

References of Molybdenum rods

Rods of the following grades are produced:

Mo-PM molybdenum rods and forged products;

Mo99.95-PM super-thin molybdenum rods.

Application

Mo-PM and Mo99.95-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, electrodes 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, Mo99.95-PM) is marked by good plastic characteristics after annealing for internal stress removal (ISR). The fragility threshold of T_x is in a temperature range well below room temperature. The $\sigma_{0.2}$ tensile strength of ISR molybdenum in the range of high temperatures drops monotonically: 95-100 MPa at $T=1200$ °C, 75-80 MPa at $T=1400$ °C, and approximately 50-40 MPa at $T=1600$ -1800 °C. The useful life of molybdenum products is affected by the metal's creep and vaporization in a vacuum. The speed of molybdenum's vaporization is $2.07 \cdot 10^{-9}$ g/cm²·sec at $T=1727$ °C; $7.3 \cdot 10^{-8}$ g/cm²·sec at $T=1927$ °C; $5.03 \cdot 10^{-6}$ g/cm²·sec at $T=2227$ °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 °C.

The temperatures of recrystallization of molybdenum are as follows: initiation at 900 °C, with full recrystallization commencing at 1100 °C (annealing within 1 hr). Once recrystallized, molybdenum is fragile at room temperature. In open air, molybdenum begins to oxidize at $T=400$ °C, while the speed of oxidation accelerates significantly at $T > 600$ °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 molybdenum 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	Σ??**
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 calculating the share of molybdenum.

** Σ?? – 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, parallelepipeds and sheets) with a diameter or rectangular edge of 30-300mm 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 σ ?, 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 Mo99.95-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 Mo99.95-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 tooling, 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 $< \pm 6.35$ 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 Mo99.95-PM rods

Diameter, mm	Tensile strength σ ?, N/mm ²	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? 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.

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