RUSATOM
METAL TECH
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NIOBIUM COPPER

Strengthened Electrical Conductors of Unique Alloy

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STRENGTHENED ELECTRICAL CONDUCTORS OF UNIQUE ALLOY

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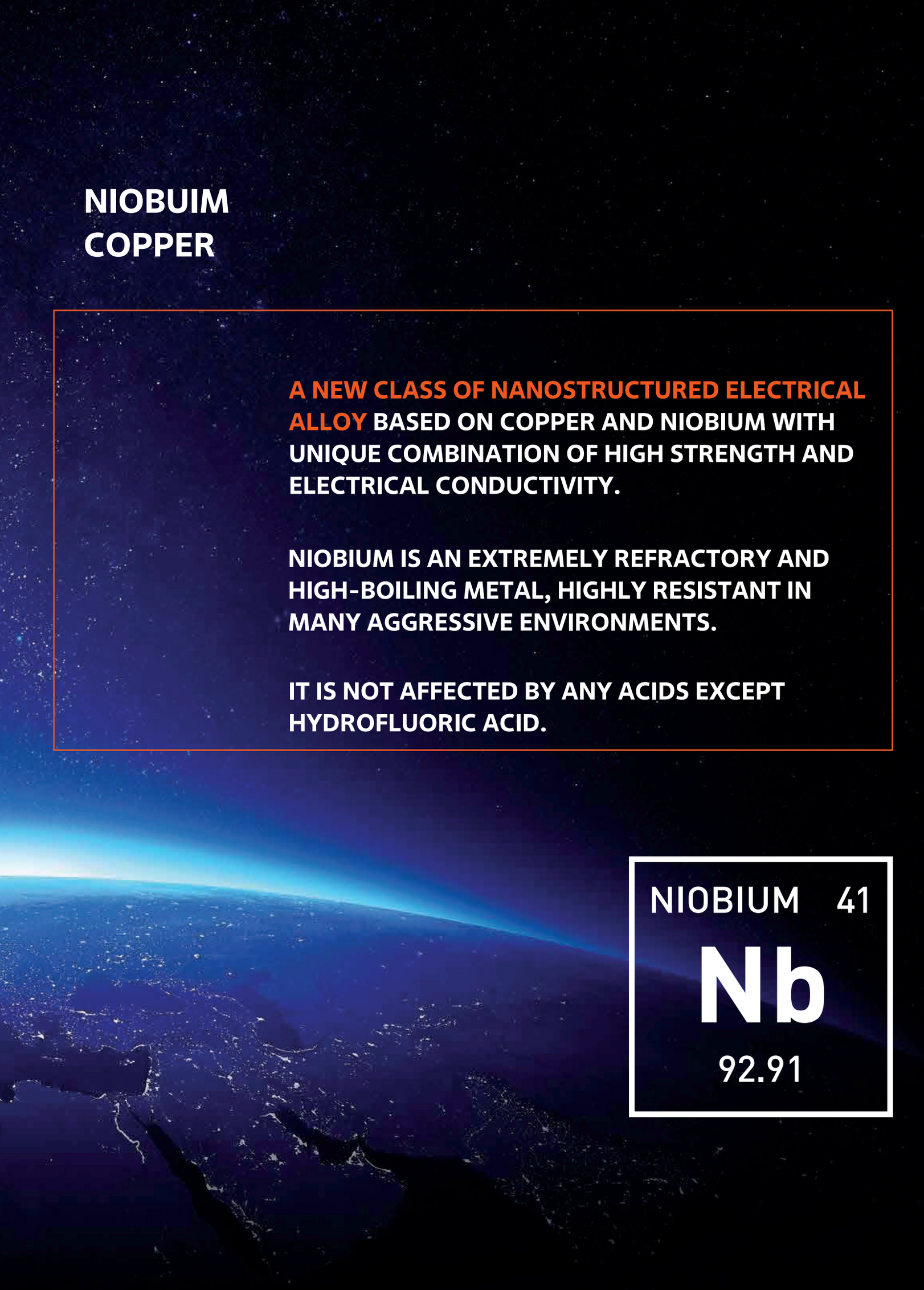
STRONGER THAN EVER

NIOBUIM COPPER

A NEW CLASS OF NANOSTRUCTURED ELECTRICAL ALLOY BASED ON COPPER AND NIOBIUM WITH UNIQUE COMBINATION OF HIGH STRENGTH AND ELECTRICAL CONDUCTIVITY.

NIOBIUM IS AN EXTREMELY REFRACTORY AND HIGH-BOILING METAL, HIGHLY RESISTANT IN MANY AGGRESSIVE ENVIRONMENTS.

IT IS NOT AFFECTED BY ANY ACIDS EXCEPT HYDROFLUORIC ACID.



ABOUT THE COMPANY

Rusatom Metal Tech LLC is a company that specializes in the development and manufacture of conductor products made of copper-niobium (CuNb) and other copper alloys and supplies fundamentally new types of wire and electrical conductors for Russian and foreign consumers.

STRATEGY

Rusatom Metal Tech LLC forms a part of Rosatom's Fuel Company TVEL and specializes in the development and manufacture of special cable products for the nuclear industry and high-tech industries in Russia and abroad. In addition, thanks to the unique properties of CuNb alloy which is produced at the enterprise, new directions will be advanced, such as the development of lightweight shielding systems for cable products of increased strength, which are already being successfully tested in the space industry.

ENVIRONMENTAL PROTECTION

Rusatom Metal Tech LLC makes every effort to minimize the harmful environmental impact of the consequences of its operation: from the use of energy-saving equipment and an economical approach to water consumption to the environmentally friendly disposal or reuse of materials, product components, and raw materials used in production.

COMPANY PRODUCTS

— hollow conductors for inductors in magnetic pulse systems

— large cross-section winding conductors for high-field pulse magnets

— high-strength microwires for various applications and industries

— high-strength nanowires for various applications and industries

— composite contact wires for high-speed rail transportation

— high-reliability wires for aerospace and defense industries

— foils and films for microelectronic

COMPANY PARTNERS

State Atomic Energy Corporation Rosatom

Bochvar Research Institute of Inorganic Materials

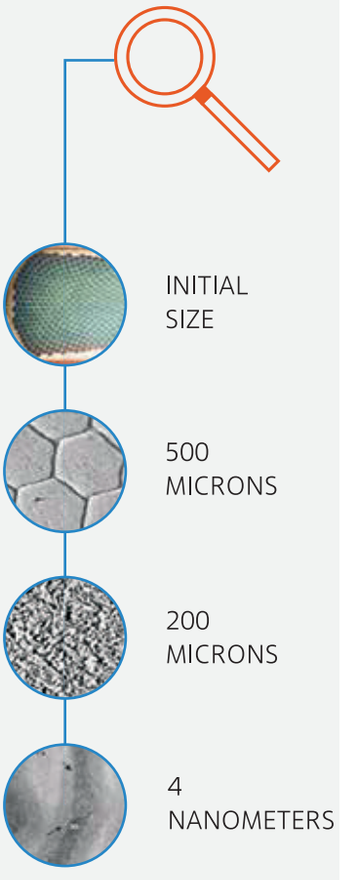
Russian Railways (JSCO RZD)

LLC Chepetskiy Mechanical Plant

National Research Centre Kurchatov Institute

As well as a number of other manufactures, research institutes and centers, research laboratories in the USA, Belgium, the Netherlands, Germany, Switzerland, Poland and other countries

TECHNICAL PROCESS



THE DEVELOPMENT TEAM OF THE BOCHVAR RESEARCH INSTITUTE HAS BEEN WORKING FOR MORE THAN 20 YEARS ON THE CREATION OF A FUNDAMENTALLY INNOVATIVE TECHNOLOGY FOR THE PRODUCTION OF A NEW GENERATION OF NANOCOMPOSITE CONDUCTORS.

The conducted experiments revealed unique properties of both strength and high conductivity of Cu-Nb composite wires, which are produced by plastic deformation: rolling from ingots of these alloys with preservation of microstructure in the finished product. In the course of the study a significant increase in the tensile and deformation strength was found during the rolling of niobium copper ingots to the state of thin nano- and microwires. The effect of anomalous increase in strength and electrical conductivity in the composite material is caused exclusively by the nanometer structure and is associated with the formation of a new type of phase-to-phase semi-coherent interfaces of superconductor components. It was proved that the developed alloys retain UTS values at 1,100 MPa with wire diameter of 0.1- 0.3 mm within 2,600 hours of thermal exposure at 350°C. The electrical conductivity of these wires was recorded to be 60-70% of IACS or electrical conductivity of high-purity annealed copper.

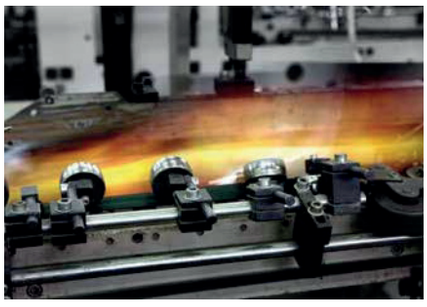
The products developed at the Bochvar Research Institute have a unique combination of high strength and electrical conductivity, as well as record-high low-cycle fatigue properties. These products have no known analogues in the world at the present time. The technical process makes it possible to produce long composite wires from a new class of material.

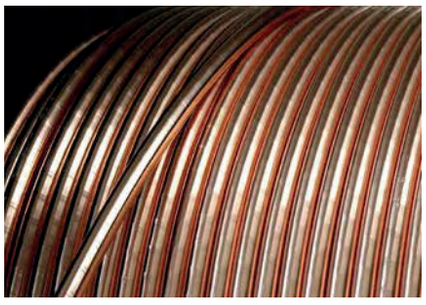
Rusatom Metal Tech LLC wields 22 objects of intellectual property to confirm the uniqueness of the technical process developed by the enterprise.

AWARDS AND CERTIFICATES

The Company's technical process has received native and global recognition in the form of prestigious certificates and diplomas from Russian and foreign organizations, in particular, Business Eureka, Los Alamos National Lab, Westmoreland Mechanical Testing & Research Inc, and many others.

PROCESS PROCEDURE





INGOT CASTING/MELTING

The first stage of the process procedure is the melting of ingots of niobium copper-based alloys to produce billets of up to 200 mm in diameter and 1,500 mm in length in a vacuum induction furnace, as well as billets of up to 195 mm in diameter and 1,000 mm in length in electric arc vacuum furnaces with a consumable electrode.

METAL FORMING

Next, ingots from copper-based alloys and other materials are pressed on a press with a force of 1600 tf from containers of 180, 150, 130, 100, and 95 mm in diameter with a system of extrusion speed precision control. Then, the process procedure involves drawing from 50 mm diameter bars up to 50 μm diameter microwires on a line of drawing mills and machines.

PRODUCTION OF SPECIALIZED COMPOSITE SUPERCONDUCTORS

Another optional process step is the development and manufacture of Nb3Sn superconductors with an internal tin source from 1.0 to 0.3 mm in diameter with critical current density of up to 2500 A/mm^2 (12 Tesla, 4.2K), strength of up to 1,000 MPa, and hysteresis losses not exceeding 1,500 mJ/cm^3 (±3Tesla).

QUALITY CONTROL OF MANUFACTURED PRODUCTS

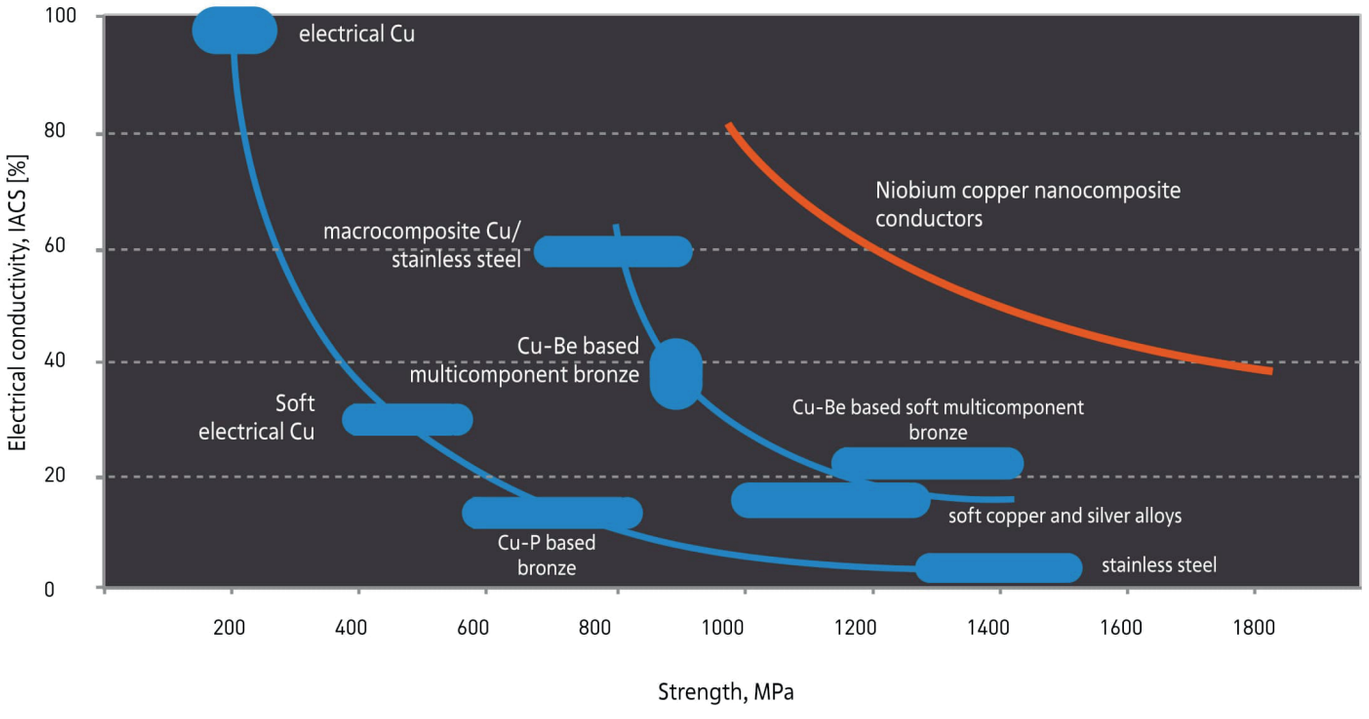
An important and essential step of the Rusatom Metal Tech LLC process procedure is the quality control of manufactured products at the output of production. For this purpose, mechanical properties are measured and metallographic analysis of σB, σ0.2, δ parameters of conductor samples is performed on Swiss universal testing machines LFMZ-10, LFMZ-100 with loads from 1 to 100kN.

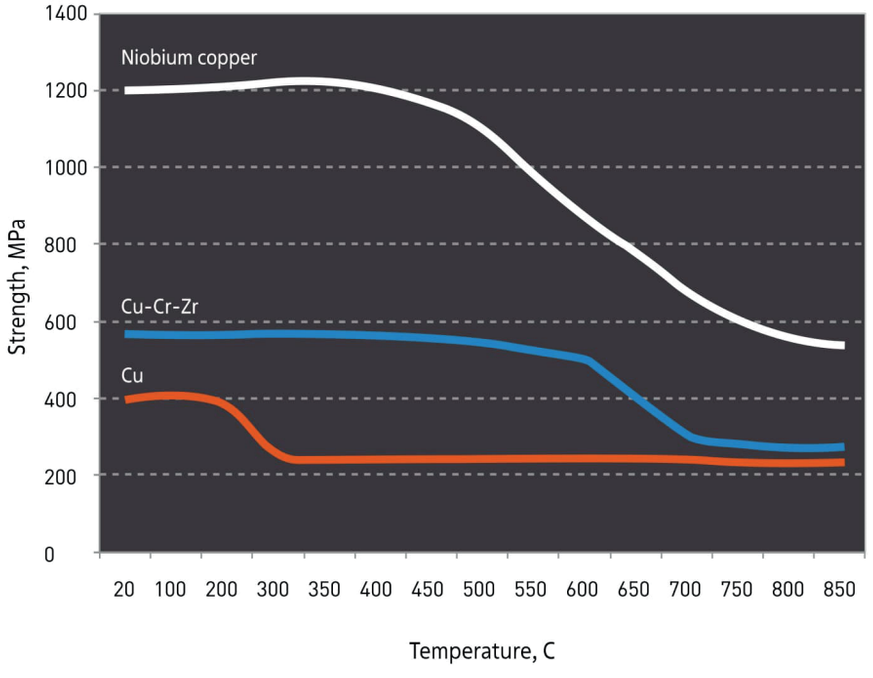
HEAT TREATMENT OF METALS

The next process step is the heat treatment of billets of up to 500 mm in diameter and up to 9,000 mm in length, as well as of coils of wires and wire samples at temperatures up to 1,200 °C in furnaces with air atmosphere and in vacuum with degrees not lower than 10-5 mm Hg with the possibility of cooling using argon in a protective gas environment.

PROPERTIES

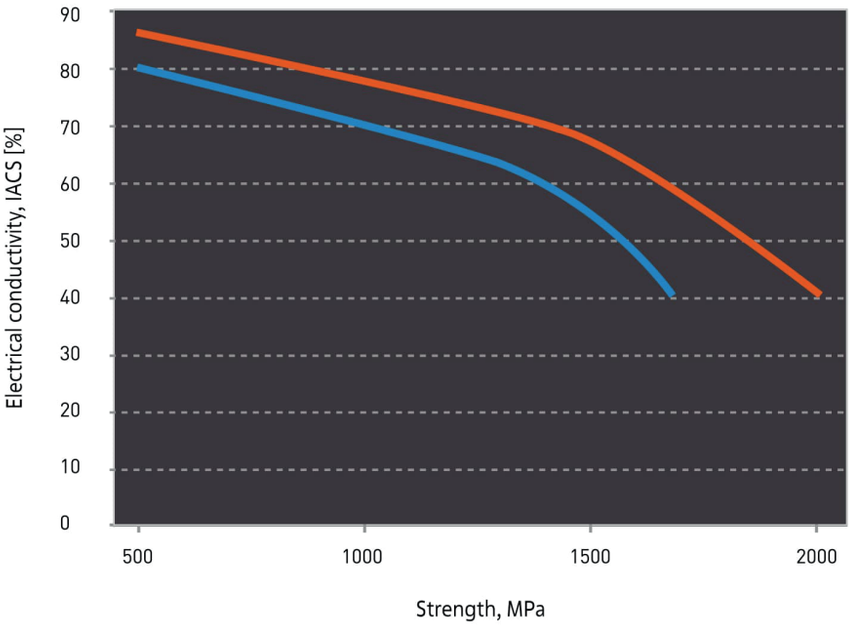
THE WIRES PRODUCED BY THE COMPANY COMBINE A UNIQUE SET OF HIGH MECHANICAL STRENGTH AND INCREASED ELECTRICAL CONDUCTIVITY AND SHOW THE HIGHEST LEVEL OF PROTECTION AGAINST METAL FATIGUE



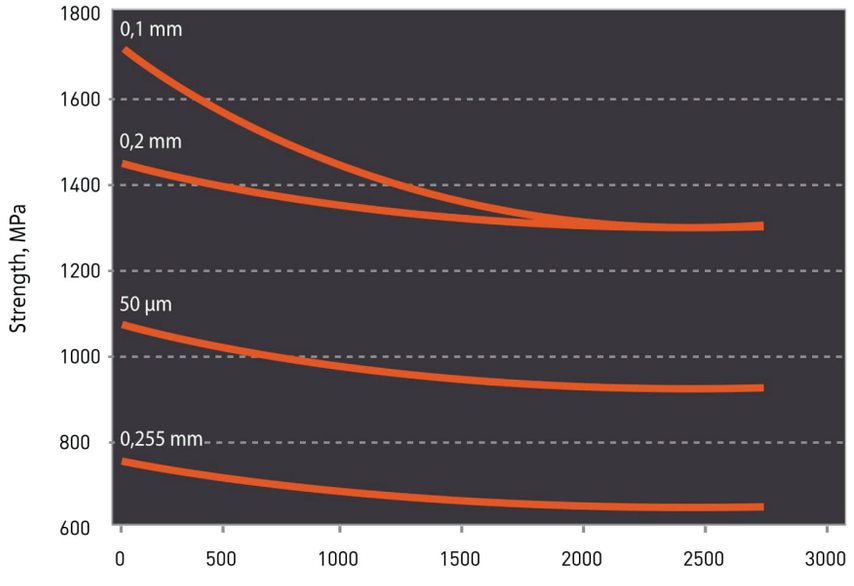


Nanocomposite wires have mechanical strength comparable to steel (1200-1500 MPa). Their electrical conductivity level reaches 70-85% of the absolute electrical conductivity characteristic of pure copper. The technical process of nanocomposite wires production is currently considered unique in Russia and worldwide and allows to manufacture wires of any diameters and cross sections from innovative material.

The effect of asymmetric increase in strength and electrical conductivity of nanocomposite material is achieved due to its nanometer structure and is associated with the formation of a new type of interphase semi-coherent boundaries of metal atoms in Cu-Nb alloy.



The figure shows the range of values of the combination of strength and electrical conductivity of niobium copper-based nanocomposite wires. The upper red curve limits the field for achieving the maximum achieved values of the combination of strength and electrical conductivity of such wires. The lower blue curve characterizes the normally achieved level of combination of these values.



Strength properties of niobium copper nanostructured wires during long-term exposure at 350°C

The curves shown in the graph demonstrate the strength properties of nanostructured conductors of 0.1 mm, 0.2 mm, 50 µm, and 0.255 mm in diameter during tests at 350°C. The graph illustrates the high stability of niobium copper-based nanostructured materials strength properties. The strength of thin and fine conductors exceeds the strength properties of conventional electrical wires significantly even after 2,660 hours of exposure at 350°C.

EXTRA THIN
WIRES

STRENGTH = 900 ÷ 1,700 MPA
ELECTRICAL CONDUCTIVITY = 54 ÷ 80% IACS

MATERIAL

Nanocomposite niobium copper alloy.

GAUGE

Wires of
0.025–0.09
mm in diameter

IMPLEMENTATION AREAS

- microelectronics;
- electronics;
- robotics;
- electric motor manufacturing;
- precision engineering;
- aerospace and aeronautics;
- defense industry.

PRODUCT ADVANTAGES

- high mechanical strength (3-4 times higher than copper), including for operation at elevated temperatures: from 120 C° below zero to 350 C° above zero at all times and up to 500 C° above zero short-term without loss of strength;
- improved low-cycle fatigue properties in relation to wires made of copper and copper-based dispersion-hardened alloys (withstands cyclic loads up to 90% of the proportional limit 5 times better);
- lower weight of the product due to the use of thinner CuNb wires (from 0.025 mm in diameter) with equal strength.
- optical density of each braid layer is not less than 90%
- improved EMI shielding due to multilayer microstructure

DESIGNS

Springs, bundling, winding wires, current collector contact pairs, shielding braids/materials, enhanced performance spacecraft antennas.

COPPER 29
Cu
63.55

NIOBIUM 41
Nb
92.91

THIN
WIRES

STRENGTH = 500 ÷1,200 MPA
ELECTRICAL CONDUCTIVITY = 70 ÷ 95% IACS

MATERIAL

Nanocomposite niobium copper alloy.

GAUGE

Wires of
0.01–0.9 mm in diameter

IMPLEMENTATION AREAS

- electronics;
- robotics;
- precision engineering;
- aerospace and aeronautics;
- oil and gas industry;
- nuclear industry;
- defense industry.

PRODUCT ADVANTAGES

- longer service life of products (2-2.5 times compared to traditional materials);
- the number of 180° bend-unbend tests at room temperature is 5 times higher than that of pure copper wire;
- ensuring reliable operation of products with this type of electric wire in incredibly harsh conditions: high temperatures, high hydrostatic pressure, sharp temperature and pressure fluctuations, stretching loads
- the highest characteristics in reproduction accuracy and stability in cut quality in electric erosion machining.

DESIGNS

Heat- and radiation-resistant wires (for rocket engines, nuclear reactors), self-supporting geophysical cables for oil submersible pump, for use as high-strength electric erosion wire.

HEAVY
CONDUCTORS

STRENGTH = 700 ÷1,050 MPA
ELECTRICAL CONDUCTIVITY = 60 ÷ 80% IACS

MATERIAL

Nanocomposite niobium copper alloy.

GAUGE

Conductors of round, square, and rectangular cross-section with cross-sectional area from 1.4 to 37.4 mm2 and linear dimensions as follows: thickness from 0.8 to 5.2 mm, width from 1.5 to 7.2 mm.

IMPLEMENTATION AREAS

- high-pulse magnets with induction of up to 70–100 Tesla;
- scientific research;
- robotics;
- precision electrical equipment;
- equipment for magnetic-pulse treatment of metals.

PRODUCT ADVANTAGES

- new opportunities for studying magnetic field: a world record was set during the tests of pulse magnets made of nanocomposite Cu/Cu-Nb wires at Los Alamos National Laboratory in March 2012, the achieved level of magnetic field induction was 100 Tesla without destruction of the magnet;
- withstand more than 1,000 cycles of loading at a stress of 1,400 MPa at liquid nitrogen temperature and more than 10,000 cycles of loading at a stress of 900 MPa at room temperature without failure.

DESIGNS

Springs, winding wires for heavy-duty magnetic field reducers and other applications, withstanding record voltage levels

COPPER 29 Cu 63.55

NIOBIUM 41 Nb 92.91

HOLLOW
CONDUCTORS

STRENGTH = 1,100 ÷ 1,250 MPA
ELECTRICAL CONDUCTIVITY = 68 ÷ 78% IACS

MATERIAL

Nanocomposite niobium copper alloy.

GAUGE

Hollow conductors of square and rectangular cross-section with dimensions from 4x4 mm to 9x9 mm with a wall thickness of 1–2 mm.

IMPLEMENTATION AREAS

- precision engineering;
- devices for magnetic pulse processing of metals:
  - molding;
  - stamping;
  - melting;
  - rolling;
  - etc.

PRODUCT ADVANTAGES

- allow high-precision stamping in a single operation;
- magnetic pulse welding method allows to join the most dissimilar materials, up to metallic with non-metallic ones;
- increase the life of inductors and technical and economic indicators of magnetic pulse processing of metals in general.

DESIGNS

For installations of magnetic pulse processing of metals (stamping and heat treatment).

WIRE ROD

STRENGTH = 420 ÷ 460 MPA
ELECTRICAL CONDUCTIVITY = 85 ÷ 95% IACS

MATERIAL

Nanocomposite niobium copper alloy.

GAUGE

Wires from
1.00 to 4.00 mm in thickness

IMPLEMENTATION AREAS

Raw material for the production of thin and extra thin electrical wires.

PRODUCT ADVANTAGES

Nanoelectro offers not only the finished product, but also wire rods for the production of conductors.

DESIGNS

Customized conductors.

COPPER 29
Cu
63.55

NIOBIUM 41
Nb
92.91

CONTACT
LINES

STRENGTH = 510 ÷ 570 MPA
ELECTRICAL CONDUCTIVITY = 85 ÷ 95% IACS

MATERIAL	GAUGE	IMPLEMENTATION AREAS
Nanocomposite niobium copper alloy	Standardized wires with cross-section from 100 to 150 mm2	Suspended and coiled contact systems of railroad electric transport.

PRODUCT ADVANTAGES

- allow for the production of contact lines with high tension and provide for speeds of railway traffic of up to 450 km/h;
- increase the wear resistance and improve the reliability of contact system operation significantly;
- provide increased span lengths, thereby reducing the number of supports for the contact network of the railway infrastructure.

DESIGNS

High-speed rail transportation.

THIN AND NANO WIRES OF NIOBIUM COPPER

PRODUCT TYPE	RECTANGULAR SECTION AREA (A X B) mm^2	293K			77K	SUPER-CONDUCTIVITY, IACS, %	ELECTRIC RESISTANCE AT 20°C micro-Ohm•cm	RESIDUAL RESISTANCE COEFFICIENT, $RRR_{293K/77K}$
		ULTIMATE RUPTURE STRENGTH, STRENGTH, MPa	ULTIMATE TENSION K, $YS_{0.2}$ MPa	ELONGATION , δ, %	ULTIMATE RUPTURE STRENGTH, STRENGTH, MPa			
IS1708	1150÷1170	900÷910	3÷5	1520	63÷64	63÷64	2.74÷2.69	4,1÷4.6
IS23_350	5.8 (2 x 3)	1200÷1250	940÷1000	3.5÷5	>1400	60÷65	2.78÷2.65	4.0÷4.3
IS235_350	7.0 (2 x 3.5)	1130÷1160	900÷930	4.3÷5.7	1330÷1360	64÷65	2.69÷2.65	4.3÷4.6
IS34_391	12 (3 x 4)	1150÷1200	900÷950	2.5÷3.0	>1250	65÷70	2.43÷2.42	4.2÷4.6
IS358_600	17 (3 x 5.8)	1100÷1200	950÷1000	>5	1450÷1480	65÷72	2.65÷2.46	42.÷4.6
IS46_745	24 (4 x 6)	1100÷1130	950÷1000	>5	>1300	71>574	2.43÷2.33	4.6÷4.8
IS01_09	Ø 0.1÷0.9	1100÷1500	900÷1000	1.5÷4	1360÷2000	65÷75	2.65÷2.30	4.0÷5.5
IS1_10	Ø1÷10	750÷780	>550	>8	>1000	80÷82	2.16÷2.10	4.5÷5.8

PRODUCT SPECIFICATIONS

NIOBIUM COPPER WIRES

WIRE MATERIAL	CROSS-SECTION, mm2	ULTIMATE RUPTURE STRENGTH, STRENGTH, MPa		ELECTRICAL CONDUCTIVITY, IACS, %		LINEAR RESISTANCE, Ohm/km		WIRE LINEAR WEIGHT (calc.), kg/m
		INCREASED STRENGTH	INCREASED ELECTRICAL CONDUCTIVITY	INCREASED STRENGTH	INCREASED ELECTRICAL CONDUCTIVITY	INCREASED STRENGTH	INCREASED ELECTRICAL CONDUCTIVITY	STRENGTH AND ELECTRICAL CONDUCTIVITY
NIOBIUM COPPER	0,1 ÷ 0,2	1400 ÷ 1700	1100 ÷ 1200	50 ÷ 58	64 ÷ 68	4390,1 ÷ 946,3	3430 ÷ 806,9	(0,071 ÷ 0,267) x10^{-3}
	0,39 ÷ 0,50	870 ÷ 1000	750 ÷ 850	72 ÷ 75	82 ÷ 85	200,5 ÷ 117,1	176,0 ÷ 103,3	(1,066 ÷ 1,776) x 10^{-3}
	0,668 ÷ 0,686	1100	780	68	78	72,3 ÷ 68,6	63,0 ÷ 69,8	(3,108 ÷ 3,286) x 10^{-3}
	0,798 ÷ 1,10	920 ÷ 1070	680 ÷ 760	72 ÷ 73	77 ÷ 7	47,9 ÷ 24,9	44,8 ÷ 23,0	(4,44 ÷ 8,436) x 10^{-3}
	1,128 ÷ 1,311	1000	550 ÷ 680	70	79 ÷ 80	24,6 ÷ 18,2	21,8 ÷ 16,0	(8,88 ÷ 11,99) x 10^{-3}
	1,514 ÷ 1,954	690	420	81	84	11,8 ÷ 7,1	11,4 ÷ 6,8	(15,98 ÷ 26,64) x 10^{-3}
	2,257	820	400 ÷ 520	77	83 ÷ 87	5,6	5,2 ÷ 5,0	35,52 x 10^{-3}

*IACS – INTERNATIONAL STANDARD FOR ELECTRICAL CONDUCTIVITY OF ANNEALED COPPER; 100% IACS = 1.7241 μOHM•CM AT 20 °C

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