ПОЛИМАГ

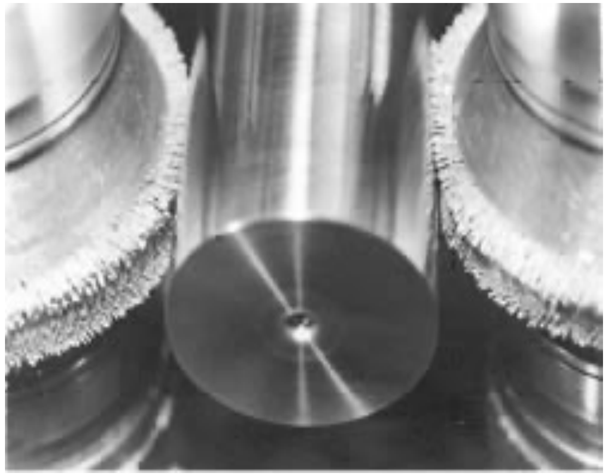
Научно-технологический парк БНТУ ПОЛИТЕХНИК

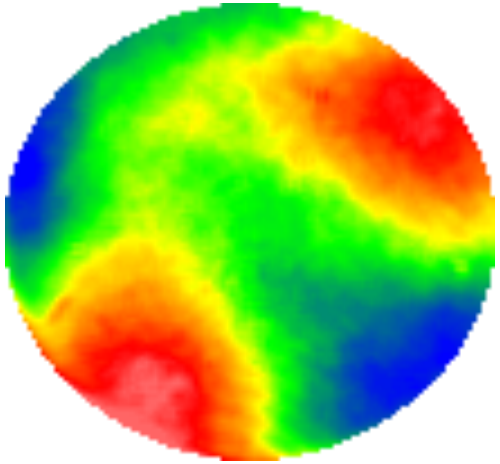
Scientific and Engineering Republican Unitary Enterprise POLIMAG

(UE “POLIMAG”)

TECHNOLOGIES AND EQUIPMENT FOR MAGNETIC- ABRASIVE TREATMENT:

polishing, cleaning, modification

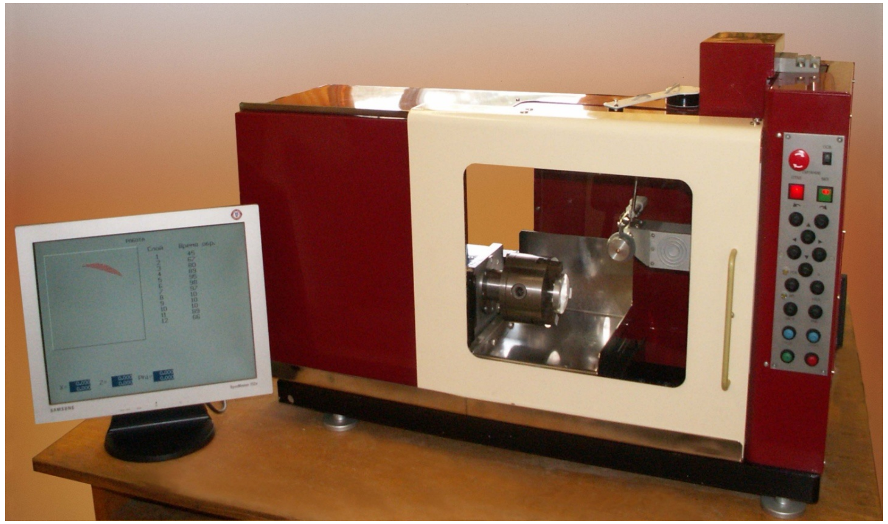




Minsk 2024

EQUIPMENT FOR SUPERTHIN MAP OPTICS

Experimental samples



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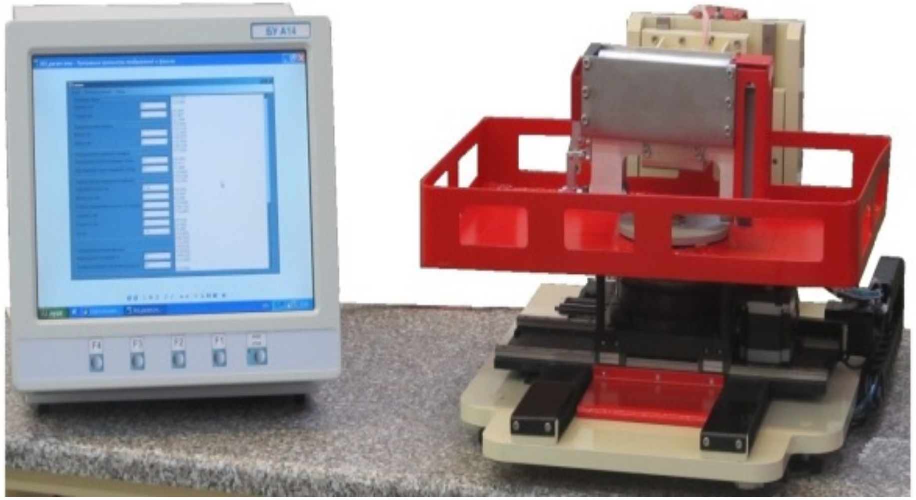
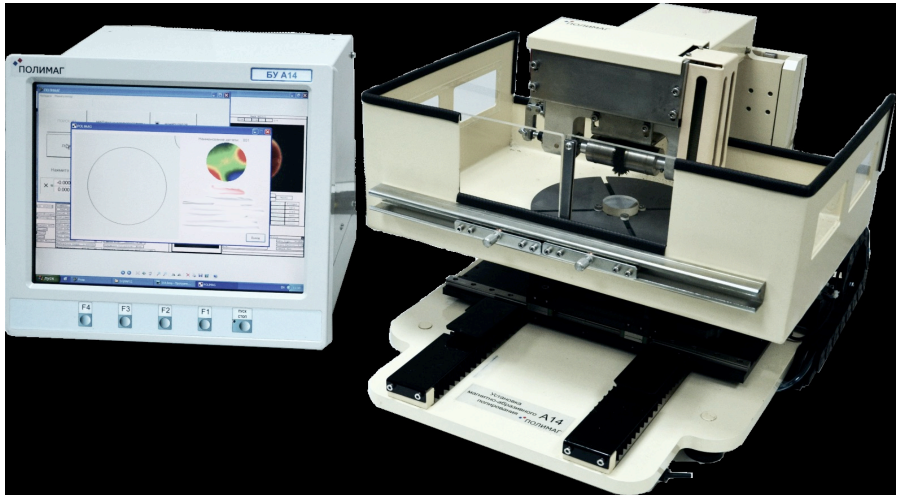
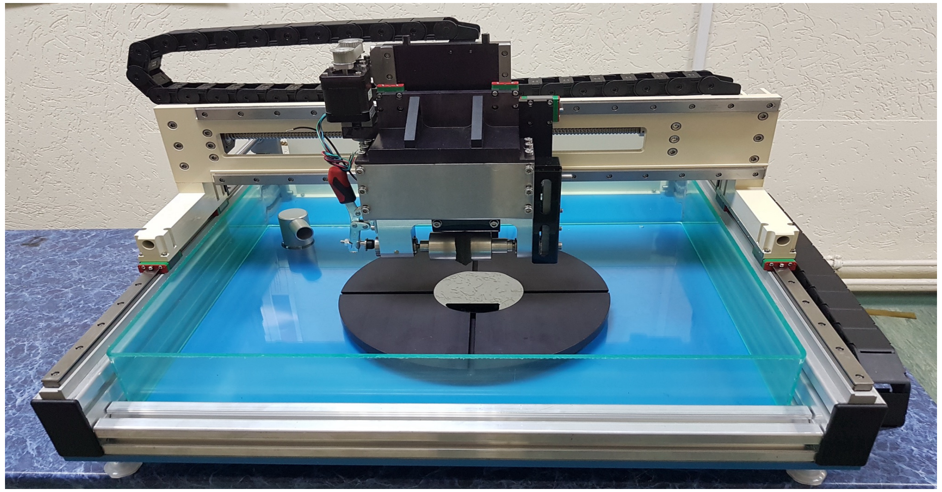


A14

Industrial designs



A17



A20-300

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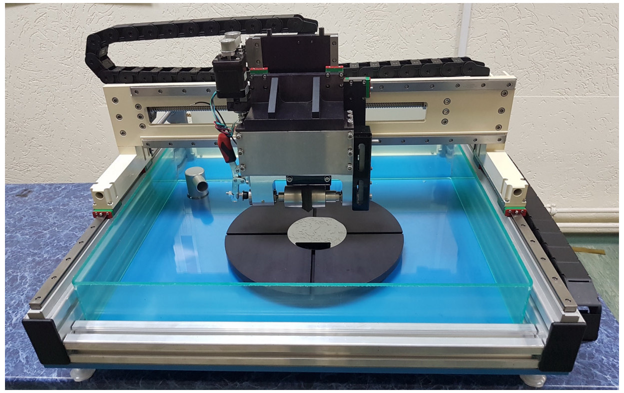
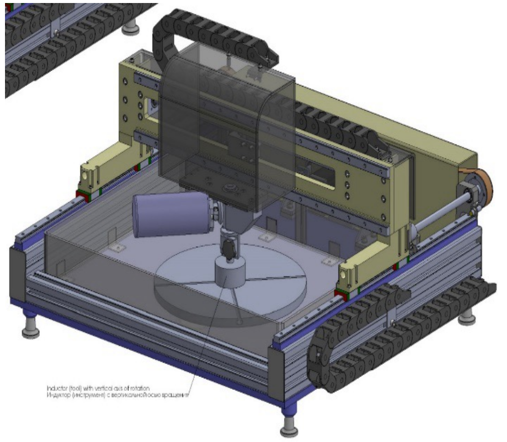
SUPERFINE MAGNETIC ABRASIVE POLISHING (MAP) OF PARTS OF OPTICS, LASERS, MEDICAL AND OTHER EQUIPMENT

SOFTWARE CONTROLLED INSTALLATION A20-300 implements 2 MAP schemes:

Scheme No. 1 with a horizontal axis of rotation of the inductor tool



Scheme No. 2 with a vertical axis of rotation of the inductor tool



Scheme No. 1 with an inductor tool with a horizontal axis of rotation performs polishing(according to a digitized interferogram of the original surface) by the periphery of a brush ring formed by a magnetic field from ferroabrasive powder. The contact area of the powder with the polished surface is about 1 square. cm. Nanorelief with Ra < 3 nm and shape parameter PV < 30 nm are provided. Using this scheme, you can polish flat, spherical and aspherical surfaces. In some cases, it is possible to polish surfaces of complex shapes.

Scheme No. 2 with an inductor tool with a vertical axis of rotation performs MAP at the end of the brush ring (by analogy with face milling) ensuring Ra < 3 nm and improving the surface shape characteristics by 30-50%. The contact area of the powder with the polished surface is about 60 square meters. cm. Nanorelief with Ra < 3 nm and shape parameter PV < 30 nm are provided.Using this scheme, you can polish flat and closesurfaces to them.

Conversion of installation from one circuitfor another no more than 15 minutes.

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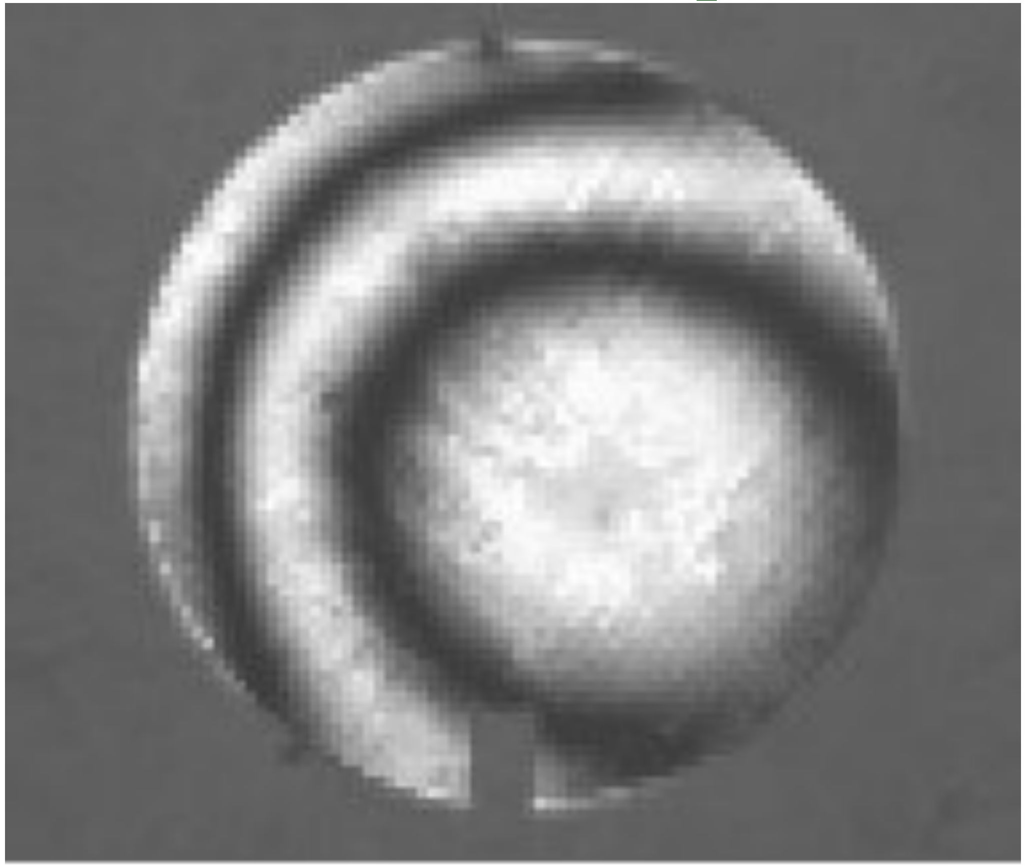
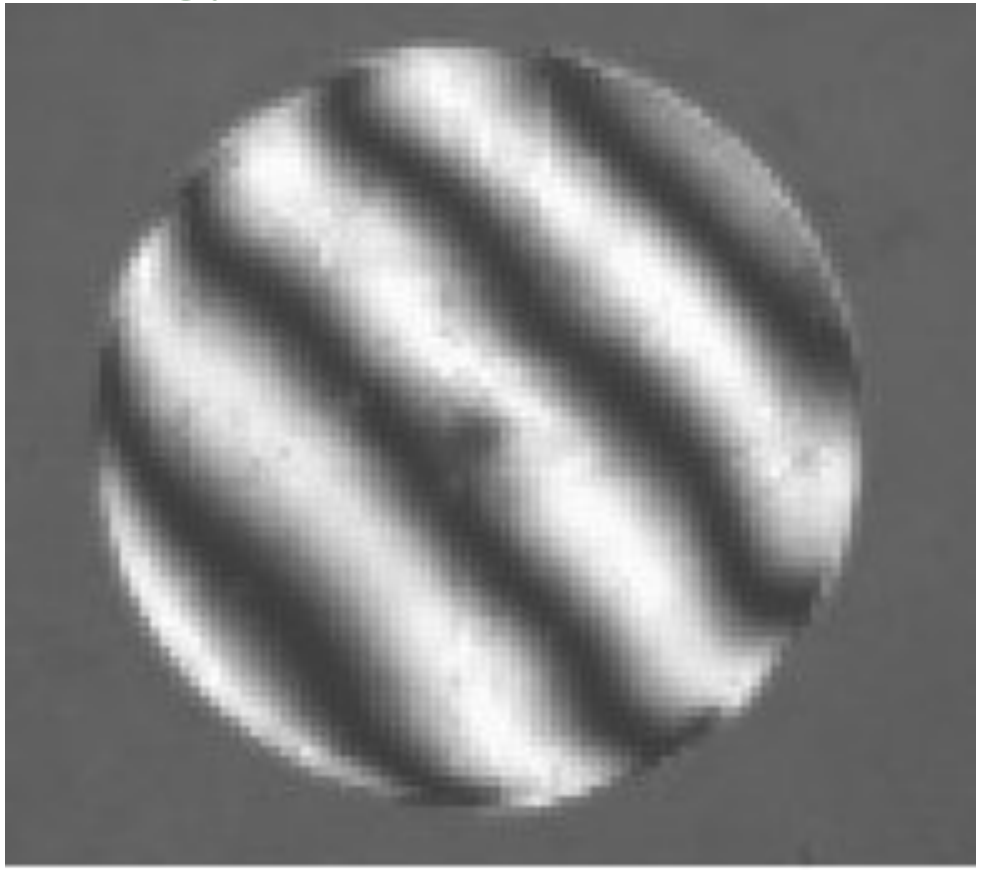
Software controlled super thin MAP optical lens technology



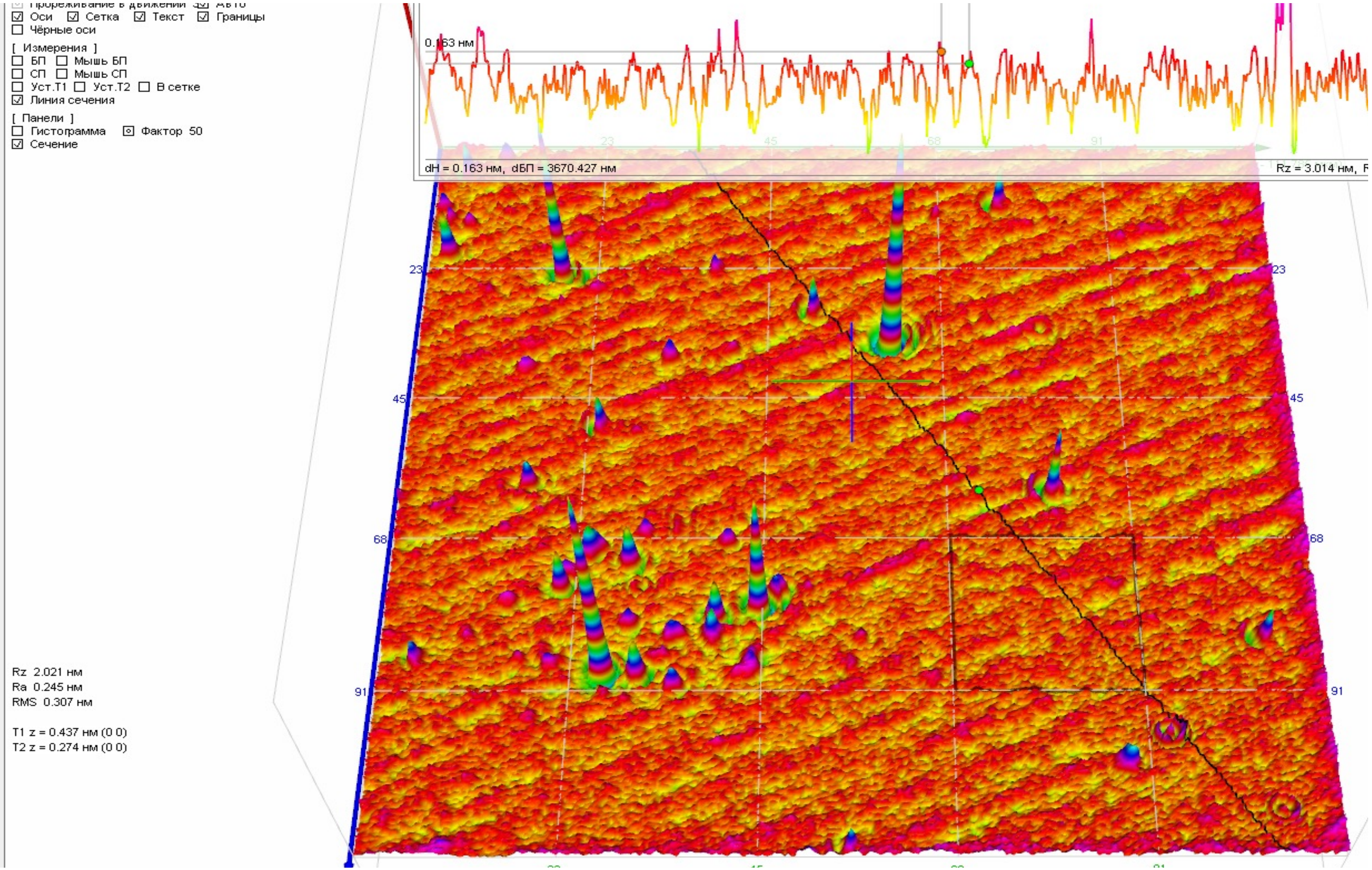
a) PV = 158 nm, Ra = 20 nm



b) PV = 30 nm, Ra = 1,4 nm

Interferograms of the surface of optical glass before (a) and after (b) MAP

THE NANORELIEF OF THE OPTICAL LENS AFTER THE MAP



Ra = 0.245 nm

(MEASUREMENTS PERFORMED AT KTI NP SB RAS)

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LASER CRYSTAL CaF_2 AFTER MAP

Ra = 1.537 nm

Veeco

Measurement Parameters

File:	CaF2-Rand
Wavelength	605.40 nm
Wedge	0.50
X/YSize	736 X 480
Pixel size	168.48 nm
Date	04/10/2003
Time	08:39:40
Averages	1

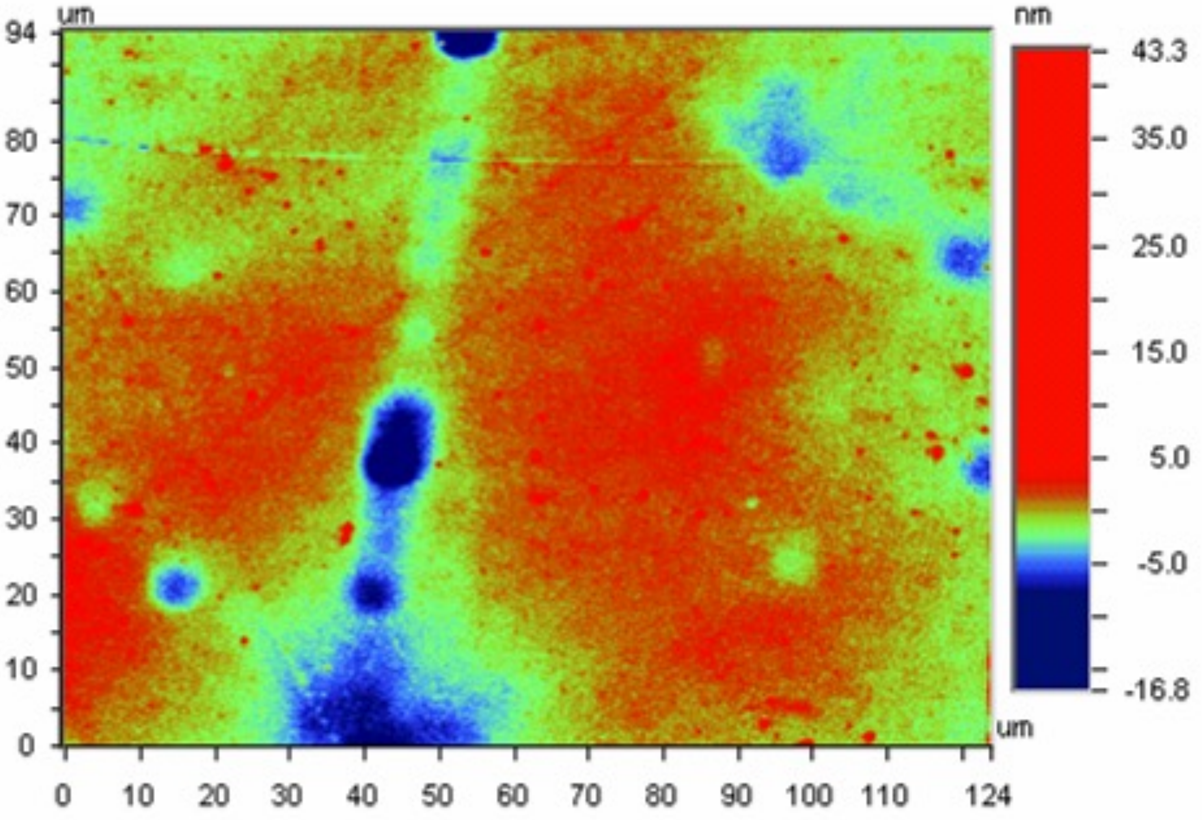
Analysis Results

Ra	1.537 nm
Rms	2.126 nm
20 Pt. PV	41.879 nm
2 Pt. PV	60.19 nm

Analysis Parameters

Terms	Tilt
Masks:	
Filtering	None
Data Restore	No
Valid Points	353280

Contour Plot



RESISTANCE TO LASER BEAM OF OPTICAL GLASS AFTER MAP

LIDARIS
LIDT Service

POLIMAG – SO1176

COMPARISON OF LIDT VALUES

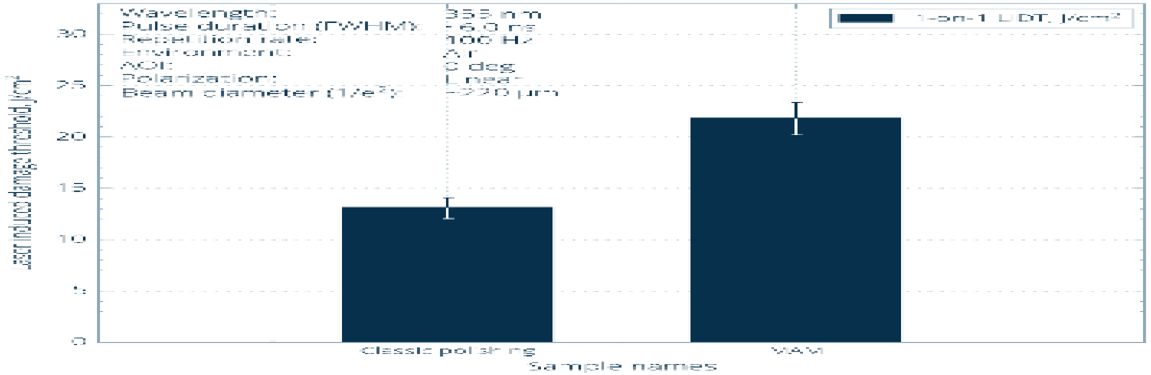


Figure 1: Comparison of SO1176 measurements.

Table 1: SO1176 data spreadsheet

Sample	Threshold (1-on-1)	Error lower	Error upper
MAM	21.80	1.58	1.58
Classic polishing	13.13	1.07	0.96

THE RESISTANCE TO LASER BEAM OF OPTICAL GLASS AFTER MAP IS 66% HIGHER, THAN AFTER MECHANICAL POLISHING

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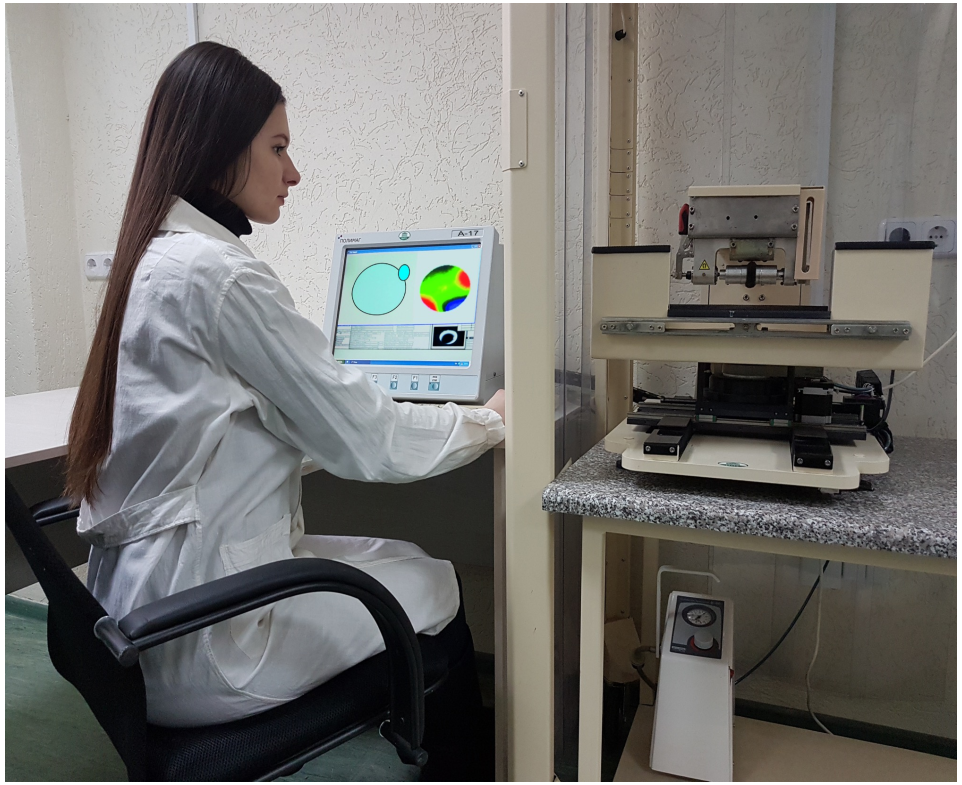
CAPABILITIES OF SUPER THIN MAP

Installation A17

Q-flex 300

Analogue MRF TECHNOLOGY

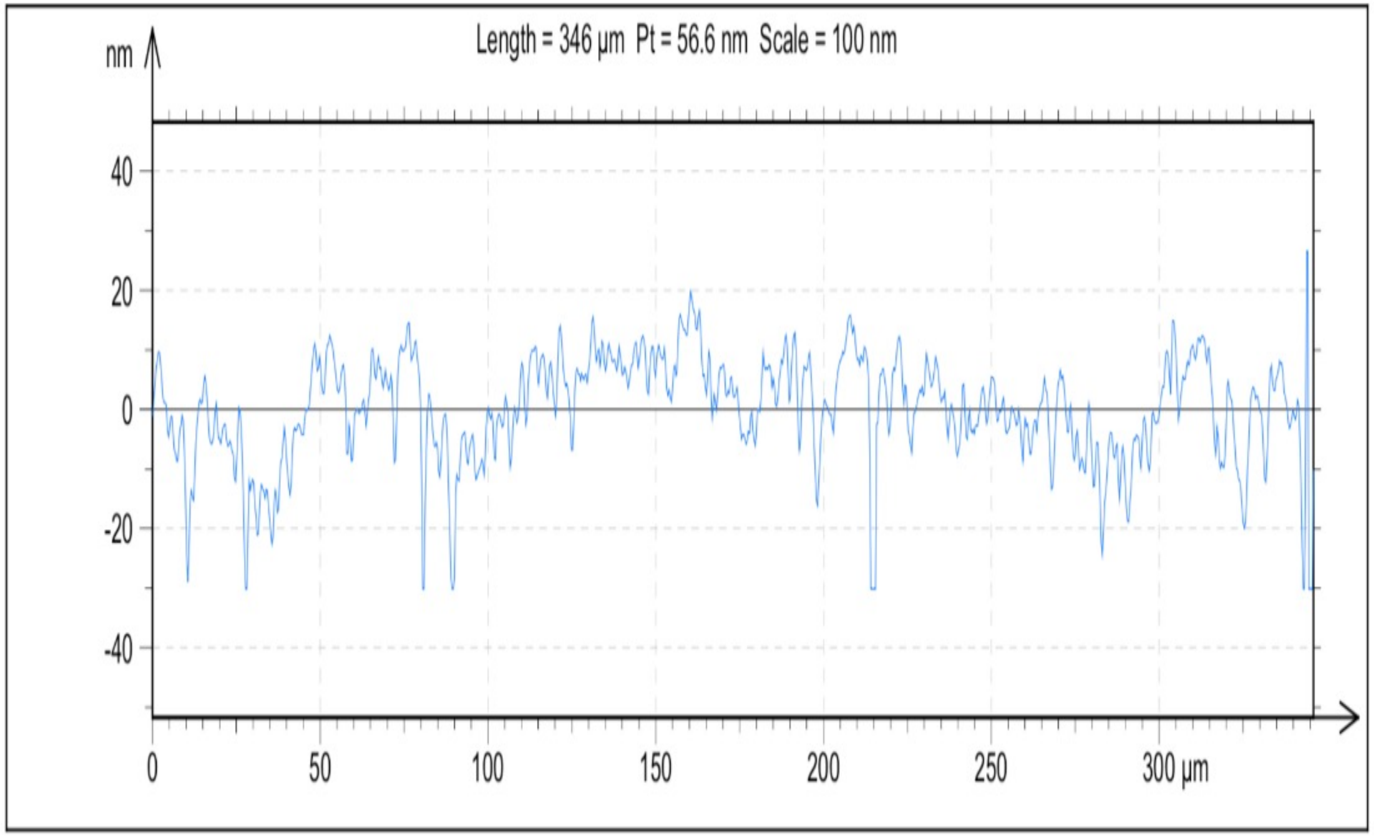


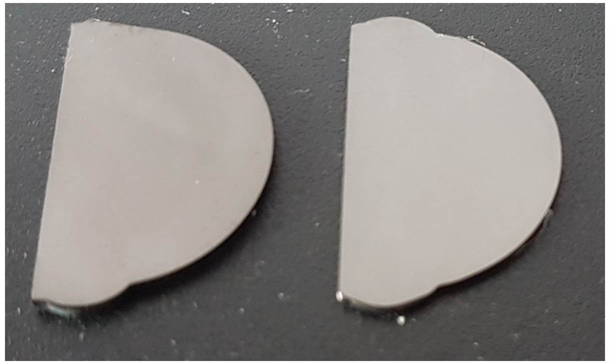
	Before MAP		After MAP
Sa	0.27 nm	Sa	0.14 nm
Sq	0.37 nm	Sq	0.19 nm
Sp	4.58 nm	Sp	1.13 nm
Sv	3.66 nm	Sv	0.74 nm
Sz	8.24 nm	Sz	1.87 nm

MAP OF LEAFTS OF ARTIFICIAL HEART VALVE

Door material (locking elements): pyrolytic carbon (ceramic glass)

NANO-RELIEF OF THE SURFACE OF VALVES





AFTER MAP, nm

Rz = 24,39

Sq = 9,41

Ra = 3,91

NANORELIEF OF SILICON WATER AFTER MAP

Veeco

Mag: 49.9 X

Mode: PSI

Surface Data

Surface Statistics:

Ra: 0.72 nm

Rq: 0.89 nm

Rz: 6.77 nm

Rt: 10.39 nm

Set-up Parameters:

Size: 736 X 480

Sampling: 168.48 nm

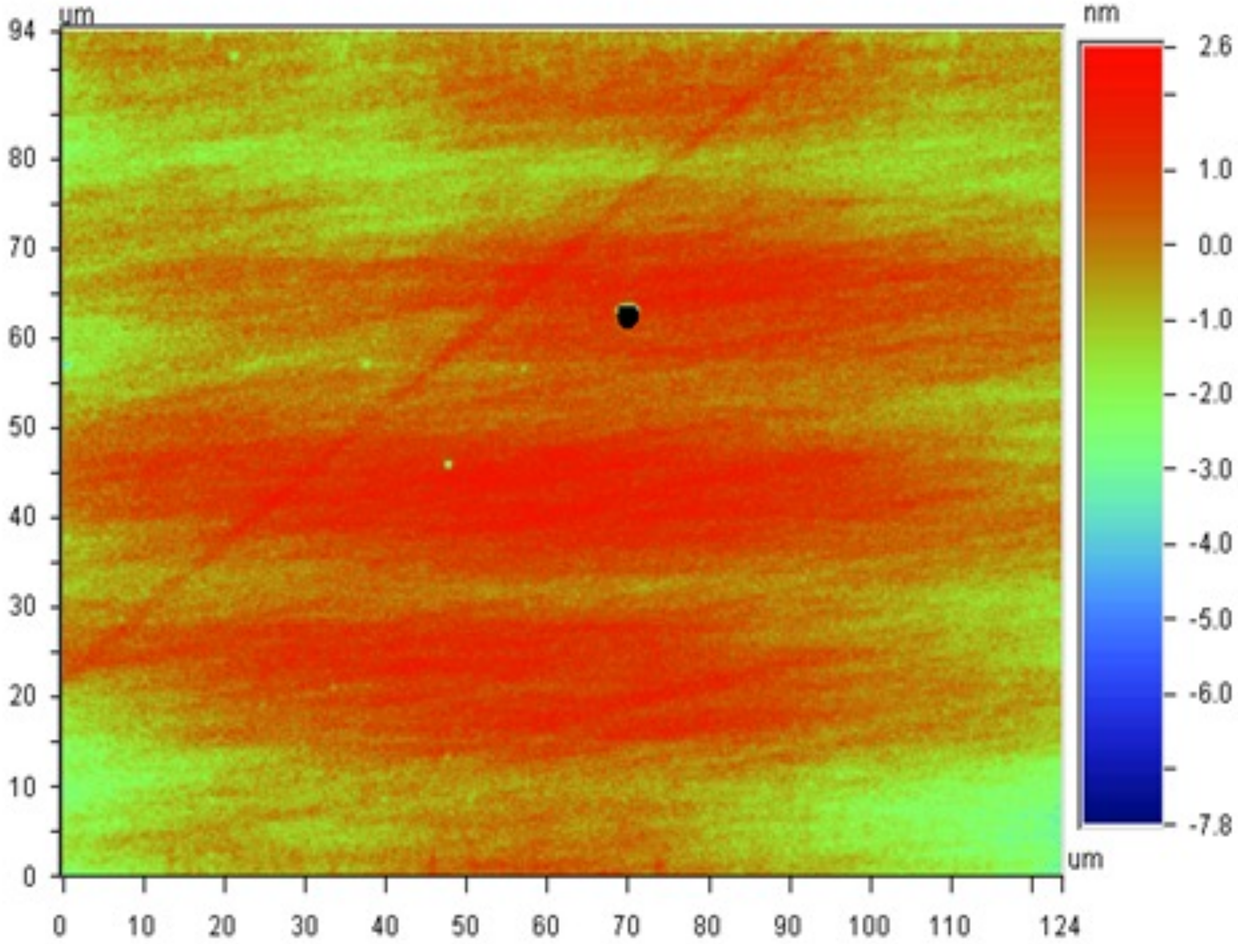
Processed Options:

Terms Removed:

Tilt

Filtering:

None

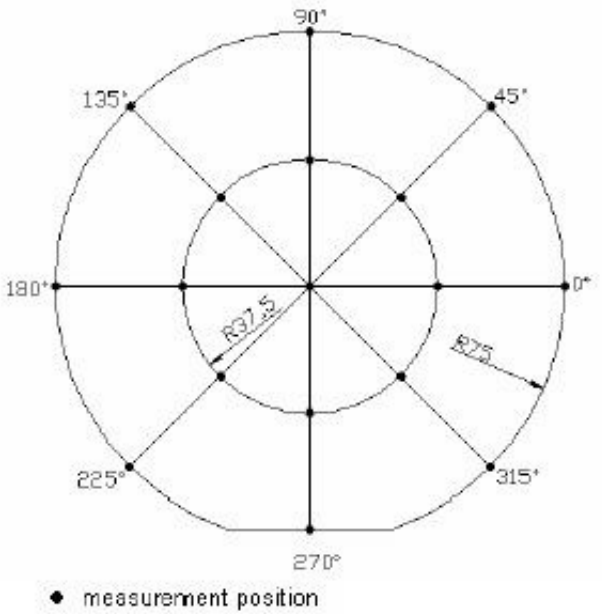


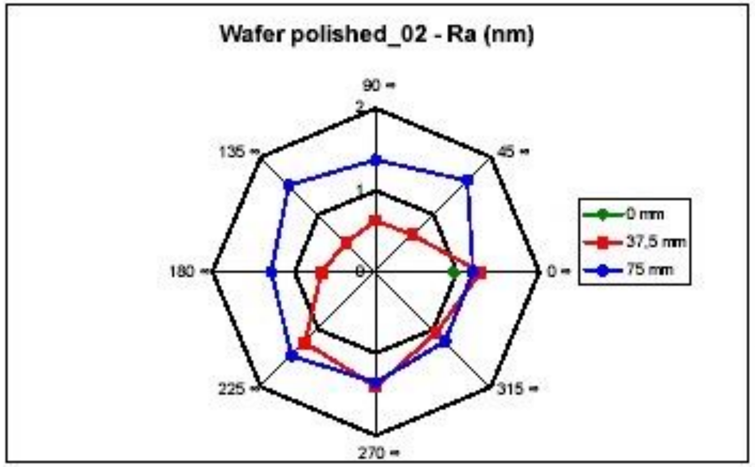
Ra = 0.72 nm

TTV = 2.9 µm

SUPERTHIN MAP OF SILICON MONOCRYSTAL WAFER
Ra = 0,51 … 1,57 nm

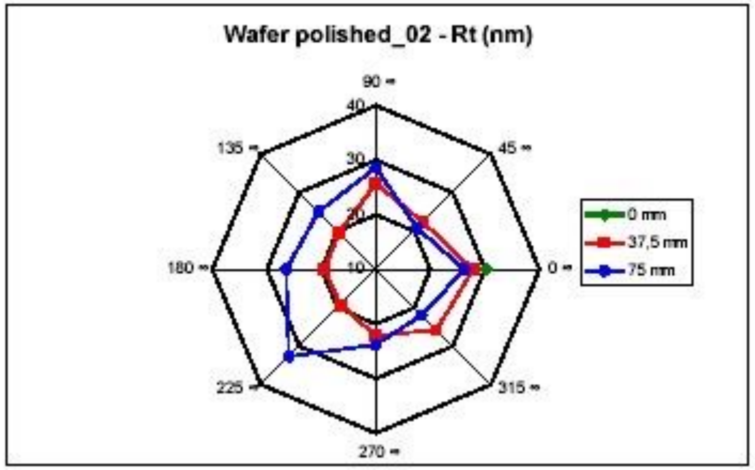
- Equipment: Wyco NT1100
- Amplification: 10x PSI
- Wafer: polished – 150 mm





Ra ñ values (nm)

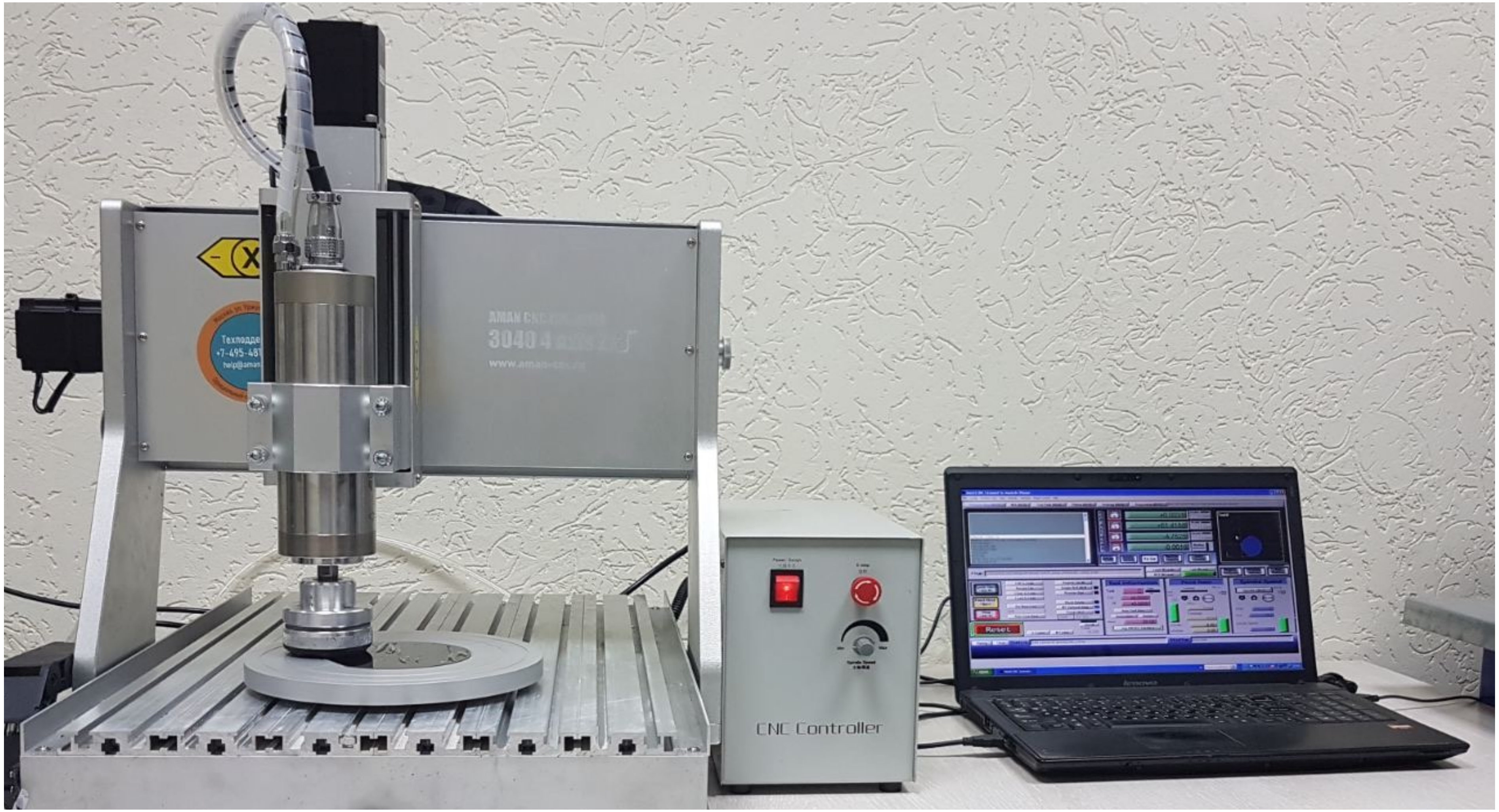
Angle/Radius	0 mm	37,5 mm	75 mm
0 ∞	0,95	1,28	1,18
45 ∞		0,65	1,57
90 ∞		0,64	1,37
135 ∞		0,51	1,51
180 ∞		0,66	1,28
225 ∞		1,23	1,44
270 ∞		1,41	1,36
315 ∞		1,05	1,21



Rt ñ values (nm)

Angle/Radius	0 mm	37,5 mm	75 mm
0 ∞	30,15	27,56	25,97
45 ∞		21,95	20,49
90 ∞		25,51	28,53
135 ∞		19,41	24,67
180 ∞		19,48	26,43
225 ∞		19,18	32,11
270 ∞		22,10	23,64
315 ∞		25,54	21,86

A23 INSTALLATION FOR SUPER THIN MAP Si-PLATES



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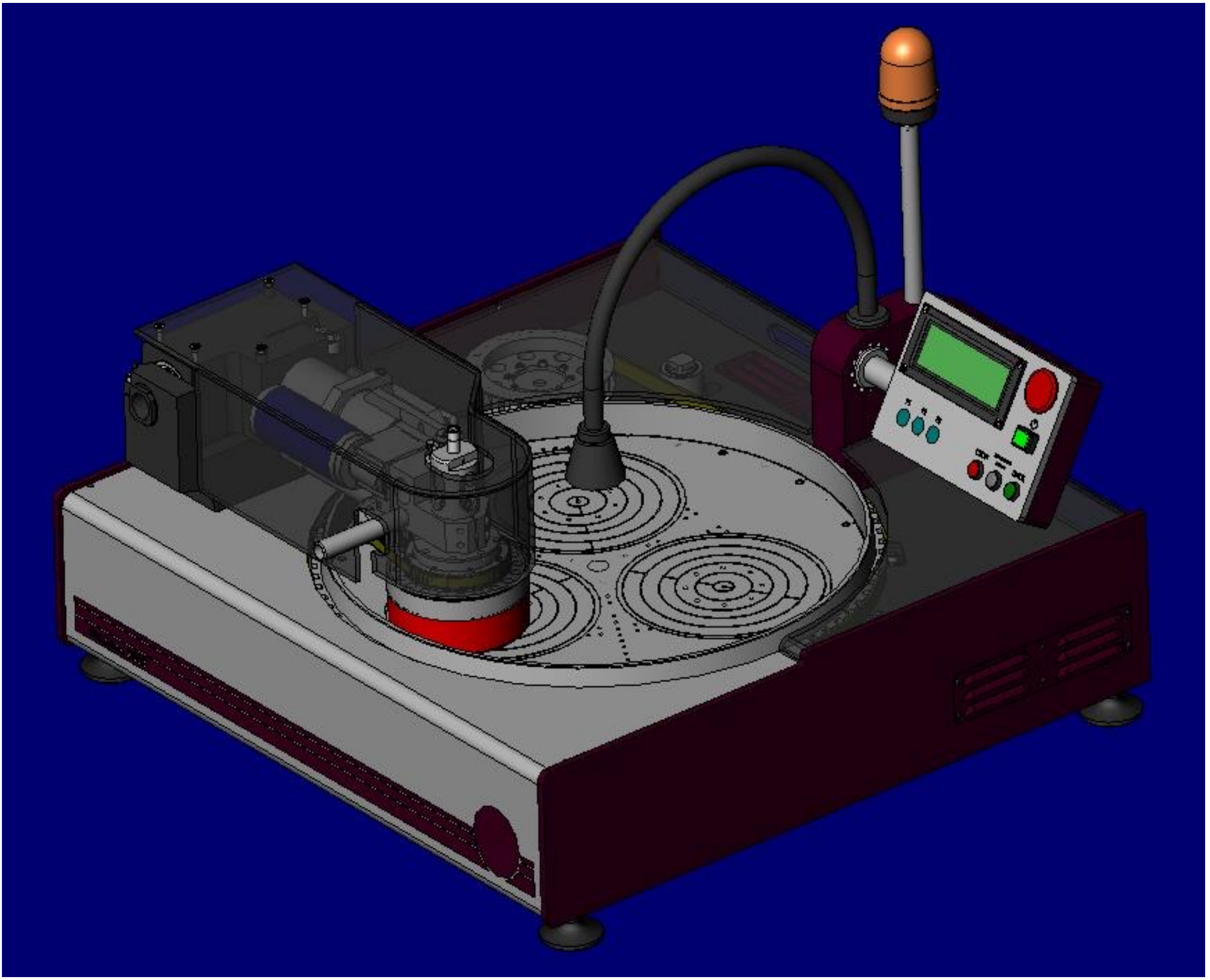
INSTALLATION MA08.01 FOR SUPER-THIN MAP Si-PLATES
(in production)



Technical characteristics of the MA08.01 installation:

- diameter of processed parts, mm	10 -300
- thickness of processed parts, mm	0,1 – 30
- shape accuracy PV, microns	2,9
- surface roughness Ra, nm	< 0,5
- processing time, min	3 – 15
- power, kWt	1,5
- overall dimensions (LxWxH), mm	700x700x500
- weight (approximately), kg	80

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SOLVING THE PROBLEM OF "AGING CHIPS«

The drawing CHIP has "aged" and collapsed

For the industrial implementation of nanoelectronics production technologies at a level of less than 10 nanometers, it is necessary to improve the process of superfine polishing of semiconductor wafers (for example, Si-Wafer) with a nanorelief parameter Ra < 1 nm and a minimum of defects in the structure of the surface layer.

The currently used technology of gas etching of the surface of the plates is environmentally harmful and has a major drawback: defects at the atomic and molecular level remain on the surface of the plates in the form of electrochemical cells of the structure remaining after the etching process is completed. The operations of thorough washing of the plates do not solve the problem of removing these defects, the dimensions of which are close to the dimensions of conductors and transistors formed using technology less than 10 nm.

In defects in the form of electrochemical cells on the surface of the formed chips under operating conditions (for example, in cars), chemical reactions of oxidation and mechanical destruction of the chip substrate and its elements are activated under the influence of humidity, temperature and vibrations. This phenomenon has recently been given the name "chip aging". As a result of the "aging" of the car's electronics (all or part of it) fails.

При массовом применении технологии менее 10-и нм в производстве наноэлектроники «старение чипов» при эксплуатации значительно снижает их надежность и является актуальной проблемой.

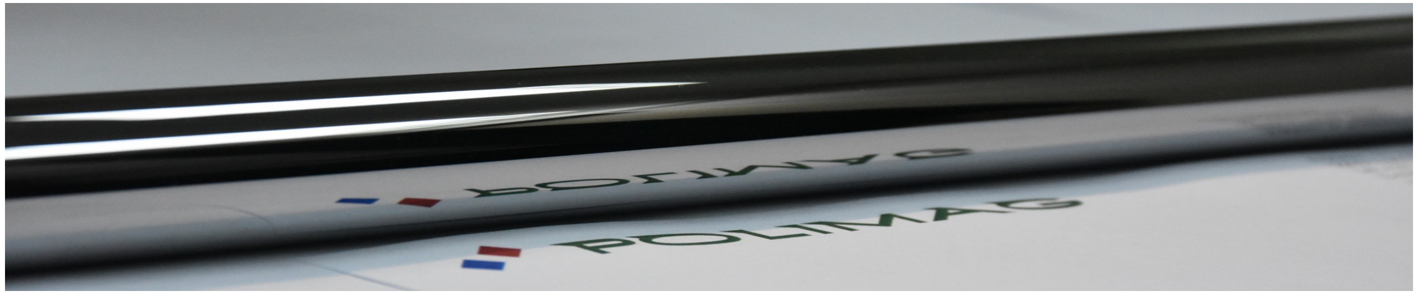
With the mass application of technology less than 10 nm in the production of nanoelectronics, the "aging of chips" during operation significantly reduces their reliability and is an urgent problem.In order to significantly slow down the process of "chip aging", increase their reliability and extend their service life, it is necessary to form a super-smooth surface with the minimum possible number of structural defects at the finishing operation of super-fine polishing of Si-Wafer plates.

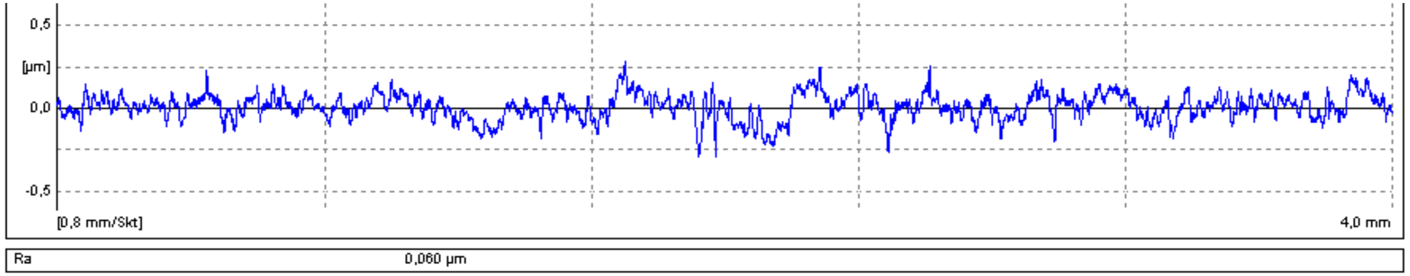
This task can be solved much better by using super-fine magnetic abrasive polishing (MAP) technology instead of gas etching technology. During the MAP process, a pulsed magnetic field acts on weakly fixed defects in the structure of the surface layer of the polished plate, "shakes" them and brings them to the surface of the plate, where they are removed by a polishing "elastic brush" from a ferroabrasive powder tool.

As a result, the MAP forms a nanorelief of the plate with the parameter Ra < 1nm and with a minimum number of defects in the structure of the near-surface layer. Conditions are being created for the manufacture of chips to ensure their high reliability and resistance to "aging".In the production of nanoelectronics using technology less than 10 nm, the main indicators of the MAP method (quality, productivity, economics and ecology) are significantly better than those of the gas etching process currently used.

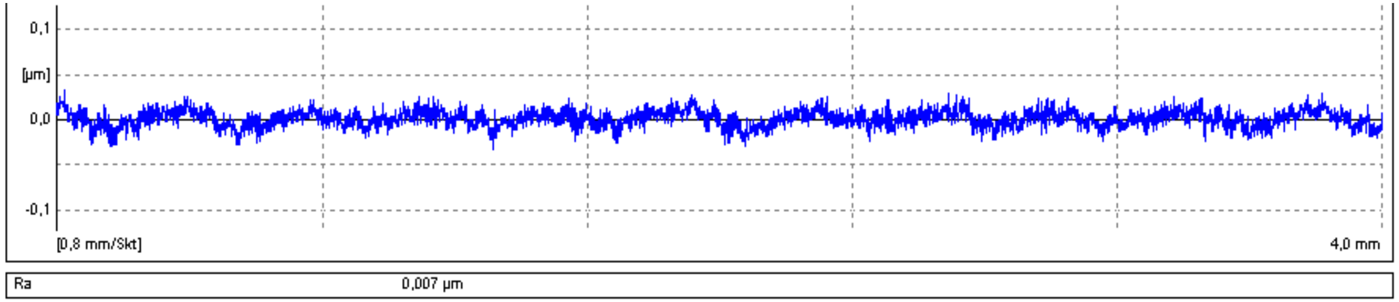
MAP OF THE SURFACE OF THE WC - Co ALLOY PRODUCT

Cylindrical sample (DxL = 22 x 280 mm) made of WC - Co alloy





Before MAP Ra = 53 nm



After MAP Ra = 7 nm

Ra, nm	
Before MAP	After MAP
56	7
48	7
52	7
60	8
47	7
53	7

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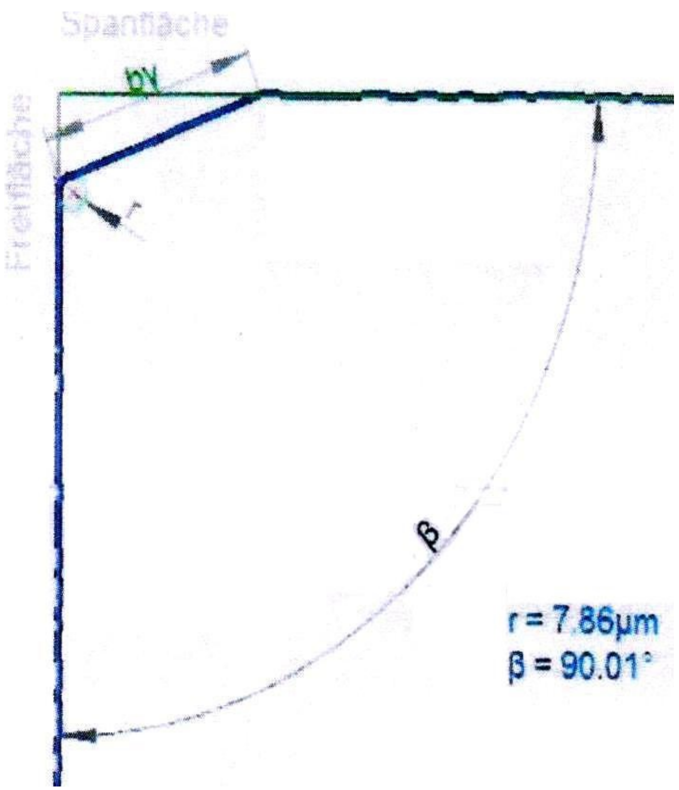
MAP CERAMICS: PLATES FOR CUTTERS AND MILLS

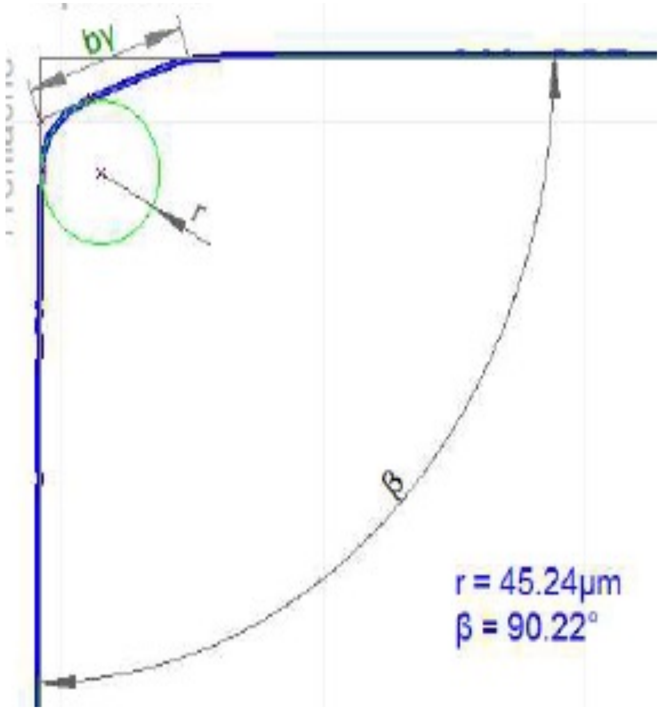
Before MAP

r = 7.86 µm

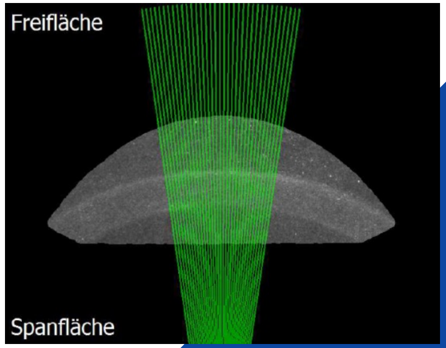


After MAP

r = 45.24 µm



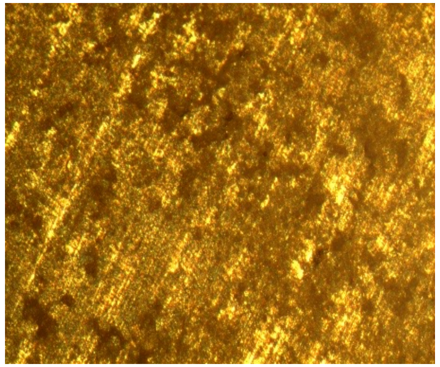
Material	Microhardness, GPa
Diamond	100
Borazon	88
SiC	33
Al_2O_3	20
Si	12



Vandurit GmbH, Germany

MAP OF PUNCH SURFACES

Before MAP | **After MAP**



100x

200 мкм

100x

200 мкм

Measure-ment No.	Roughness Ra, µm		
	Before MAP	After MAP	
		Number of passes	
		20	30
1	2,897	0,328	0,024
2	2,761	0,413	0,021
3	2,555	0,382	0,029
4	2,671	0,384	0,040
5	2,437	0,685	0,040
6	2,634	0,623	0,034
7	2,666	0,449	0,026
8	2,664	0,325	0,038
9	2,660	0,379	0,098
10	2,788	0,510	0,052

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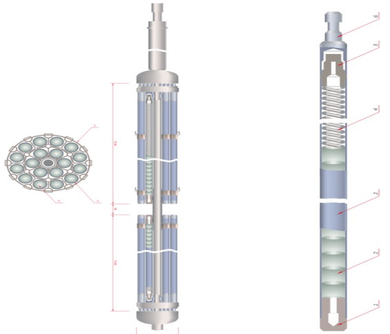
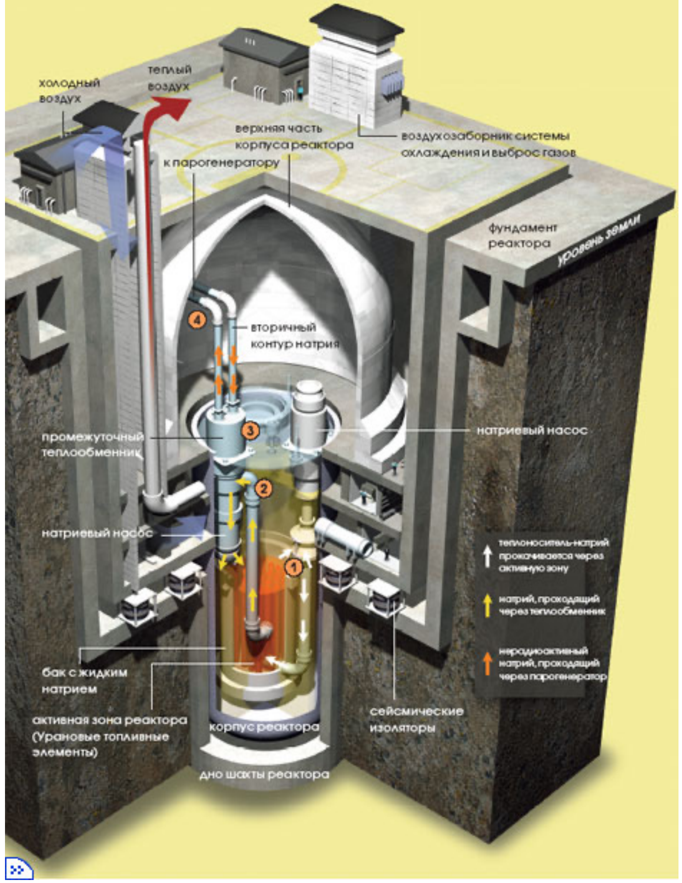
MAGNETIC-ABRASIVE POLISHING (MAP) OF TUBE-SHELLS OF FUEL ELEMENTS OF NUCLEAR REACTORS



Fuel element

Fuel rod assembly



Nuclear reactor diagram

Installation of T15 for MAP fuel rod cladding tubes

MAP technology improves the quality of fuel element cladding by 20-50% compared to traditional chemical etching and grinding technologies

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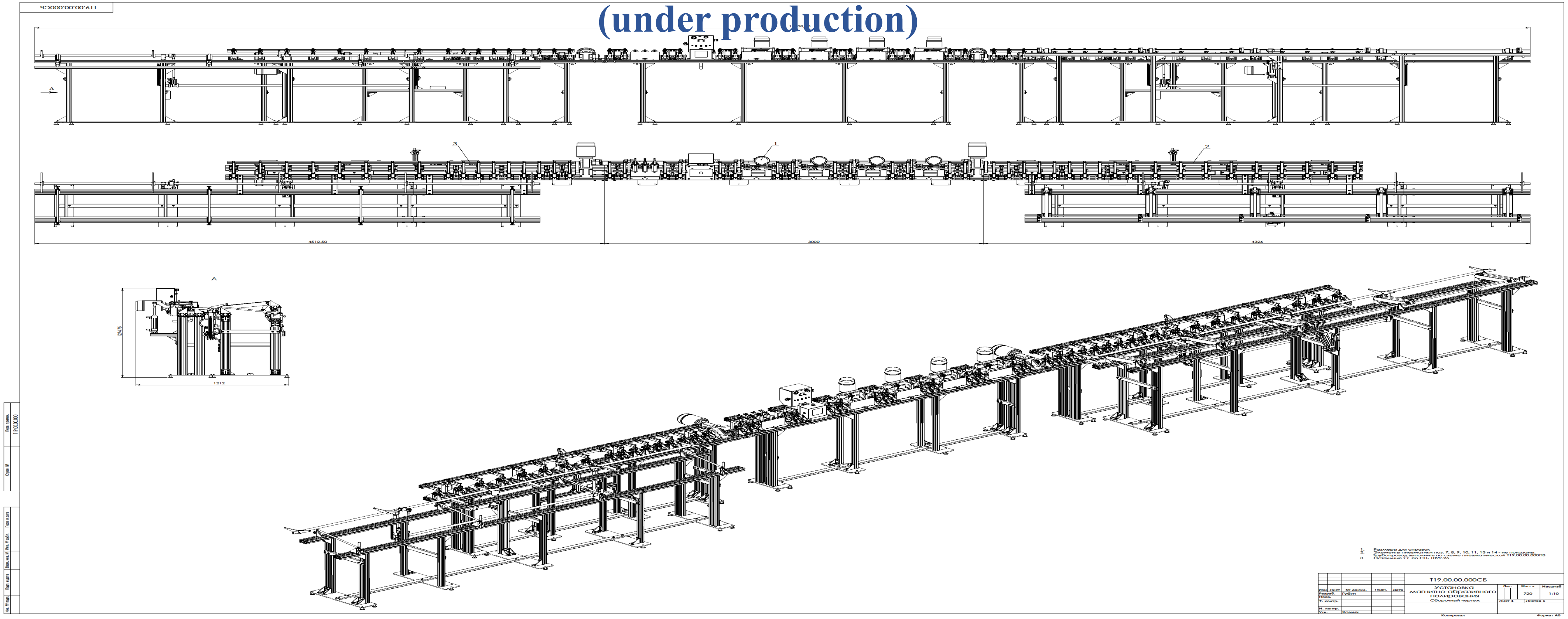
AUTOMATIC INSTALLATION T19 FOR MAP PIPE OF FUEL ELEMENTS

(under production)



Technical characteristics of the T19 installation:

- pipe rotation speed, rpm: 300 - 500 rpm;
- pipe feed (MAP capacity), m/min: 0.5 – 2.0;
- - installation energy consumption, kW: 2.5;

- installation dimensions (LxWxH), m: 13.0x1.0x1.5

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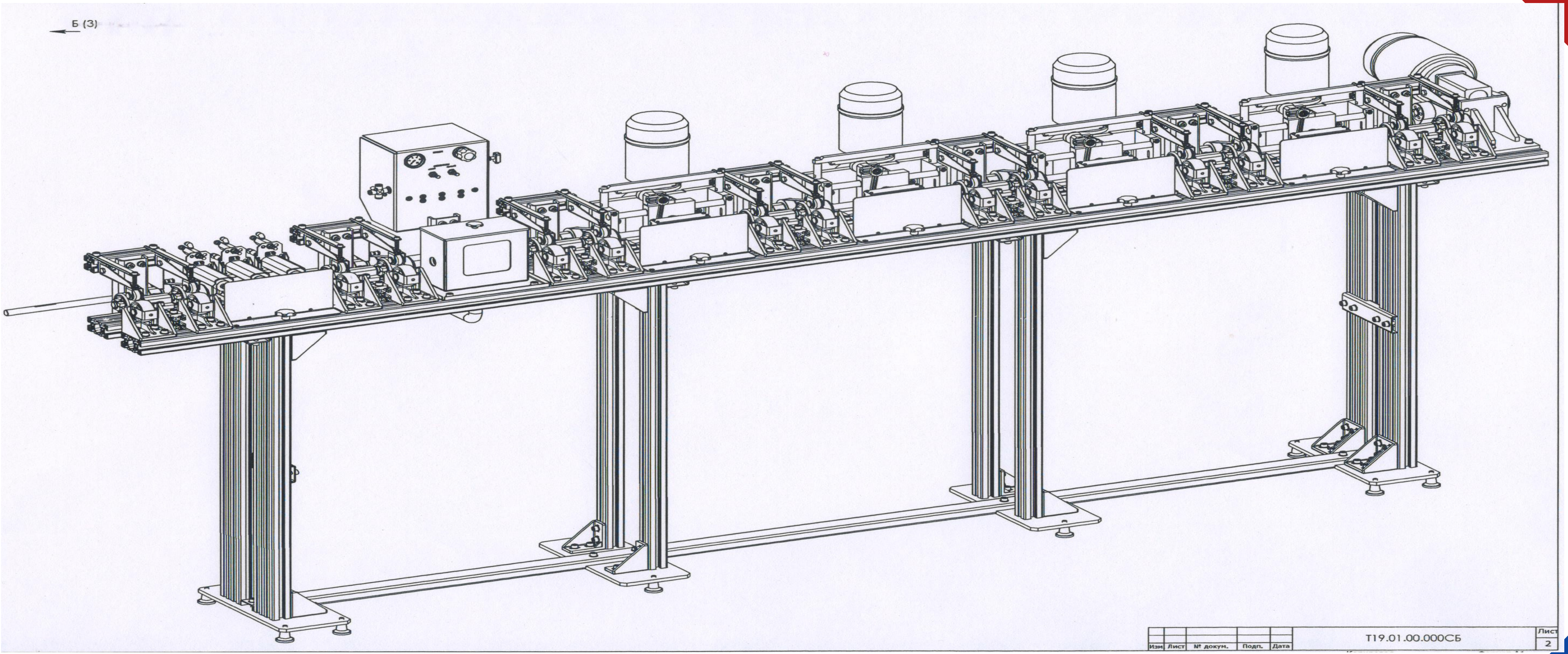
WORKING MODULE OF THE T19 INSTALLATION

THE T19 INSTALLATION SIMULTANEOUSLY POLISHES THE OUTER AND INNER SURFACES OF THE PIPE



The working module contains 4 autonomous polishing units, pipe washing and drying apparatus, automatic mechanisms for loading and unloading pipes from the working area

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Test results of pipe samples Ø9.13x7.73 mm made of E110 alloy with MAP

Mechanical properties of pipe samples Ø9.13x7.73 mm made of alloy E110 with MAP

Sample number	Mechanical properties									Anisotropy coefficient
	Тисп.=20ºС			Тисп.=380ºС						
	σв⊥, кгс/мм²	$\sigma_{0,2}^{\perp}$ кгс/мм²	δ ⊥, %	σв⊥, кгс/мм	$\sigma_{0,2}^{\perp}$ кгс/мм²	δ⊥, %	σв//, кгс/мм²	$\sigma//_{0,2}$, кгс/мм²	δ,// %	
1	39	35	34	19	16	39	20	10	62	1,6
2	39	34	36	19	16	42	20	10	56	1,6
3	41	35	36	20	17	42	20	12	62	1,6
Technical specifications 95 2594-96	at least 28	at least 21	at least 28	at least 15	at least 13	at least 33	–	at least 8	–	at least 1,4
Technical specifications 001.392-2006	at least 28	at least 21	at least 24	at least 15	at least 13	at least 33	–	at least 8	–	at least 1,4

The results of corrosion tests of pipes Ø9.13x7.73 mm made of alloy E110 with MAP

Sample number	Weight gain, mg/dm²	Surface quality
1	13	Satisfactory
2	14	Satisfactory
3	14	Satisfactory
Technical specifications 95 2594-96	no more 22	Satisfactory
Technical specifications 001.392-2006	no more 22	Satisfactory

The TVEL-MAP project is focused on solving the main tasks:

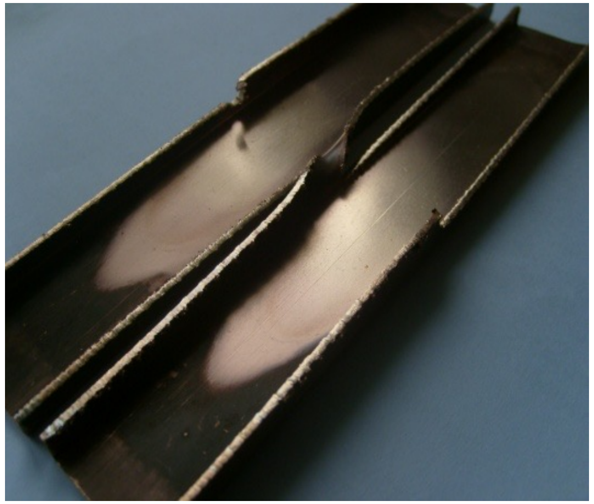
- 1. The development of magnetic-abrasive polishing (MAP) technologies for fuel element shell pipes at industry enterprises instead of outdated chemical etching and grinding technologies.

- 2. As a result of the MAP, the most important functional characteristics of pipe surfaces are improved - resistance to corrosion, wear, flooding and mechanical destruction. Increasing the service life and reliability of fuel rod and reactor assemblies.
- 3. Environmental safety: the rejection of the use of environmentally harmful processes of transportation, use and storage of aggressive acids (fluoric, nitric). There is no need for high costs for the disposal of waste acid solutions.
- 4. Import substitution: installations and tools for MAP are Russian – there is no need to import equipment and consumables (abrasive belts and pastes).
- 5. Improvement and improvement of working conditions of employees. Automation of MAP processes.

6. MAP equipment, technologies and tools are patented and competitive in the global market (China, France, Yu.Korea, etc.

7. The cost of implementing MAP technologies is lower than the cost of using existing etching and grinding technologies.

MAP OF THE INTERNAL SURFACES OF WAVEGUIDES



Waveguide materials:

alloys of Cu, Al, Si, steel, etc.

Before MAP: Ra = 0,80 µm

. After MAP: Ra = 0,08 µm

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POLISHING OF AIRCRAFT ENGINE BLADES

we have experience in POLISHING COMPRESSOR AND TURBINE BLADES UP TO 100 MM LONG,

ensures rounding of the working edge of the blade

in 5 – 20 minutes the Ra parameter decreases from Ra = 1.0 μm to Ra = 0.08 μm

MAGNETIC-ABRASIVE POLISHING

ELECTROLYTE-PLASMA POLISHING

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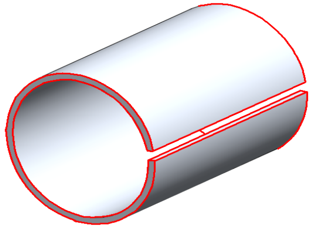
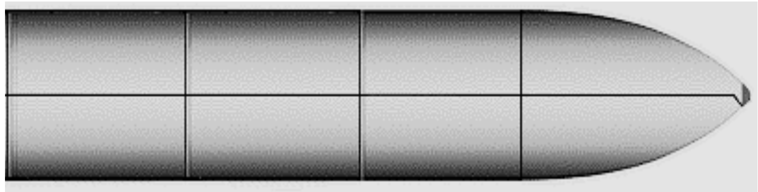
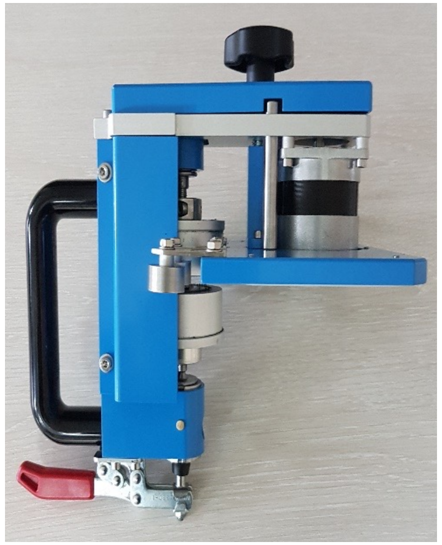
MAGNETIC-ABRASIVE CLEANING OF PARTS EDGES BEFORE WELDING





Cleaning the edges of body elements before welding in aerospace, shipbuilding and other industries

Installation CFT2.126



Module K23

Specifications:

- simultaneous cleaning of the edge end and side surfaces;
- thickness of the stripped edge, mm: 1-12;
- stripping width, mm: 10 – 15;
- edge material: Al-Mg, Ti alloys, stainless steels, etc.
- stripping speed, m/min: 0.5 – 3.0;

Examples of edge cleaning of Al-Mg alloy products (weldability):

- after chemical etching – 8 hours,
- after mechanical cleaning – 48 hours,
- after magnetic abrasive cleaning – 720 hours.

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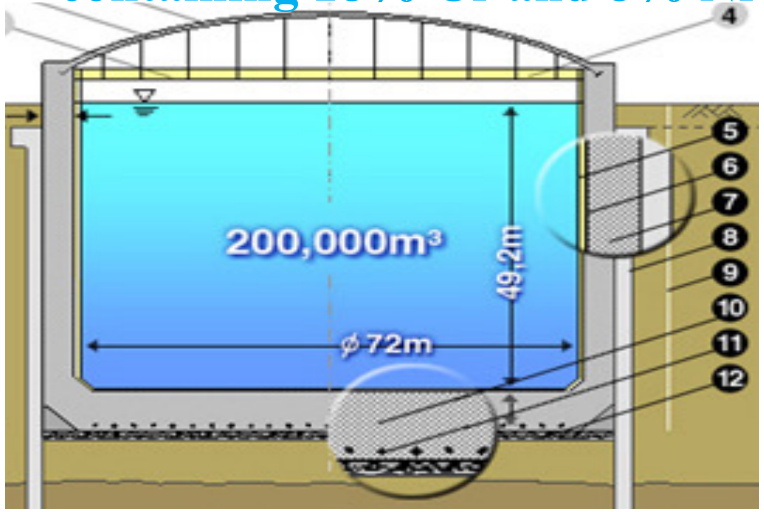
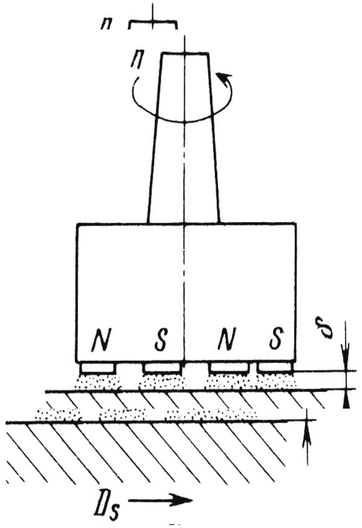
Magnetic abrasive cleaning of the edges of alloy steel sheets before welding

LNG tank design diagram

Stainless steel membrane, containing 18% Cr and 8% Ni





Magnetic inductor

Module K23 for cleaning sheet edges

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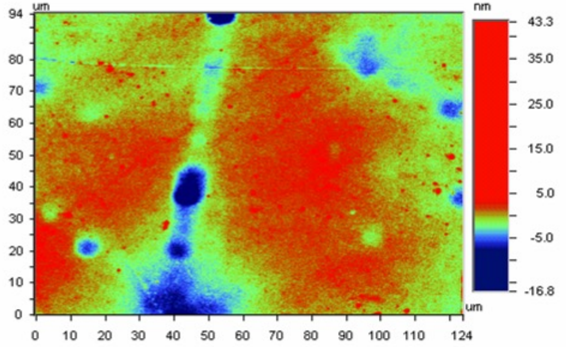
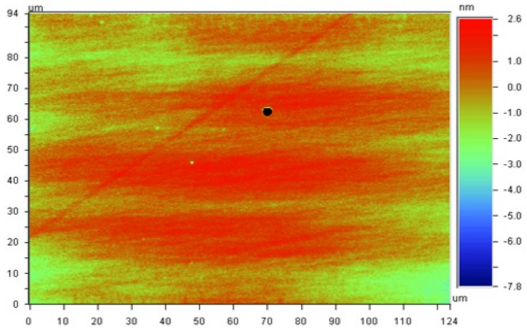
SAMPLES OF PARTS FOR MAP

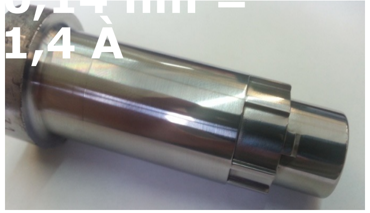
Optics



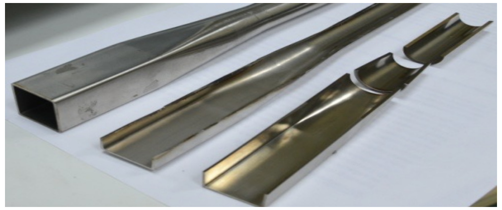
Lasers



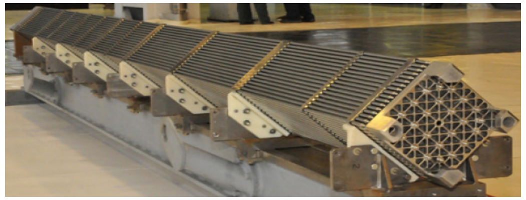
Electronics



Tool: cutters, punches, taps, drills



Pipes: external and internal surfaces



Fuel cladding tubes

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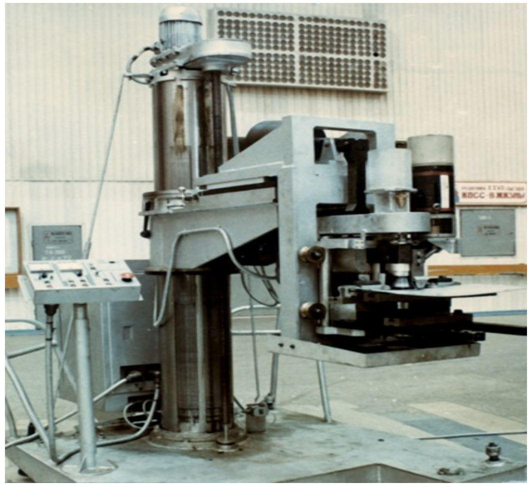
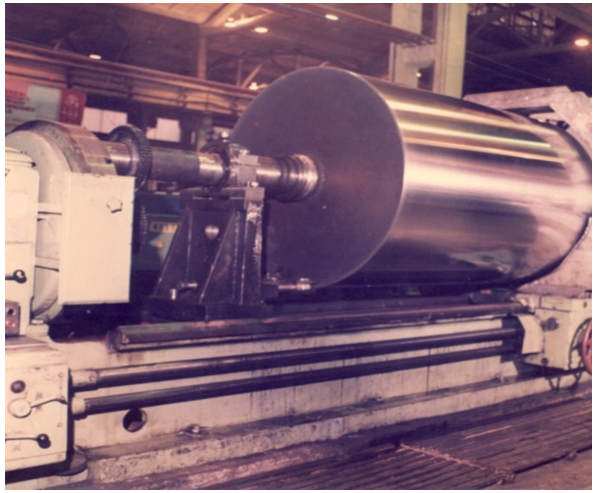
HISTORICAL REFERENCE

ABOUT EARLY DEVELOPMENTS OF THE METHOD OF MAGNETIC-ABRASIVE POLISHING

(1975 – 1995)



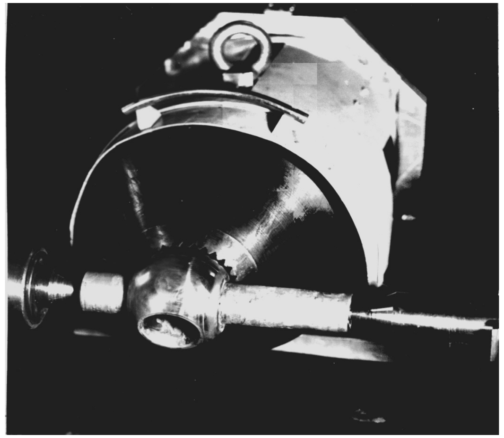
Cleaning edges before welding



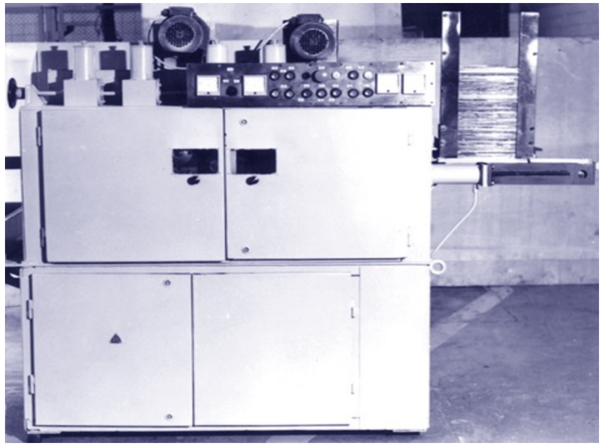
MAP shafts

MAP screws

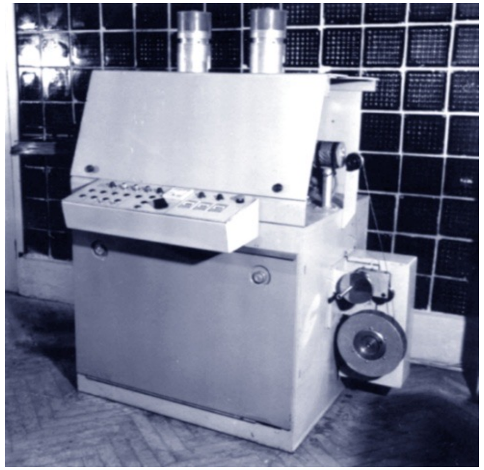
MAP sheets and tapes



MAP spheres



MAP pipes



MAP wire

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FEATURES AND ADVANTAGES OF SUPER-FINE MAGNETIC ABRASIVE POLISHING (MAP) TECHNOLOGIES

1. POLISHING IS PERFORMED IN SUBMICRO-CUTTING AND SMOKING MODESWITH THE PREMIUMINESS OF SHEAR STRESS IN THE MATERIAL OF THE PART, A SURFACE LAYER WITH A MINIMUM OF STRUCTURE DEFECTS IS FORMED

2. THE MAGNETIC FIELD IMPROVES THE STRUCTURE OF POLISHED MATERIALS DUE TO MAGNETOPLASTIC, ELECTROPLASTIC AND MAGNETOSTRICTIVE EFFECTS

3. A SURFACE NANORELIEF WITH $Ra < 0.2$ NANOMETERS AND A SURFACE LAYER WITH A MINIMUM OF STRUCTURE DEFECTS – POTENTIAL SITES OF CORROSION, WEAR AND MECHANICAL DESTRUCTION IS FORMED

4. MAP TECHNOLOGIES SUCCESSFULLY REPLACE LABOR-INTENSIVE AND ENVIRONMENTALLY HAZARDOUS PROCESSES CHEMICAL ETCHING AND ELECTROCHEMICAL POLISHING

5. MAP PROCESSES SUPERIOR THE BEST ANALOGUES IN TECHNOLOGICAL CAPABILITIES, ECONOMIC AND ENVIRONMENTAL INDICATORS

AWARDS

The Organizing Committee of the International Exhibition HI-TECH (St. Petersburg, April 17-20, 2023) based on the results of consideration of 83 submitted applications for the competition “Best Innovative Project and Best Scientific and Technical Development of the Year” recognized the project of UE “POLIMAG” as the winner of the competition “ Technologies and equipment for superfine magnetic abrasive polishing" with the presentation of a special prize and 3 diplomas

Publications: 176 scientific publications

74 patents

Partners:

China

内蒙金属材料研究所
INNER MONGOLIA METALLIC MATERIALS RESEARCH INSTITUTE

浙江師範大學
ZHEJIANG NORMAL UNIVERSITY

Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences

蘭州大學
LANZHOU UNIVERSITY

Harbin Institute of Technology

Russia

РОСАТОМ

МИФИ — Национальный исследовательский ядерный университет

РОСКОСМОС

ВНИИНМ имени А.А. Бочвара

Germany

Fraunhofer

Hochschule Deggendorf

EWE

VM-TIM TECHNOLOGIES INSTRUMENTS MATERIALS

South Korea

KAERI

Italy

University of Ferrara

ricos s.r.l.u. stampi, attrezzature e lavorazioni tubi

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