Technologies and Nanotechnologies of Magnetic-Abrasive Machining of Surfaces

Speaker:

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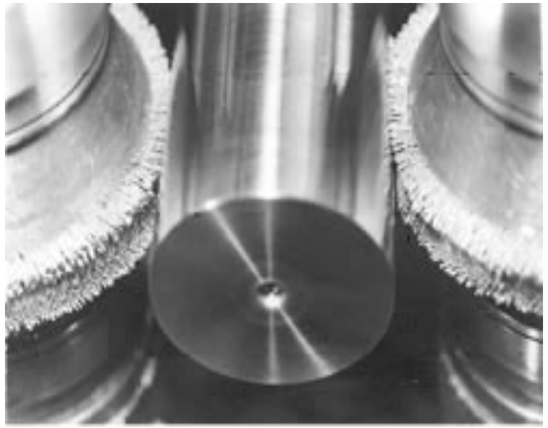
Minsk 2021

Method

- The magnetic field transforms the ferroabrasive powder into a kind of an "elastic brush" and polishes the surface

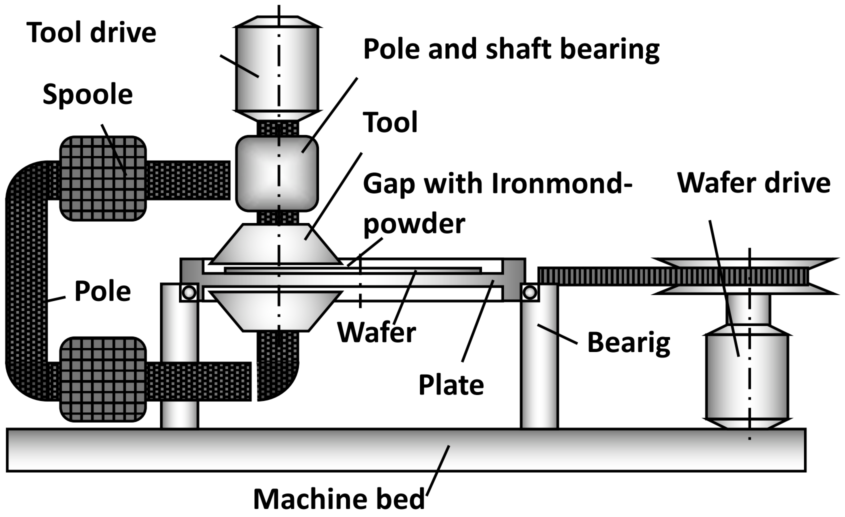


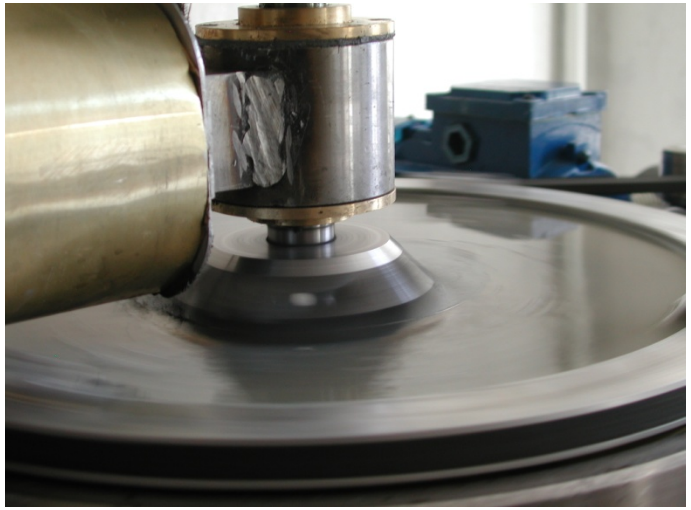
- Pulsing magnetic field improves the structure of the preface layer of the material

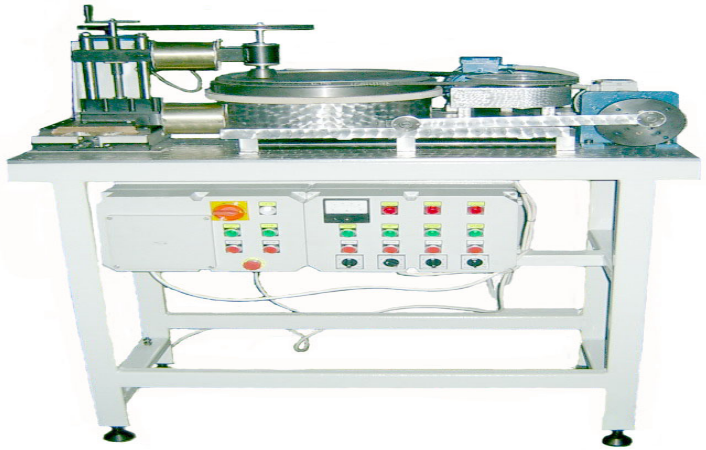
Application

- Formation of surface nanorelief
- Polishing surfaces before coating
- Cleansing surfaces before welding
- Polishing surfaces to increase resistance to corrosion, wear and mechanical destruction
- Surface modification under physical-chemical processes (diffusion, adhesion, etc.)

Experimental model for polishing plate surfaces



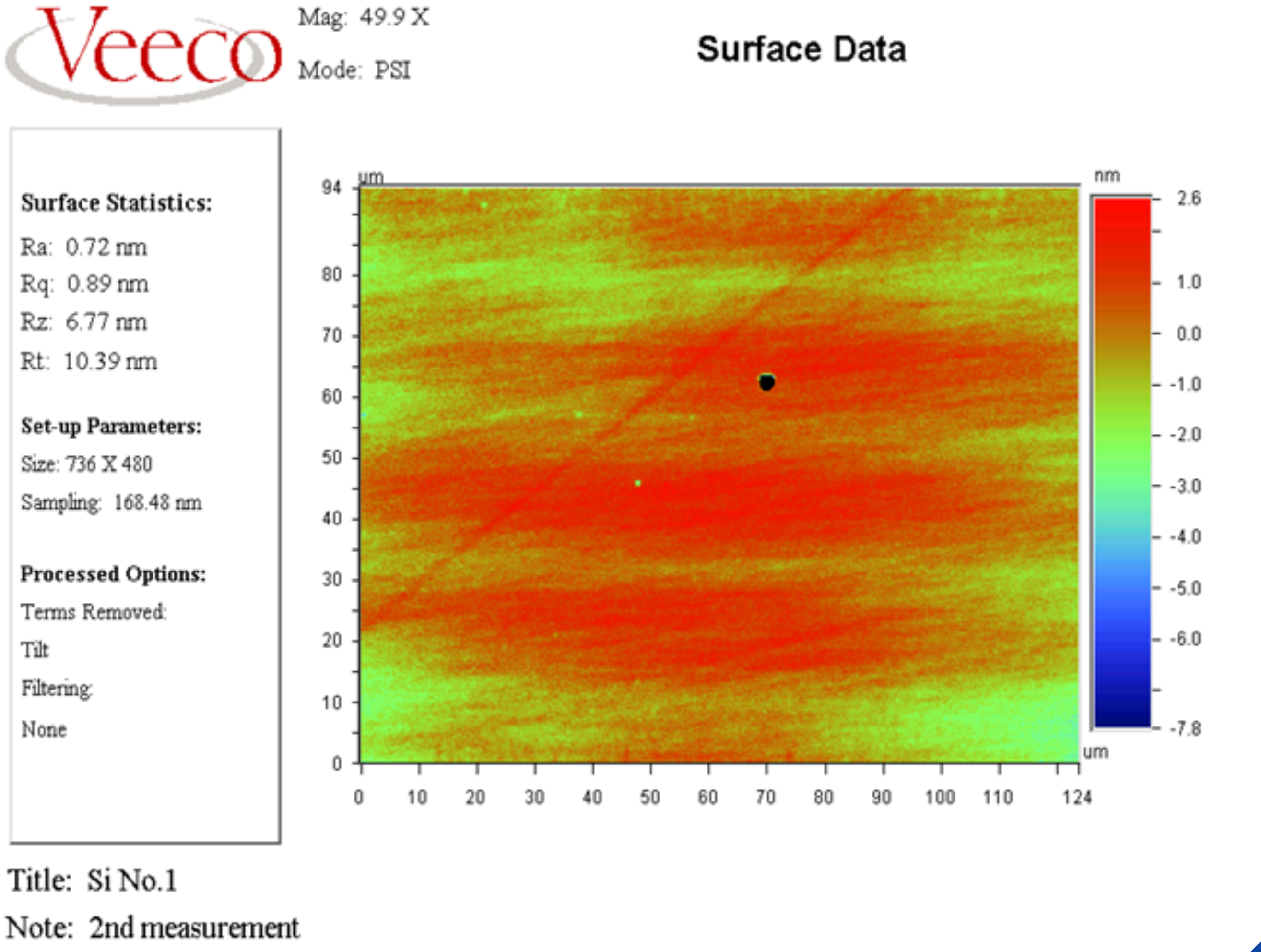




Polishing of electronics: Si-wafers

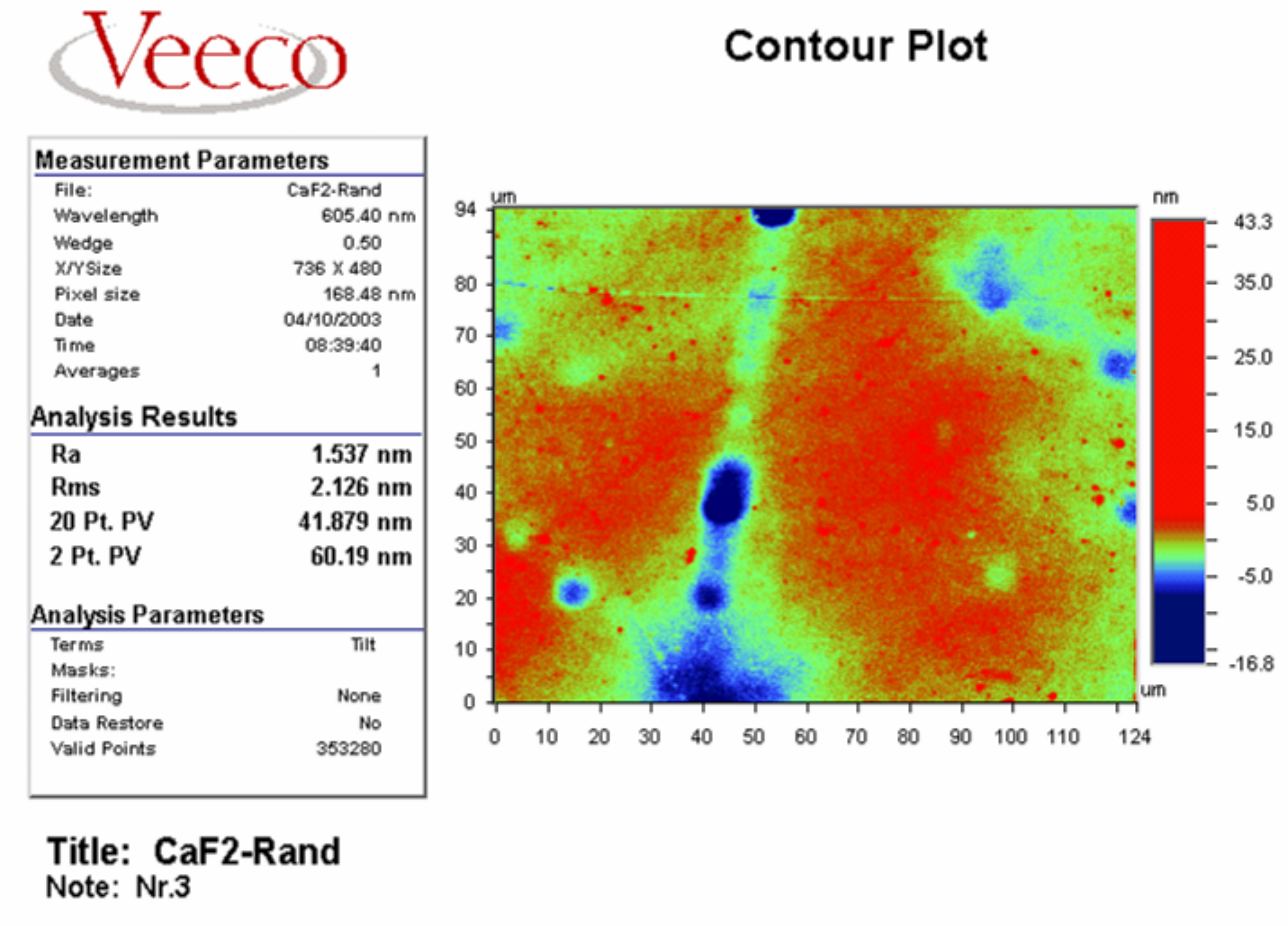
Ra = 0.72 nm

TTV = 2.9 µm



Polishing laser crystals (CaF_2 and other)

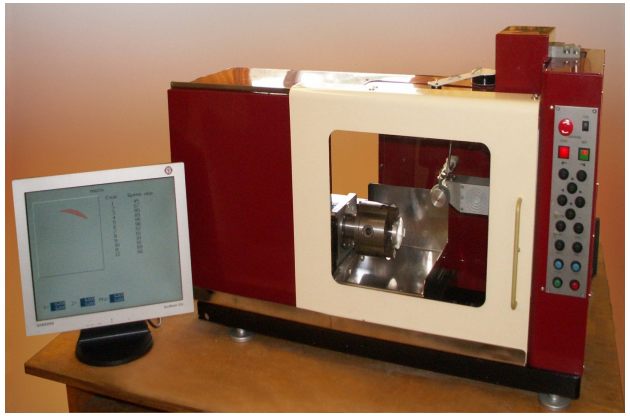
Ra = 1.537 nm



Equipment for Superfine polishing

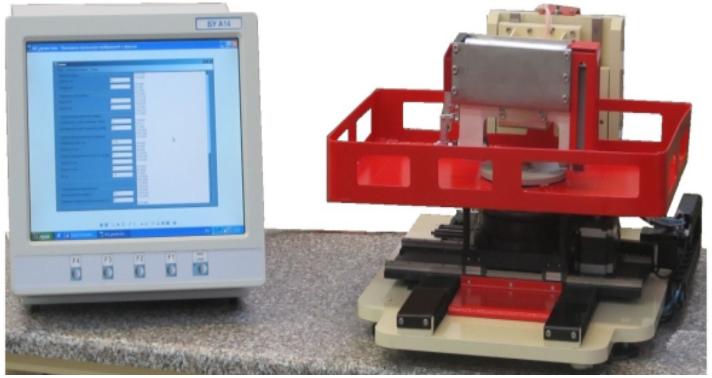
3905

Valid layout



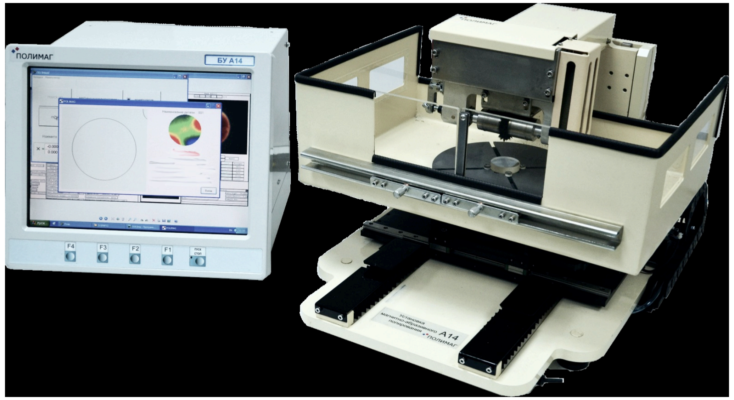
A09

Experimental sample



A14

Experimental sample



A17

Industrial plant

Features of superfine polishing

Application:

surfaces of high-precision details of optics, lasers, micro- and nanoelectronics, etc.

Benefits:

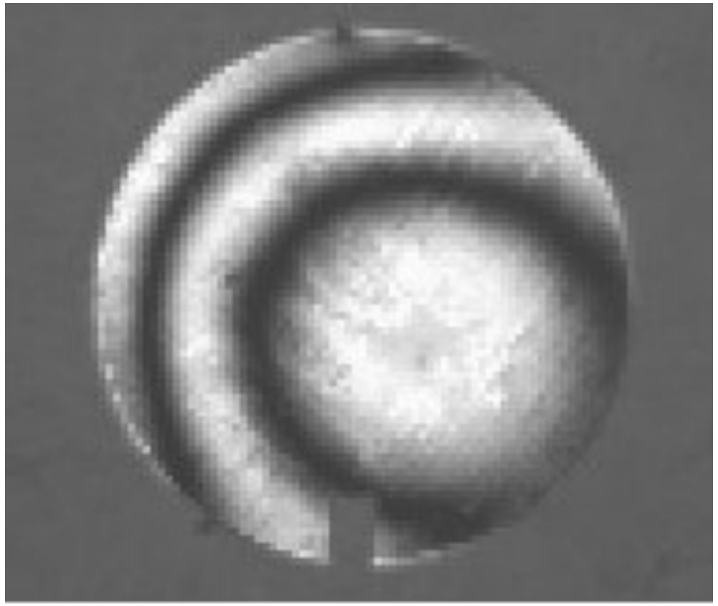
- Very high quality
  - Roughness, Ra:

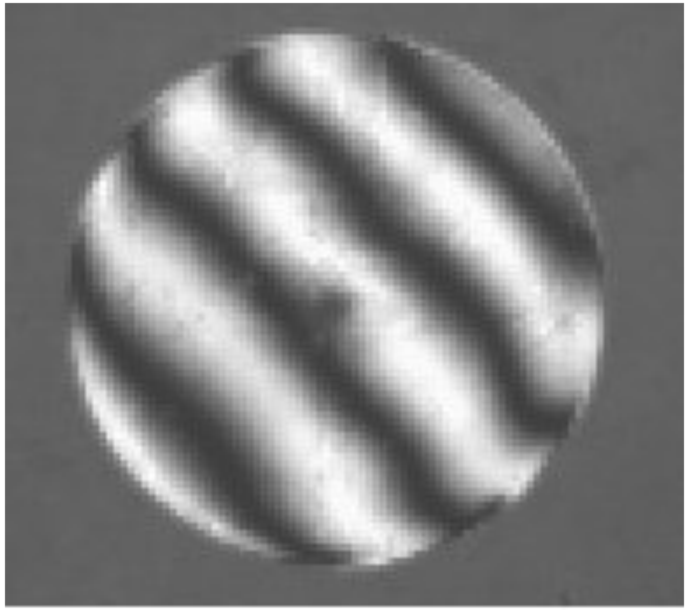
    before: 8 – 10 nm

    after: 0.2 – 0.8 nm
  - minimum defects in the structure of the surface layer
- Performance is 4-10 times higher than that of other technologies
- Cost is 3 - 5 times lower than cost of other technologies
- Environmental friendliness

Optical glass polishing

Interferograms of optical glass before and after MAM





Before MAM: **PV = 158 nm**
Ra = 20 nm

After MAM: **PV = 30 nm**
Ra = 1.4 nm

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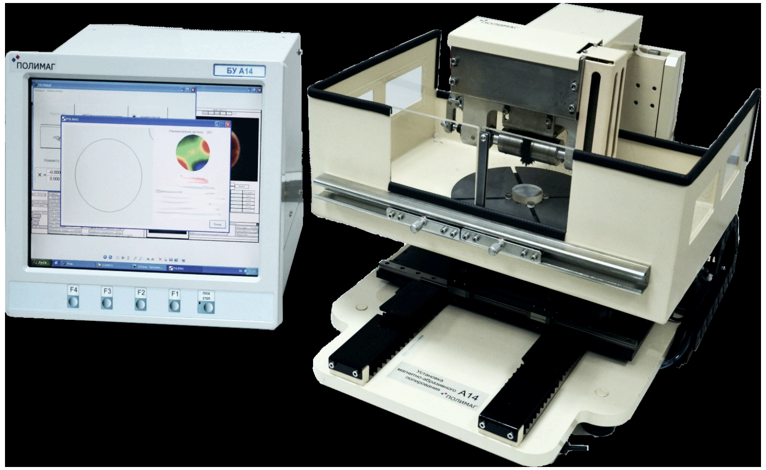
Magnetic-Abrasive Polishing of plain, spherical and aspherical surfaces

Model A17



Before MAM		After MAM	
Sa	**0.27 nm**	**Sa**	**0.14 nm**
Sq	0.369 nm	Sq	0.189 nm
Sp	4.58 nm	Sp	1.13 nm
Sv	3.66 nm	Sv	0.735 nm

ISO 25178

Technical characteristics

Piece diameter	10 - 200 mm
Ra of the polished surface	0.2 – 0,8 nm
Polishing time	2 - 15 min
Power consumption	1.5 kW
Size L×W×H	900 × 500 × 500 mm
Weight	80 kg

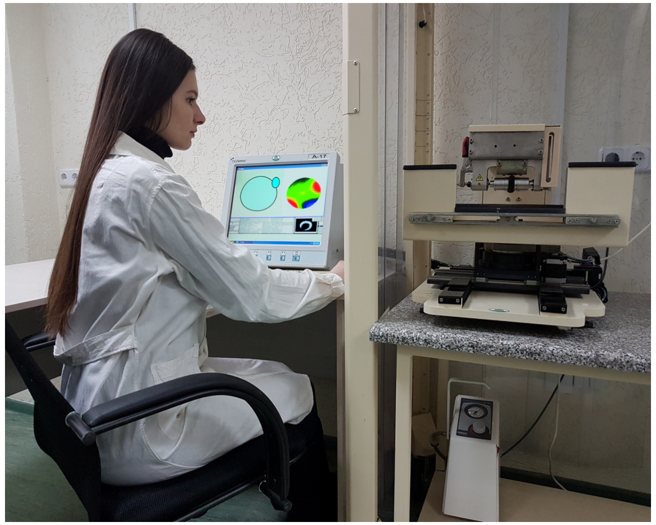
MAM potential

MRF (Q22-XE)

Q-flex 100

Analogs

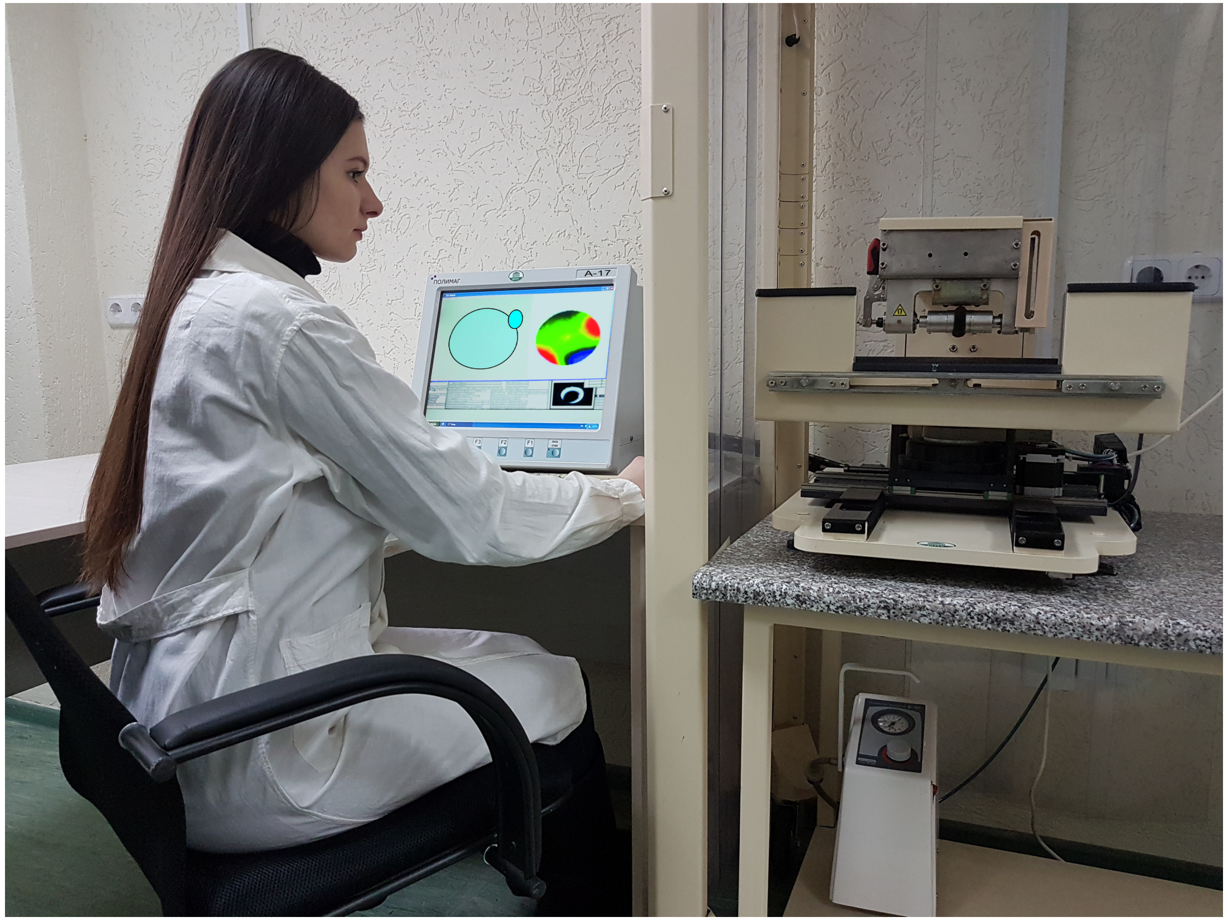
Model A17



Before MAM		After MAM	
Sa	**0.27 nm**	**Sa**	**0.14 nm**
Sq	0.369 nm	Sq	0.189 nm
Sp	4.58 nm	Sp	1.13 nm
Sv	3.66 nm	Sv	0.735 nm
Sz	8.24 nm	Sz	1.87 nm

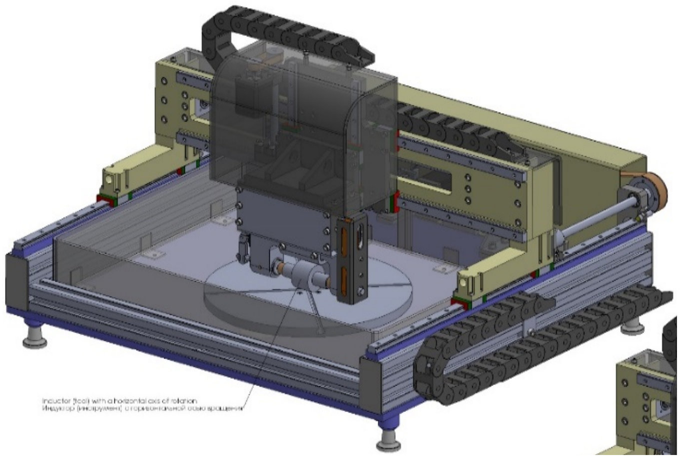
ISO 25178

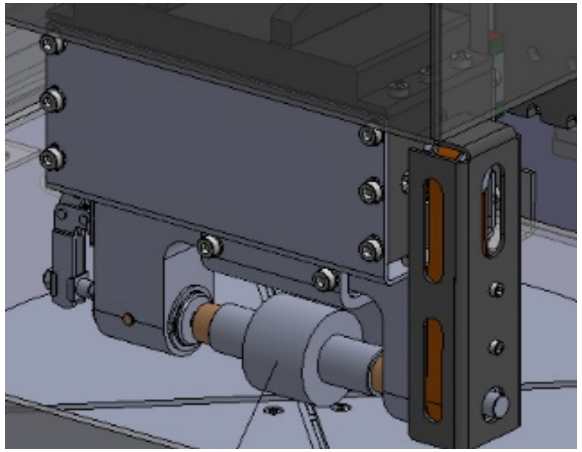
Model A17



A17 in the autonomous
clean zone

Model A20-300 with horizontal axis



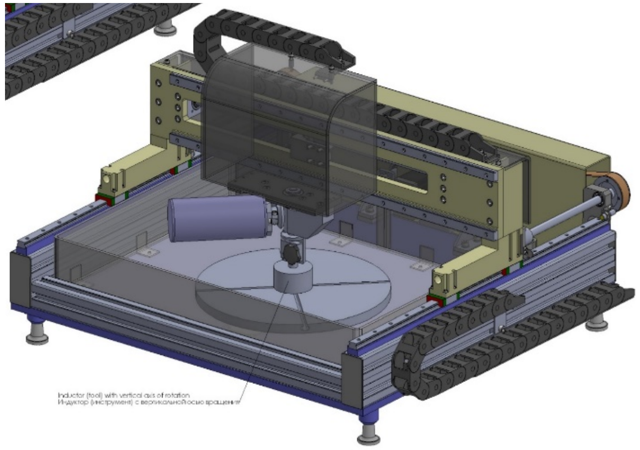


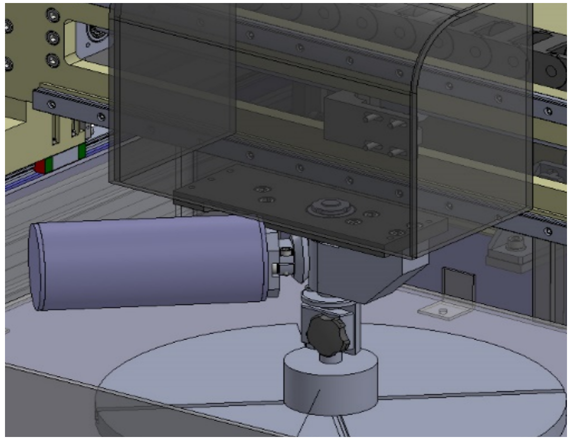
Horizontal axis of rotation of the inductor-tool

- carries out polishing (according to the digitized interferogram of the original surface) with the periphery of the brush ring formed by a magnetic field from a ferro-abrasive powder
- contact area of the powder with the polished surface is about 1 cm^2
- provides nanorelief with Ra < 3 nm
- shape parameter PV < 30 nm

This pattern can be used to polish flat, spherical and aspherical surfaces. In some cases, complex surfaces can be polished.

Model A20-300 with vertical axis





Vertical axis of rotation of the inductor-tool

- implements the MAC with the end of the brush ring (by analogy with face milling)
- contact area 50 cm^2
- provides Ra < 3 nm
- shape parameter PV < 30 nm
- improves surface shape characteristics by 30-50%

This scheme can be used to polish flat and closed surfaces.

Change from one layout to another is less than 15 minutes.

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Laser induced damage threshold

LIDARIS
LIDT Service

POLIMAG – SO1176
COMPARISON OF LIDT VALUES

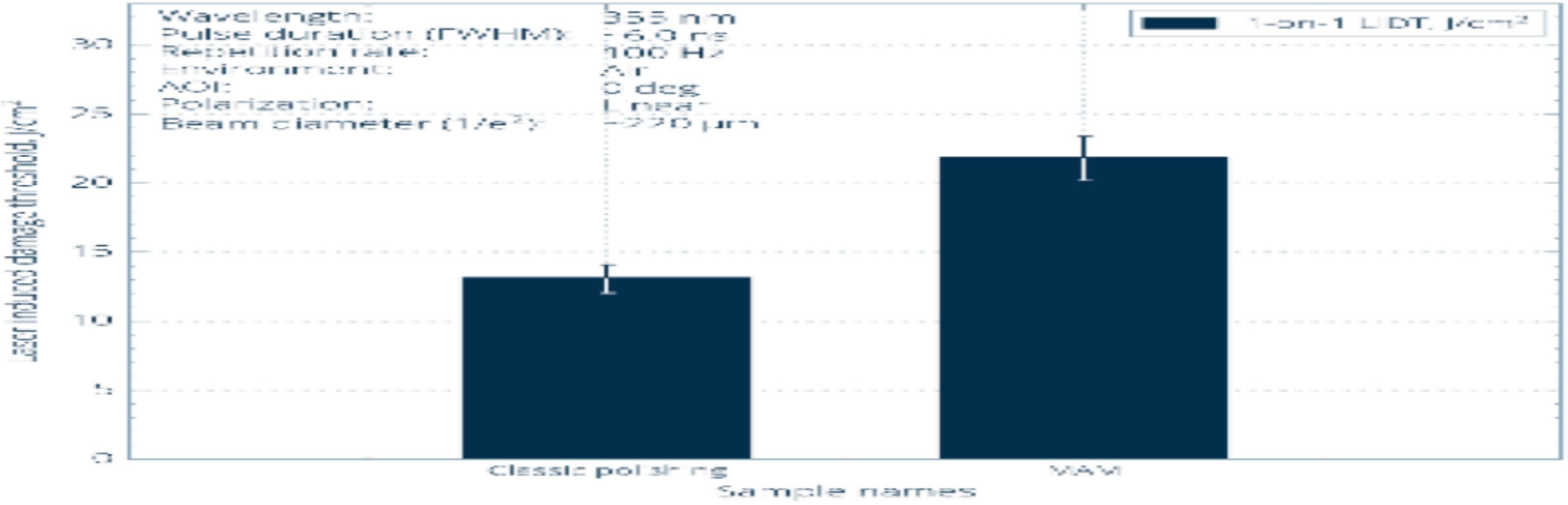
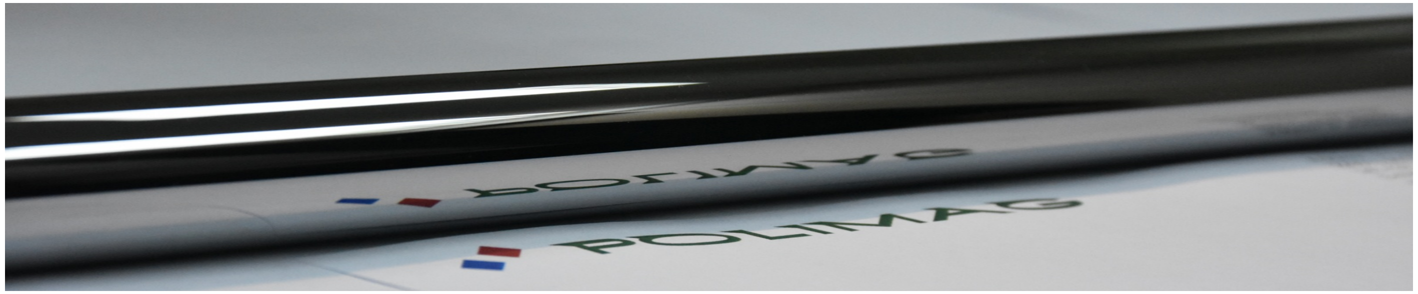


Figure 1: Comparison of SO1176 measurements.

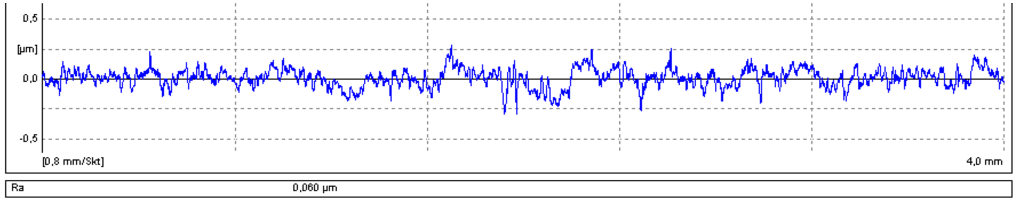
Table 1: SO1176 data spreadsheet

Sample	Threshold (1-on-1)	Error lower	Error upper
MAM	21,80	1,58	1,58
Classic polishing	13,13	1,07	0,96

Magnetic-abrasive polishing of stab WC-Co



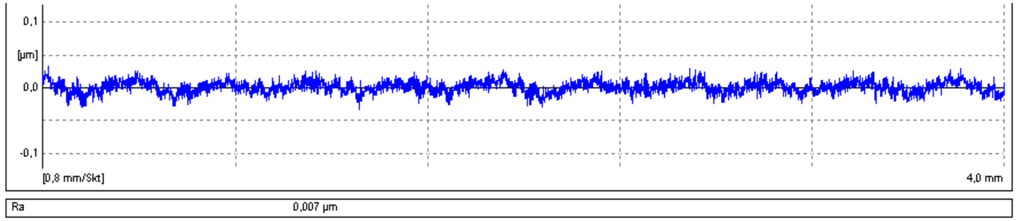
Cylindrical sample (D x L = 22 x 280 mm), of WC - Co alloy



Before MAP: Ra = 53 nm

Ra measurements

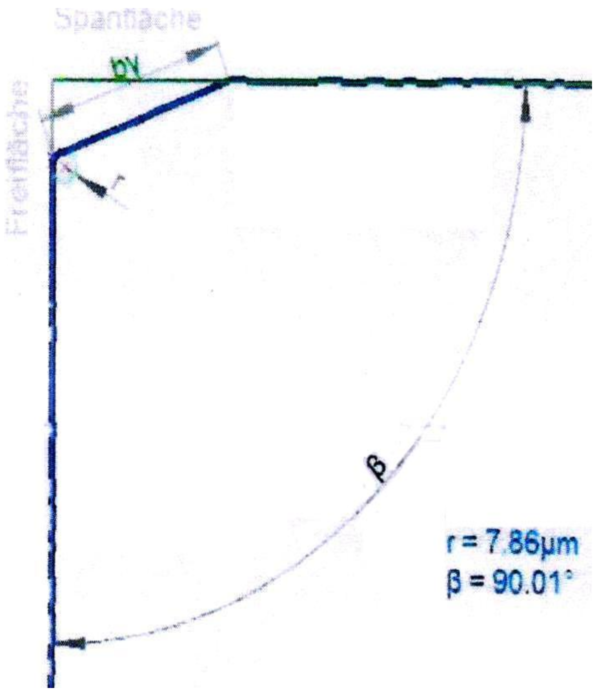
	before MAP	after MAP
1	56	7
2	48	7
3	52	7
4	60	8
5	47	7
Mean	53	7

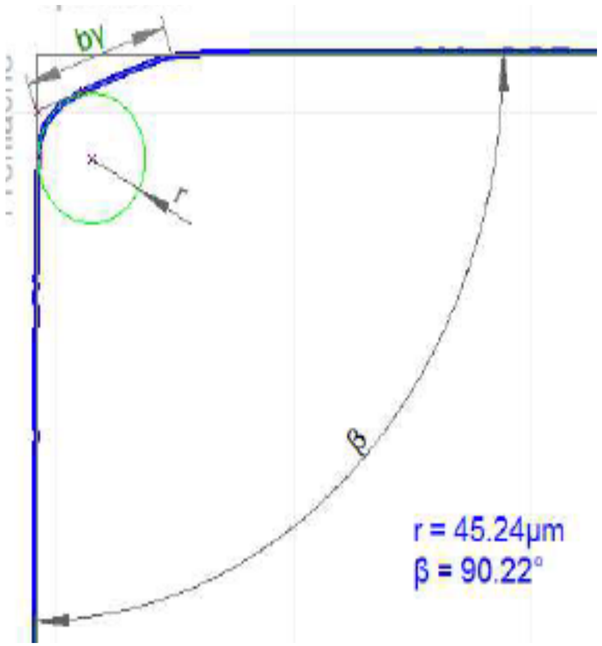


After MAP: Ra = 7 nm

Polishing ceramics: plates for cutters and mills

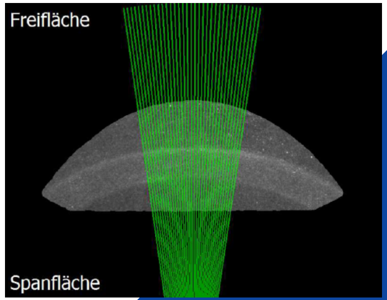
Before MAM	After MAM
r = 7.86 µm	r = 45.24 µm



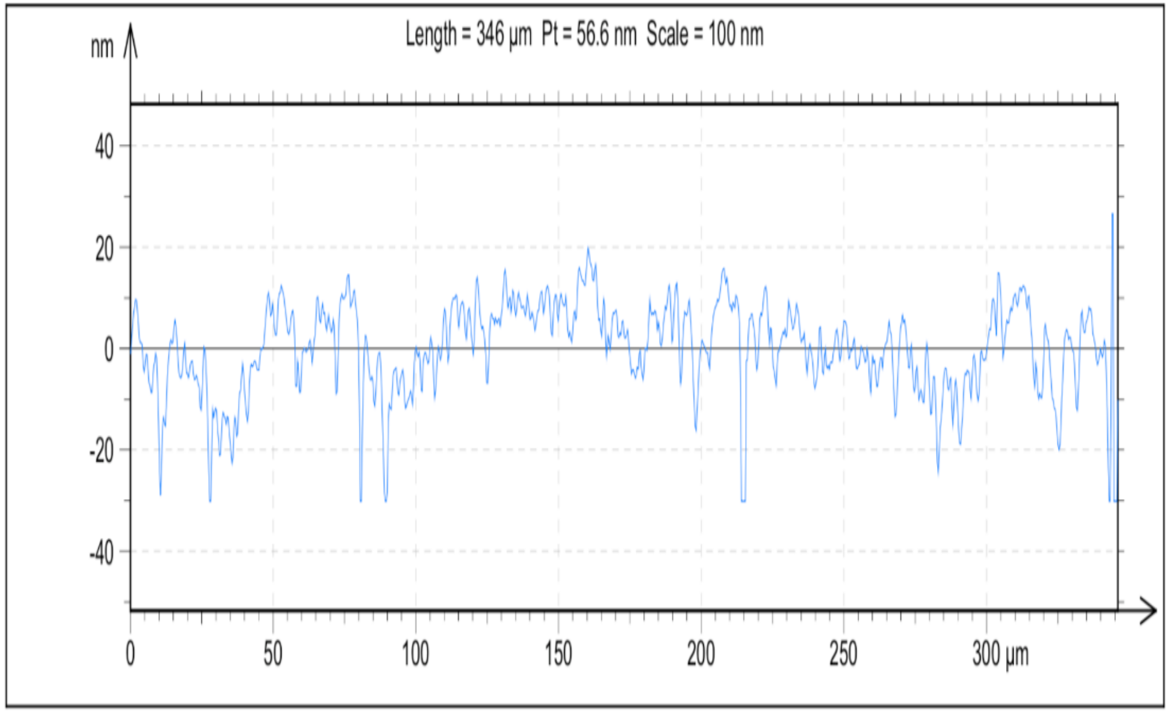


Vandurit GmbH, Germany

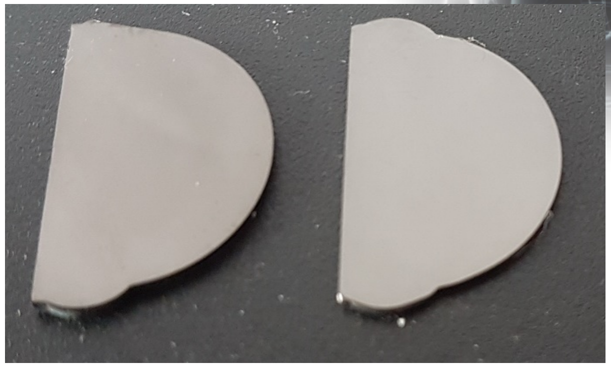
Materials	Microhardness, GPa
Diamond	100
Borazon	88
SiC	33
Al_2O_3	20
Si	12



MAP artificial heart valve: valve surface



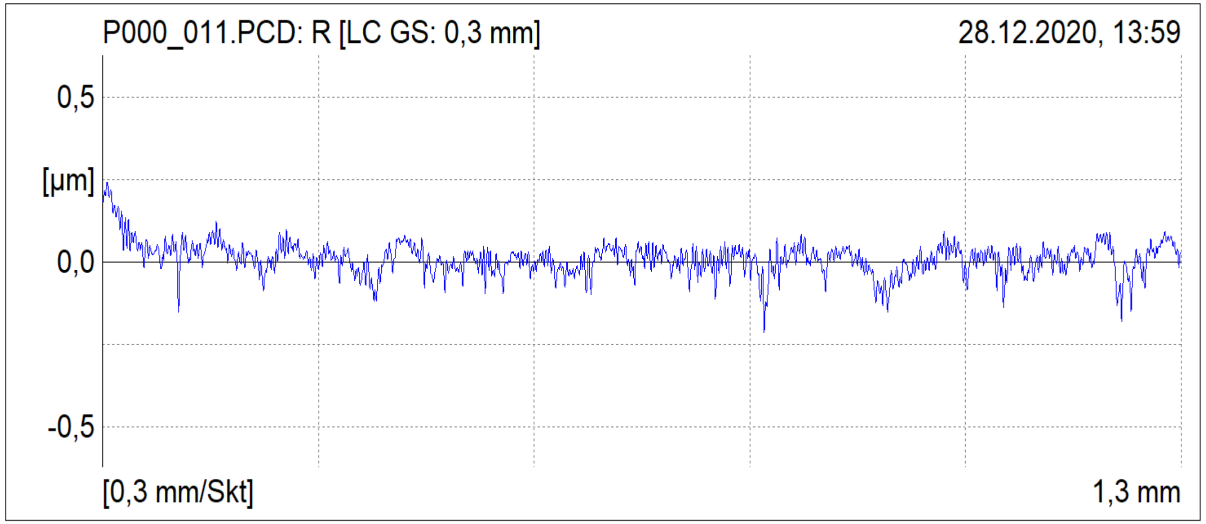
Sash material (locking elements):
pyrolytic carbon (sitall)



After MAM

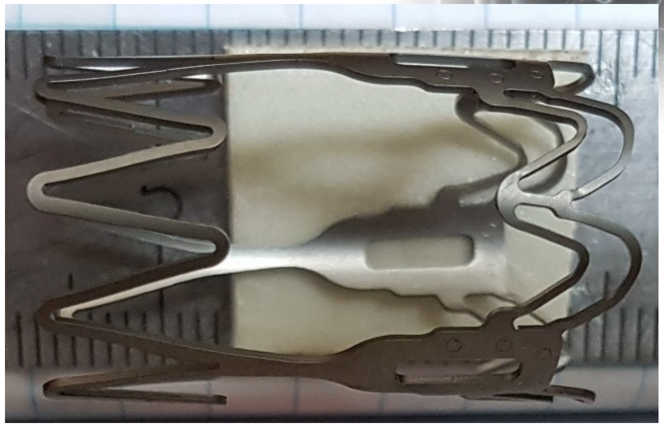
Ra	**3.91 nm**
Rz	24.39 nm
Sq	9.41 nm

MAP artificial heart valve: stent surface



Ra	0,036 µm	Rmax	0,40 µm

Stent material: Ni - Ti alloy



After MAM

Ra 36 nm

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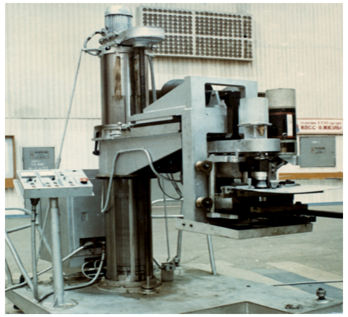
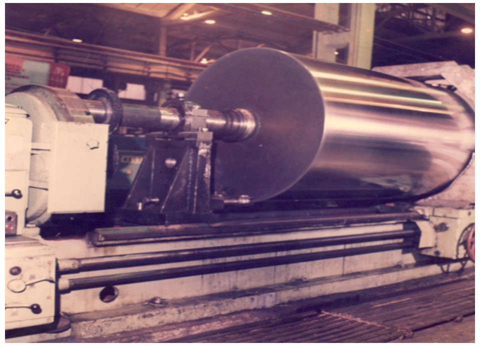
Comparison of MAM and MRF

	MRF (QED, USA)	**MAM** (Polimag, Belarus)
Technological characteristics		
intensity (capacity) %	100	200-500
roughness Ra, nm	< 1	< 1
technological tool	magnetoreological fluid	ferroabrasive powder
Technical characteristics		
complexity of process, maintenance and operation	high	medium
electricity consumption, kWt	3	2
annual consumption of technological tool	100 liters	20 kg
Cost		
cost per unit, $	500	200
annual cost, $	50 000	4 000

MAM equipment (polishing and cleansing) produced in1975 – 1995



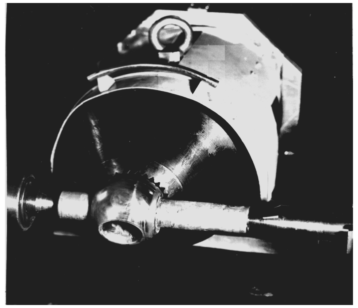
Cleansing edges before welding



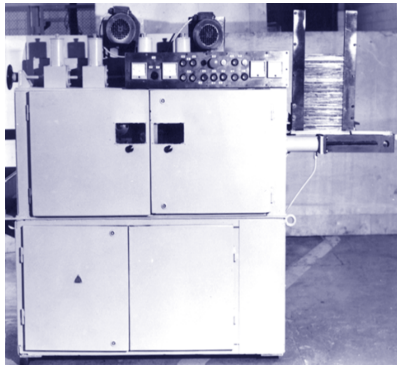
Polishing shafts

Polishing screws

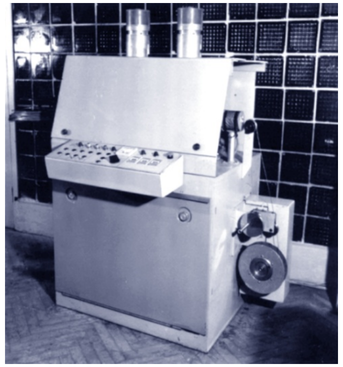
Cleansing plates and bands



Polishing spheres



Polishing and cleansing pipes



Cleansing wire

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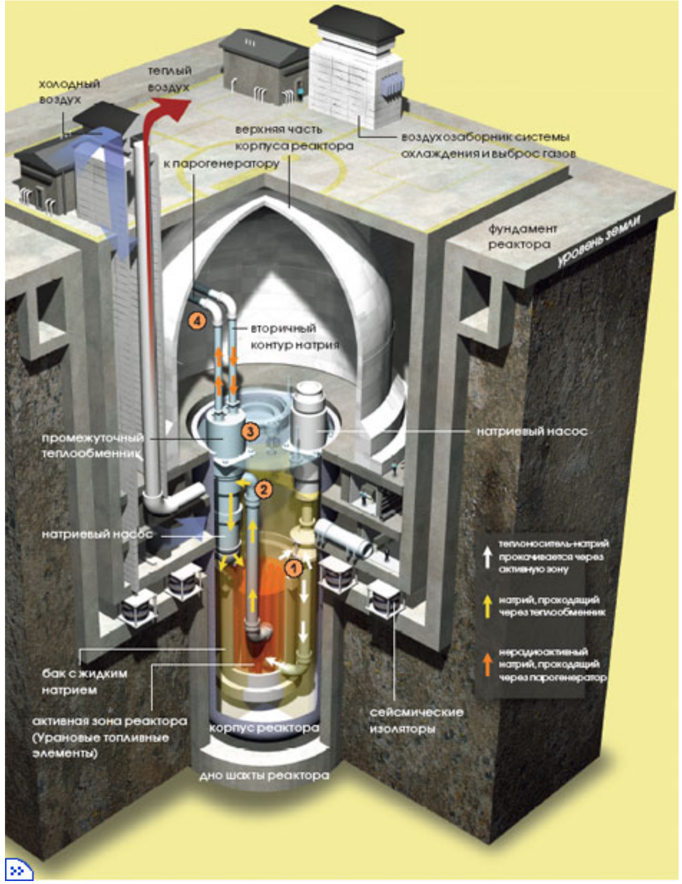
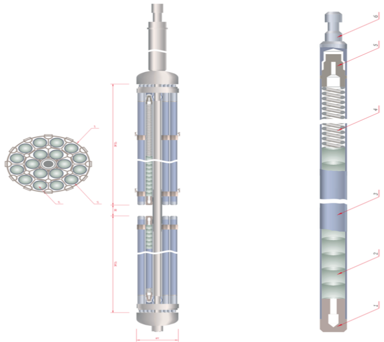
Magnetic abrasive polishing of fuel rods of nuclear reactors



Nuclear reactor scheme



Heat-releasing element (fuel rod)

Fuel cell assembly

Model T15 for polishing of pipes fuel rods

Conventional technologies (chemical etching, grinding and mechanical polishing) do not provide the required surface quality of pipes

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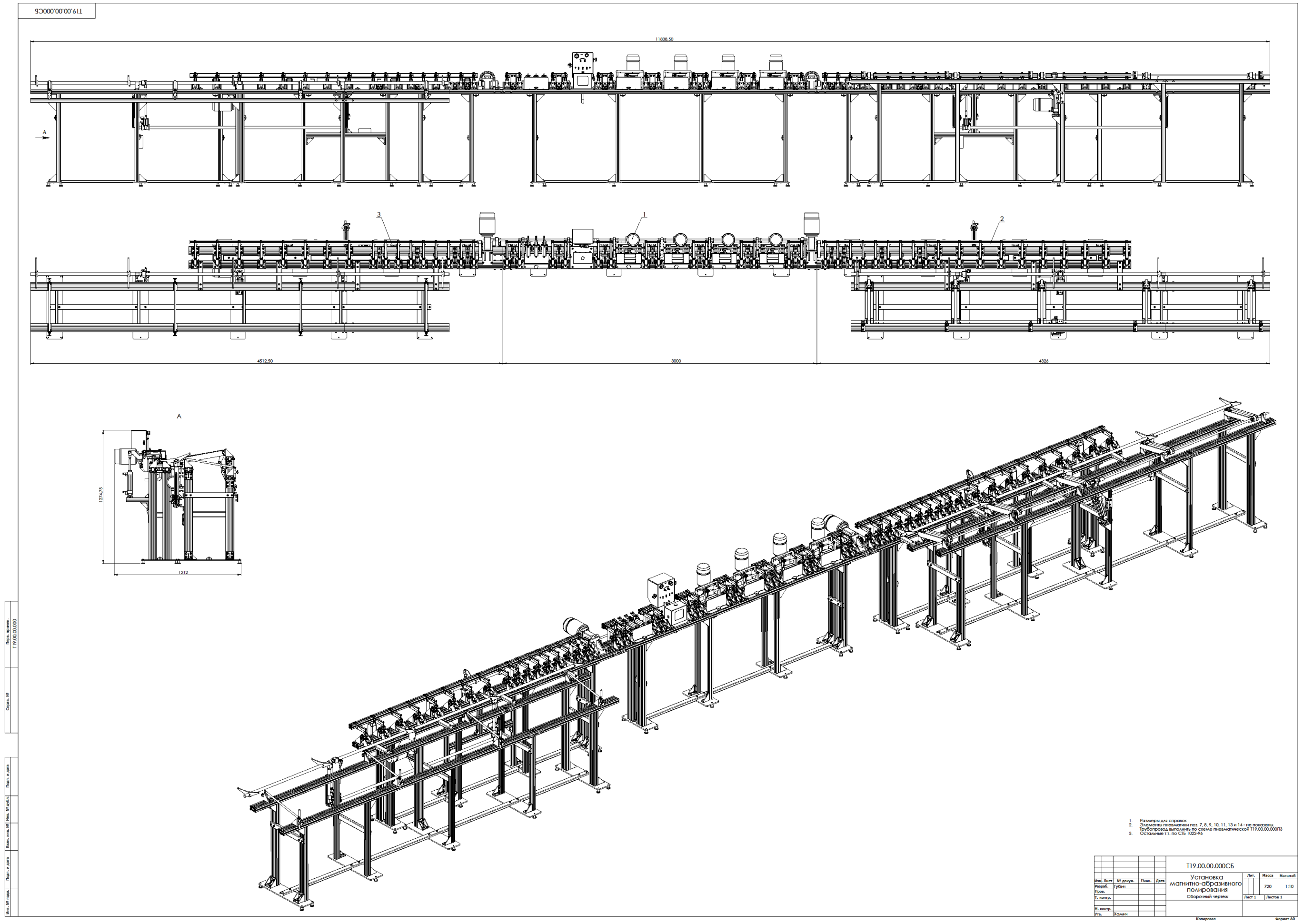
Automatic plant T19 for polishing of pipes fuel rods (under construction)



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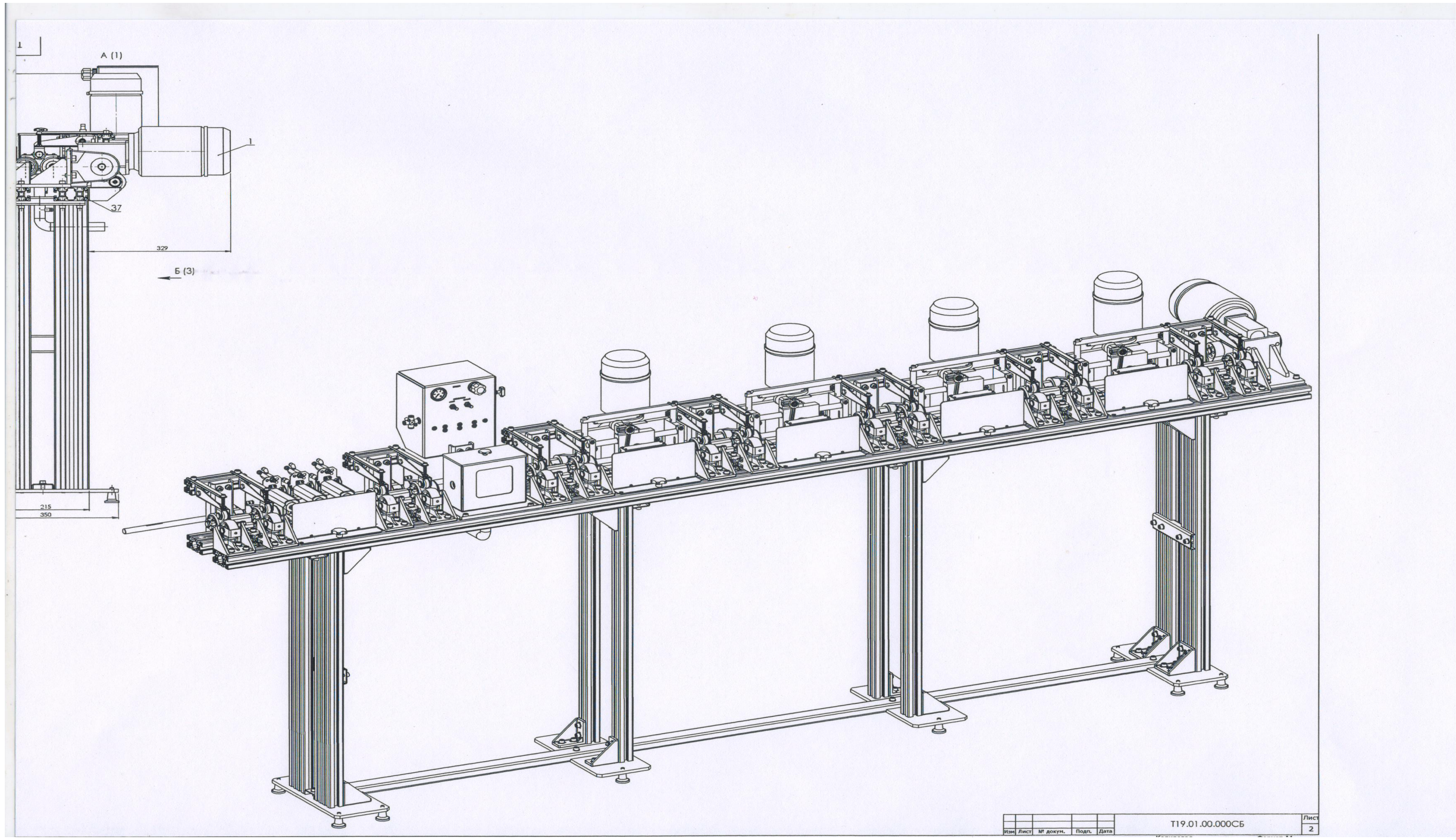
Working module of plant T19



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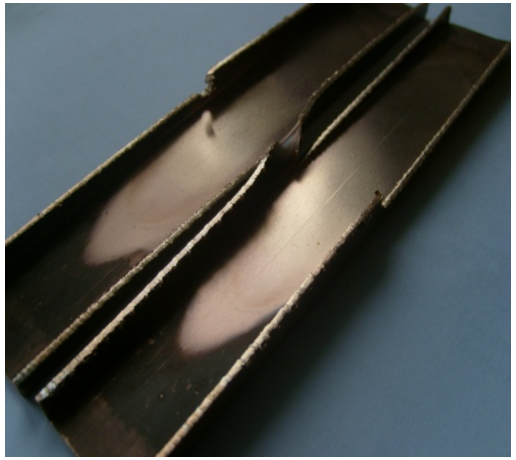
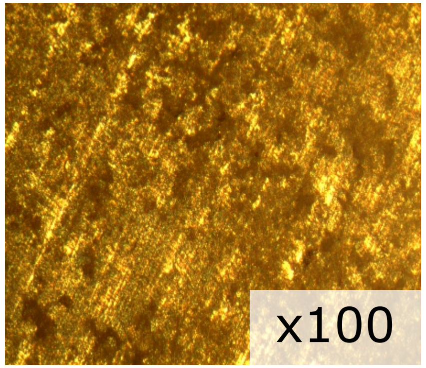
MAP of the inner surfaces of the waveguides

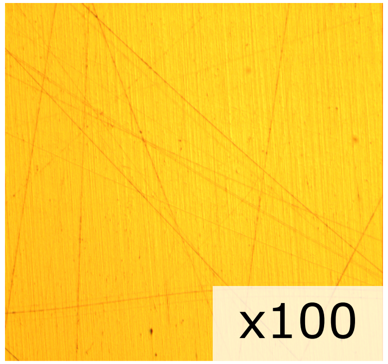


Waveguide material: alloys Cu, Al and Si, steel, etc.

Before MAP	0.800 µm
After MAP	0.076 µm

Flat punch surface

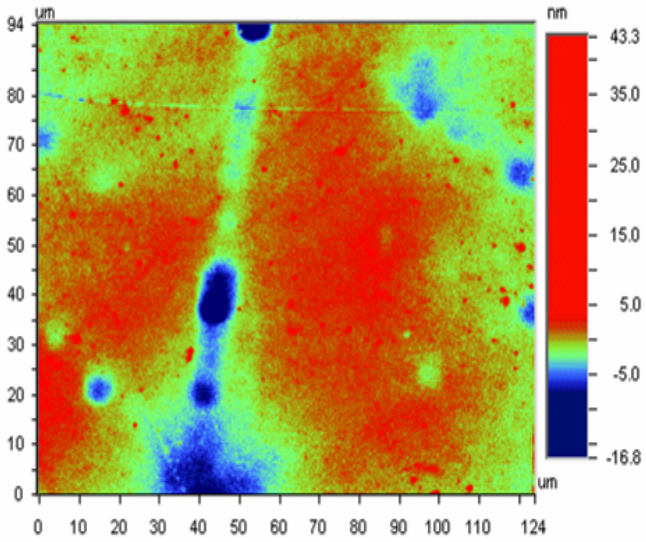


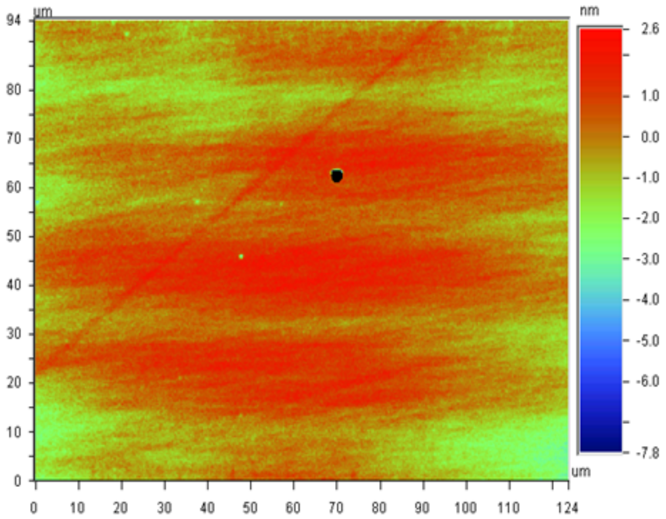


Roughness Ra, µm

	Before MAP	After MAP	
		20 passes	**30 passes**
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	0.279	0.098
10	2.788	0.510	0.052

Examples of details for MAM





Optics

Ra = 0,14 nm = 1,4 À

Laser ceramics

Ra = 1.537 nm

Si-wafers for electronics

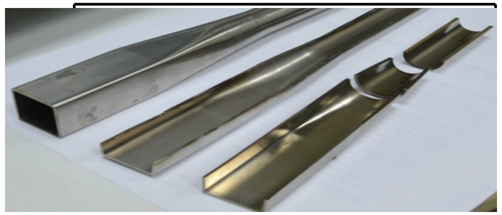
Ra = 0.72 nm

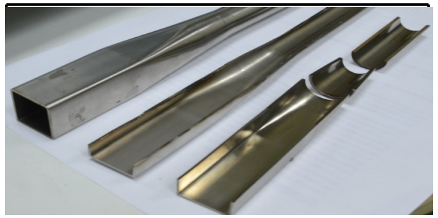
Examples of details for MAM




Tools:

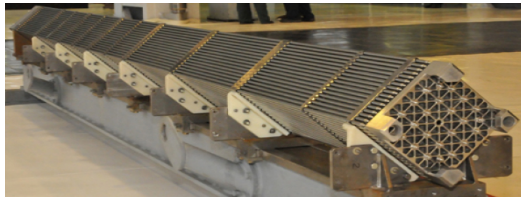
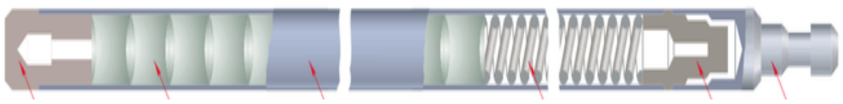
cutters, punch, drills





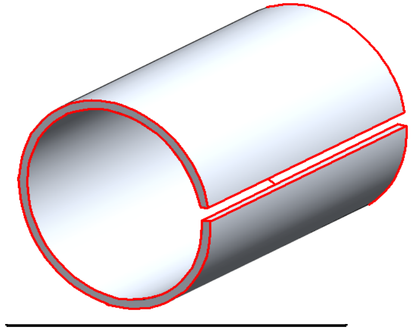
Pipes:

external and internal surfaces

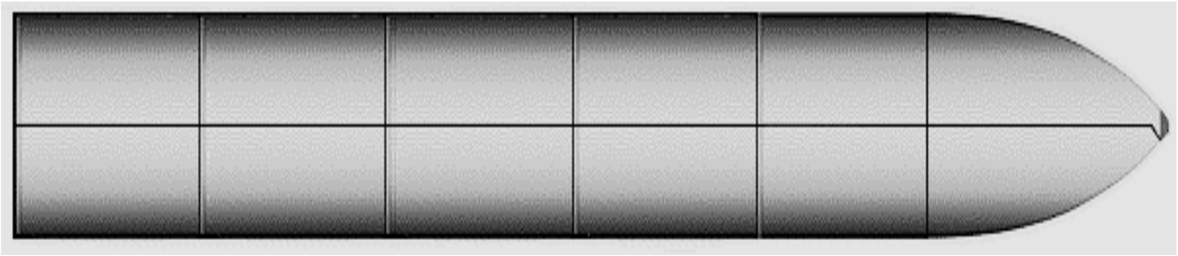



Envelopes of fuel rods of nuclear reactors

Examples of details for MAM

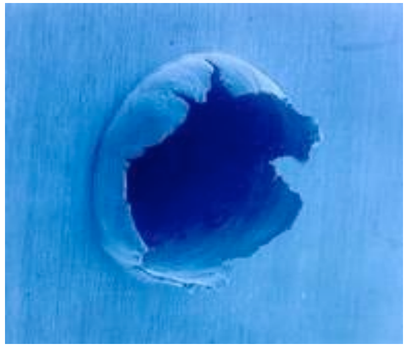


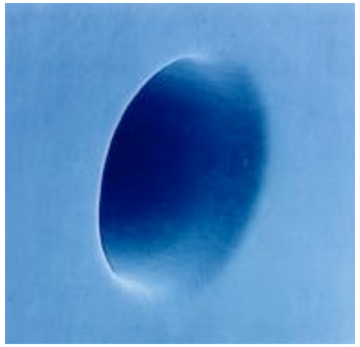
Cleansing edges
before welding



Cleansing of surfaces of details for aviation, space, ship and other industries

Polishing
aviaturbine blades





Removing burrs and edges rounding

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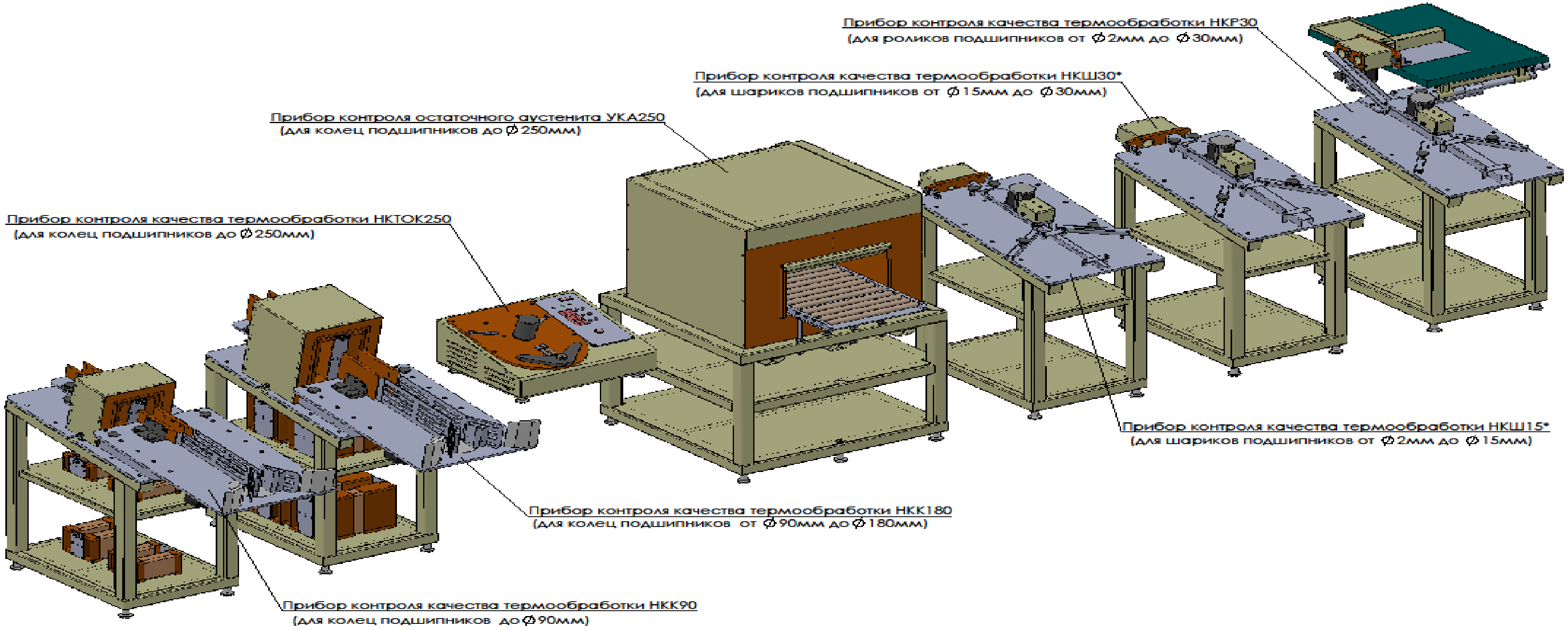
Instruments for quality control of bearing components after heat treatment



Все приборы изображены без электронных блоков управления
*Приборы изображены без устройств автоматической поштучной подачи шариков

Publications

More than 170 scientific publications

More than 70 patents

Partners

China

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

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Harbin Institute of Technology

Russia

РОСАТОМ

МИФИ

РОСКОСМОС

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Hochschule Deggendorf

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