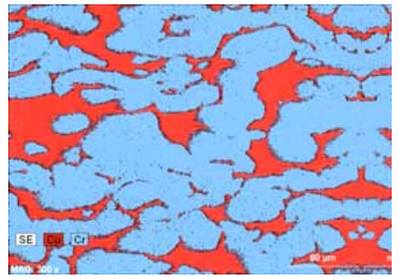


fig.2

*Fig.1: Complex 2-layer contact material structure ERCr 50Cu50 (fragment) Cr50Cu50 contact layer and Cu substratum.
*Fig.2: Contact layer structure ERCr30Cu70 (fragment) of bimetallic contact.

2. SPECIFICATIONS OF ELECTRIC CONTACT PARTS MADE FROM TUNGSTEN-COPPER MATERIAL

Grade, structure and chemical composition

Contract parts consist of two heterogeneous layers (bimetallic structure): a contact layer made of a tungsten-copper material and a substratum made of copper.

Grade, standard	Shape and structure		Chemical composition, mass %				
			W	Cu	O max	N max	S max
W70Cu30-PM (elsend)	Bimetallic disks made from W70Cu30 + Cu material	Contact layer	Balance	28-32	0,05	0,005	0,007
		Copper layer	-	Base	0,02	0,005	0,007

PM – Powder Metallurgy

Dimensions

Grade	Nominal dimensions, mm			
	Diameter	Thickness		
		Disc	Contact layer	Copper layer
W70CU30-PM	32,48	4+2,0	2±0,5	2±0,5

Parts with contacts of other sizes can be produced at the client's request.

Physical and mechanical characteristics

Grade	Minimum density, g/cm³	Minimum hardness HB*	Minimum conductivity,%**
W70Cu30-PM	11,36	145	55

* Contact layer Brinell hardness HB 5/250
** Contact layer conductivity in % of standard copper.

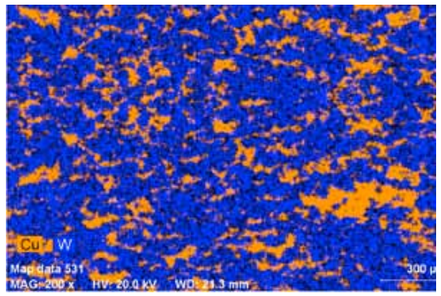


fig.3

*Fig.3: Structure of bimetal contact layer material W70Cu30-PM (fragment).

Sample structure of complex contacts

The parts' material microstructure is monitored to prevent defects, the thicknesses of the layers and the quality of the composite's transitional zone are checked.

3. CHROMOUS POWDERED BRONZE CuCr2-PM

To outfit vacuum arc-quenching chambers, parts made of powdered bronze are also used, with an increased softening temperature (more than 100 °C in comparison with cast chromous CuCr0.7 and chromium-zirconia CuCrZr bronzes), alloyed with 2% chromium: CuCr2-PM with diameters of 48,56,66,80,et al. Conductivity is at least 85%, and hardness at least 115 HB.

Typical specifications:

- density 8.86-8.88 g/cm^3,
- conductivity 87-92%,
- hardness 130-140 HB.

Chromous dispersion-reinforced CuCr2-PM bronze in the form of discs with diameters of up to 300 mm are also applied as electrodes for resistance-seam welding of carbonous and low-alloyed steels. Electrodes made from thermomechanically treated CuCr2-PM bronze are distinguished from traditional CuCr1 bronze by increased hardness, resistance to setting and service durability under contact sealing.

NICKEL

Nickel is distinguished by its high resistance to corrosion; it is stable in air, water, alkalis and in a number of acids. Its chemical stability is due to its tendency to passivity — namely, the formation on its surface of a continuous oxide film that has a protective effect.

Nickel is an element in stainless steel and forms the base of a majority of heat-resistant and fire-resistant alloys used in the air and space industry, power stations and electronics.

Pure metallic nickel is used as a construction material in reactors, for manufacturing parts that will be in direct contact with nuclear fuel and in nuclear physical plants subject to short-term radiation effects. Nickel is widely used as a catalyst in organic synthesis and for preparing the chemical apparatus when producing alkalis.

Metallic nickel's resistance to corrosion and the effects of the atmosphere, its hardness and its shine make it a highly valuable material for coating other metals.

One important quality of certain nickel alloys is heat resistance combined with high thermal conductivity.

The following nickel and Ni alloys are made:

- Nickel anodes, sheets, plates
- Sheets and boats made from Ni-Mo alloy
- Sputtering targets and vaporizable cathodes made from nickel
- Powders from pure nickel, stainless steels, heat-resistant alloys, Ni-Al and Ni-Ti intermetallics, composite materials, permalloys and catalysts

Nickel and nickel alloy products are made using powder metallurgy methods. Products made from unalloyed material are guaranteed to have a purity of at least 99.90% Ni with a minimal content of interstitial impurities.

Nickel anodes are used in electroplating to protect products from corrosion and to give them a decorative look.

Sputtering targets and evaporable cathodes made from nickel are used for vacuum spraying and depositing of thin films in electronics and electrical engineering.

Metallic powders from stainless steels and nickel alloys are produced by spraying an alloy using an inert gas and by using the restoration method. They are used in dozens of industries as protective coatings and in producing items for use in construction.

NICKEL ANODES, SHEETS AND PLATES

Nickel anodes

JSC POLEMA produces nickel hot-rolled anodes meant for use in nickel plating. The anodes are produced in the form of rectagularly-cut sheets.

Grades and chemical composition of anodes: NPA1, NPA2, NPAN under State Standard 492-2006 “Nickel, pressure-treated nickel and copper-nickel alloys. Grades”.

Anodes are delivered according to State Standard 2132-90 “Nickel anodes. Technical specifications”.

Production method: hot-rolled (H); cut: rectangular (R); precision: normal (N); length: gauge (GL), off-gauge (OL) or divisible gauge (DL). Anode dimensions: thickness from 4 to 12 mm, width from 100 to 600 mm, length from 400 to 1500 mm as the standard dimensions or based on the client's specifications.

The advantages of JSC POLEMA nickel anodes include: high metal purity (Ni

of at least 99.90 %), low content of harmful impurities, uniform dissolution of anodes in the electrolyte, absence of tendency to passivation during the nickel-plating process.

Nickel sheets and plates

JSC POLEMA produces hot-rolled and cold-rolled sheets and strips and hot-rolled plates made of nickel for various fields of industry(mechanical engineering, instrument-making, and electrical engineering for vacuum deposition of nickel coatings, etc.).

Grades and chemical composition:

- NP1, NP2 according to State Standard 492-2006, "Nickel and pressure-treated nickel and nickel-copper alloys. Grades";
- N1-PM (Ni-PM) with a chemical composition that meets the requirements for PNK-UT3 grade powder under State Standard 9722-97 "Nickel Powder".

Material purityis at least 99.90% Ni with minimal content of harmful impurities.

Nickel sheets, strips and plates of the NP1, NP2 grade are delivered in accordance with State Standard 6235-91 "Nickel Sheets and Strips", while those of N1-PM (Ni-PM) grade are delivered based on technical specifications agreed to with the client.

Dimensions: standard (with a length of up to 1500 mm) or based on the client's specifications.

SHEETS AND BOATS MADE FROM NICKEL ALLOY

JSC POLEMA manufactures precision-alloy products of the grade Ni67Mo28-PM (type NIMO-28):

- hot-rolled sheets for producing boats and other components for use in aggressive environments and at high temperatures;
- boats for reduction furnaces.

Alloy chemical composition (%,mass.):

- molybdenum 27-28;
- iron 6-7;
- remainder - nickel.

Sheets from Ni67Mo28-PM

Hot-rolled sheets from Ni67Mo28-PM grade alloy are produced with athickness of between 2.0 and 6.0 mm, a width of between 200 and 400 mm, and a length of between 300 and 900 mm. Actual dimensions and acceptable size deviations are established on an order-by-order basis.

The following mechanical characteristics are controlled for sheets with a thickness from 2.0 to 4.0 mm: tensile strength of at least 80 kg/mm^2, and a relative elongation of at least 20%.

The sheets are delivered without surface etching.

Boats from Ni67Mo28-PM

The shape and dimensions of boats made from Ni67Mo28-PM (NIMO-28) grade alloy are determined based on the client's drawings.

SPUTTERING NI, NICR TARGETS AND EVAPORABLE NI, NICR CATHODES

Field of use

Mechanical engineering, electronics. Protective coatings on machine and equipment parts.

Shape

- Simple-shape products, with rectangular or round cuts, in the form of sheets, plates, rods and discs.
- Complex-shape products (cathodes) cut according to the client's drawings.

The shape, dimensions, permissible deviations for product size and the tooling precision are determined by the client's request.

Chemical composition

Products of the grade N1-PM (Ni-PM) are produced at the client's request, products of the grades NP1,NP2 can be produced according to State Standard 492-2006.

Guaranteed purityof the material is at least 99.90 % of Ni with minimal content of harmful impurities.

The chemical composition of products is ensured to be no lower than the requirements for nickel powders of the group U under State Standard 9722-97.

Guaranteed chemical composition of N1-PM (Ni-PM) grade nickel

Grade	Ni	C	Fe	Co	Si	Cu	Mg	As	S	Zn	P	Cd	Bi	Mn	Sn	Pb	Sb	Ca
			ppm, maximum															
N1-PM (Ni-PM)	99,90 % min	0,09 % max	15	10	10	3	3	5	7	3	3	1	1	3	1	1	2	50

PM – Powder Metallurgy

Products are made using powder metallurgy. The density of deformed (hot-rolled and forged) products is at least 99% of the theoretical value. There are no internal pores or open porosity in the structure of the material of these sputtering targets and evaporable cathodes.

Sputtering NiCr targets

Guaranteed chemical composition

Grade	Ni+Cr, wt%, not less	Cr,%	Impurities, mkg/g ppm, maximum									
			Fe	Al	Si	Cu	Ca	Mn	S	C	O	N
Ni/Cr 80/20 99,9 wt%	99,90	20±1,5	500	100	100	50	50	200	100	200	500	100

Amount of metal impurities:
Ni/Cr 80/20 99,9 wt%– not more than 1000 mkg/g
Advantages

- rather high chemical purity;
- high density and homogeneous microstructure of material of the items, providing process stability of targets sputtering or arc evaporation of cathodes;
- various range of the items, designed in accordance with customers requirements.

FOR NOTES

POLEMA JSC
3, Przhevalskogo str.
300016, Tula, Russia
Phone: +7 4872 25 06 68
Fax: +7 4872 25 06 78
URL: www.polema-rus.com
E-mail: polema@polema.net