Department of materials science, welding and safety

Surfacing techniques

doctor, professor Tatiana Ilinkova

KAZAN, 13-14 April 2016

Annotation of the course

the Theory and technology of processes of production, treatment and processing of materials and coating

(7 credits, 6,7 semesters - bachelor)

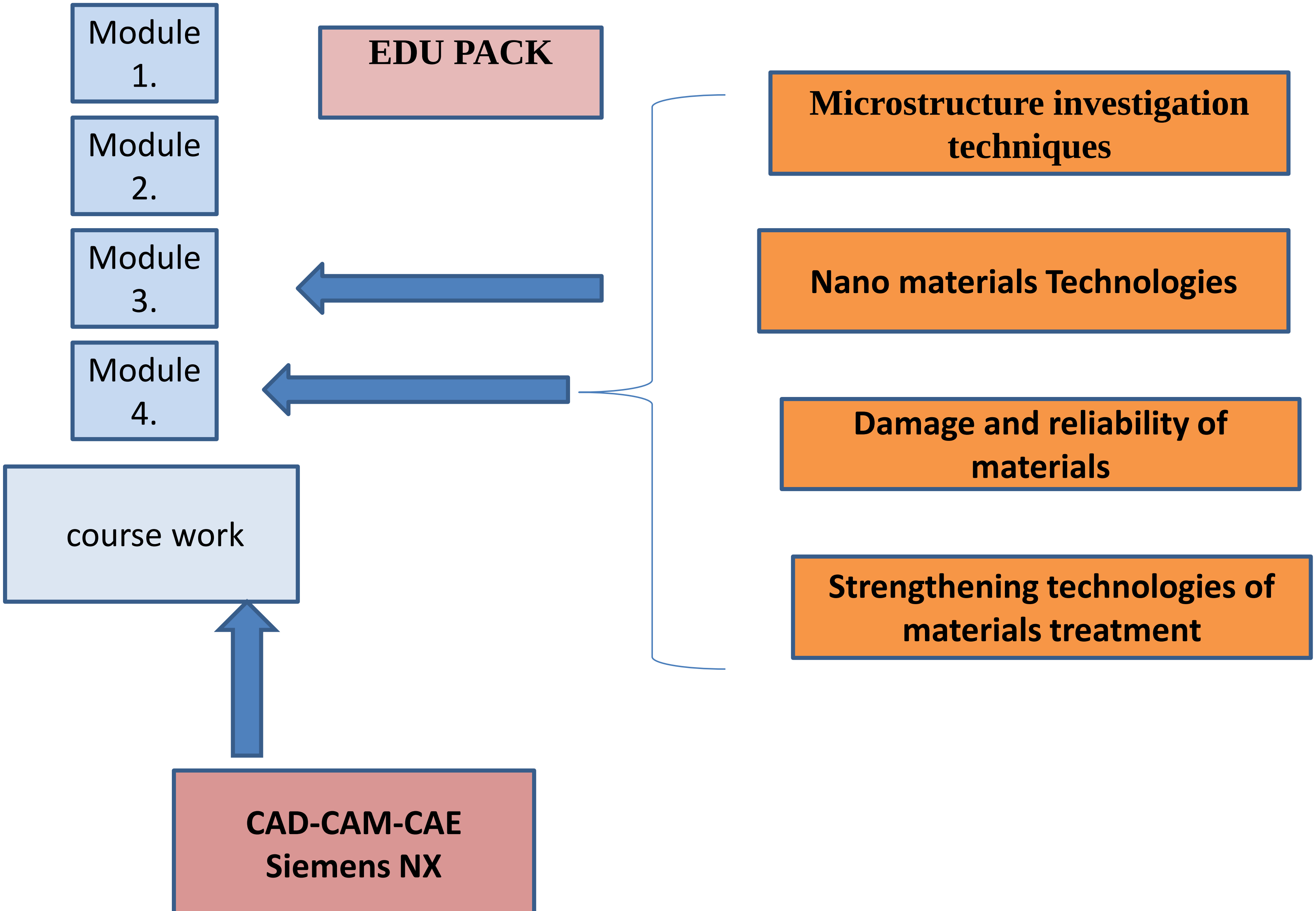
6th semester (teacher V. A. Chernoglazova):

Module 1. Theoretical fundamentals of casting processes
Module 2. Recycling of polymeric materials
Module 3. Powder metallurgy and nanotechnologies
144 h = 36+36+36+36 (ind.)

7th semester (teacher T. A. Ilinkova)

Module 4. Technological processes of deposition of inorganic coatings
108 h= 36+18+54 (ind. work)
+coursework

What made MMATENG ?



Пособия

Министерство образования и науки Российской Федерации

КАЗАНСКИЙ НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ им. А.Н. ТУПОЛЕВА-КАИ

А.В. ЧЕРНОГЛАЗОВА , Т.А.ИЛЬИНКОВА

ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ

В МАШИНОСТРОЕНИИ

Учебное пособие для студентов бакалавриата по направлению «Материаловедение и технологии материалов»

Рекомендовано к печати учебно-методическим центром КНИТУ-КАИ в качестве учебного пособия для студентов высших учебных заведений, обучающихся в бакалавриате и магистратуре по направлению подготовки «Материаловедение и технология материалов», «Машиностроение»

MMATENG Tempus

Учебное пособие разработано в рамках проекта ТЕМПУС MMATENG «Модернизация учебных планов двух уровней (бакалавриат, магистратуры), основанных на компетенциях, в области материаловедения в соответствии с лучшей практикой Болонского процесса» «Modernization of two cycles (MA, BA) of competence-based curricula in Material Engineering according to the best experience of Bologna Process»

Web-site проекта: mmateng.eu

Казань 2016

2

Министерство образования и науки РФ

Казанский национальный исследовательский технический университет

им. А.Н.Туполева

Т.А.ИЛЬИНКОВА, А.В. ЧЕРНОГЛАЗОВА

ПОРОШКОВЫЕ ТЕХНОЛОГИИ

Рекомендовано к печати учебно-методическим центром КНИТУ-КАИ в качестве учебного пособия для студентов высших учебных заведений, обучающихся в бакалавриате и магистратуре по направлению подготовки «Материаловедение и технология материалов», «Машиностроение»

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Module 4.

The purpose of applying the technology of surface treatment of parts:

educing maintenance costs;

Higher operating temperatures, reducing thermal loads;

Better resistance to erosion, abrasion, corrosion;

Reduction-oxidation;

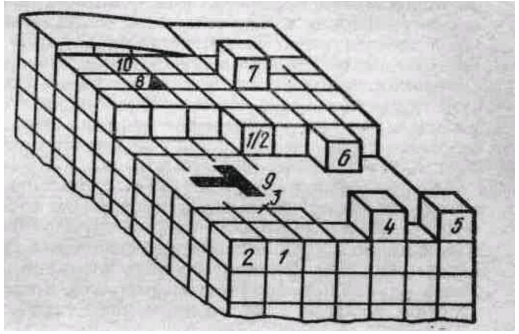
dimensional restoration

Classes and method	process
Hardening to create the surface The deposition chemical reaction Electrolytic deposition Deposition of solids from vapors Spraying	
Hardening the changes in the chemical composition of the surface layer metal Diffusion saturation	
Hardening by changing the surface structure Physico-thermal treatment Electrophysical treatment Machining Surfacing of alloyed metal	
Hardening of changing energy spare of the surface layer Treatment in a magnetic field	
Hardening by changing the surface roughness Electrochemical polishing of cutting; Plastic deformation	
Hardening changes in the structure of the entire volume of metal Heat treatment at positive temperatures Cryogenic treatment	

Classes and method	process
Hardening to create the surface **Thermal spraying:** Deposition of solids from vapors	Plasma, detonation, electric arc, flame. **Vacuum coating:** Phisycal vapoir deposition (PVD) thermal evaporation , cathode-ion bombardment, ion-plasma spraying. chemical vapor deposition (CVD)
Hardening the changes in the chemical composition of the surface layer metal Diffusion saturation **Combined technologies**	the saturation of the carbon, nitrogen, boron, grey; aluminium, chrom+aluminium) comprehensive saturation of non-metals and metals (chromosiliconization)

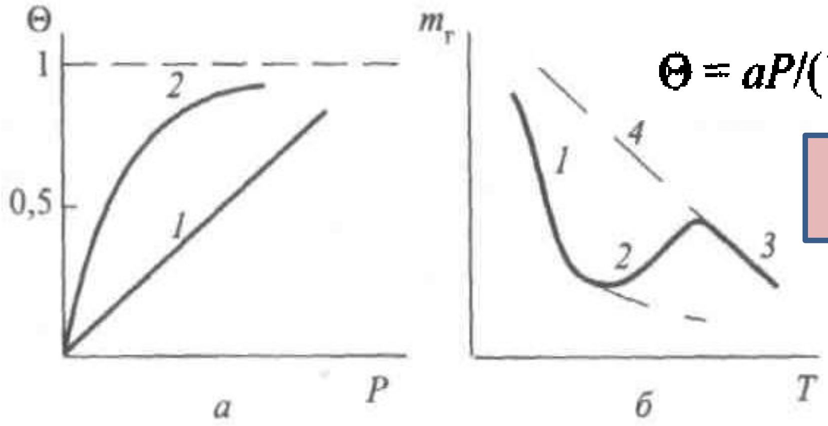
Surface phenomena

The energy required for the formation of the area of the interface unit at constant volume and temperature is called the surface energy



Absorption of substances from solutions or gases surface layer of a solid or liquid.
The driving force of the process is the presence on the surface of uncompensated forces of interatomic interaction, due to which attract the molecules adsorbed substance - adsorbate.
It occurs not only decreases the surface energy, but also the formation of different surface composition of the film.
There are:
Physical adsorption;
chemisorption

Physical adsorption



$$\Theta = aP/(1 + aP),$$

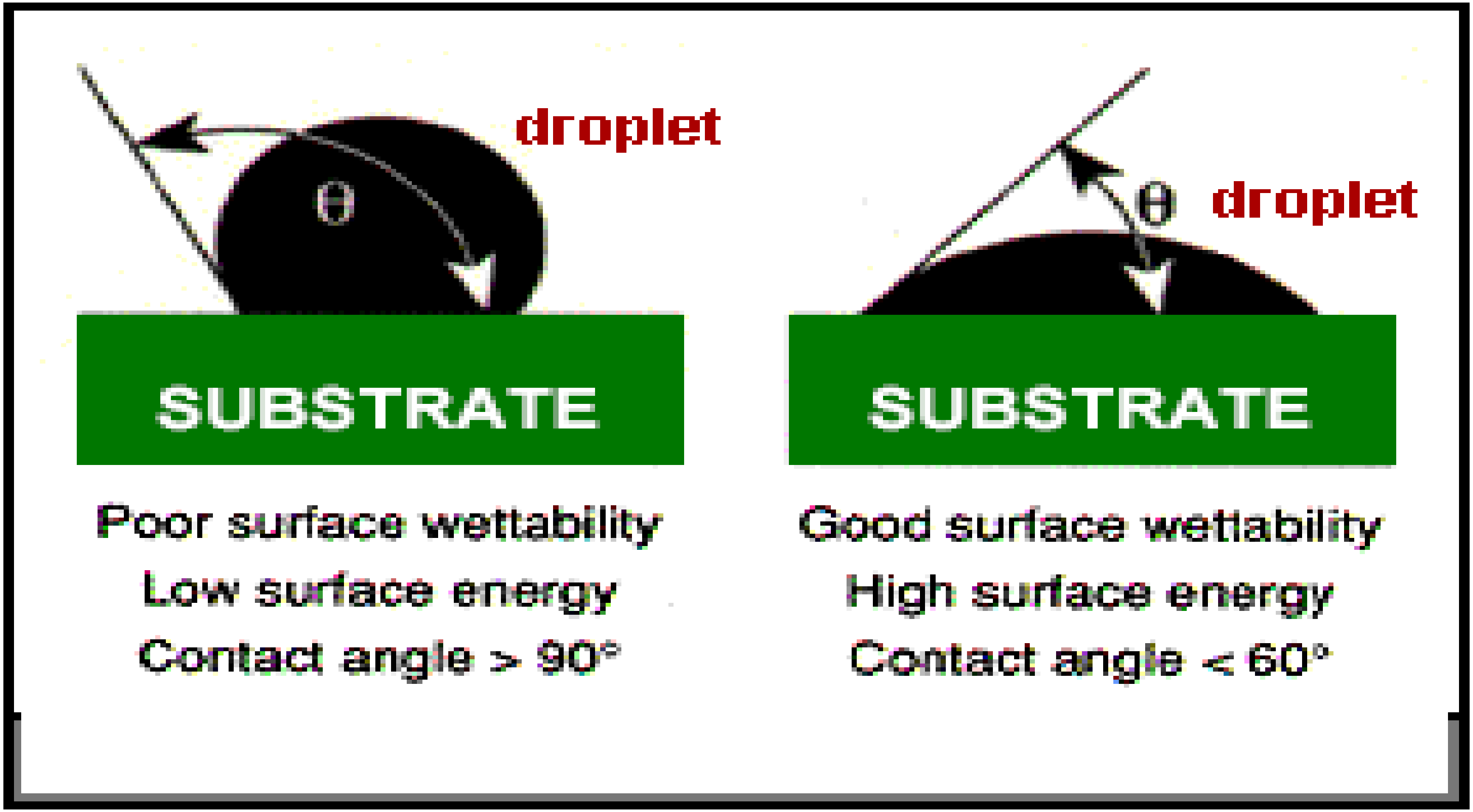
Ленгмюр

Θ = к P
Генри

chemisorption
It is the process of absorbing a liquid or solid surface materials from the environment, accompanied by the formation of chemical compounds.

In chemisorption allocated a significant amount of heat. Typically chemisorption heat lie within 80-125 kJ / mol.
The interaction of oxygen with metal (oxidation) gives a significantly higher heat value, reaching 400 kJ / mol.

Wettability and surface energy



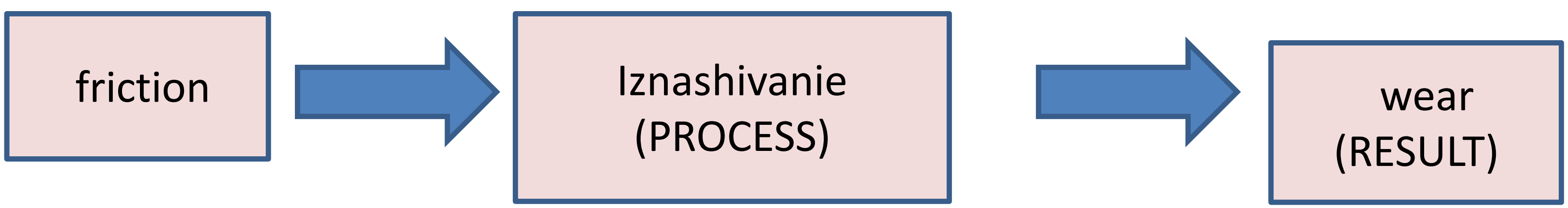
Theme 2. Harmful processes that lead to failures of machine

- The machines are distinguished:
- Workflows occurring during machine operation
- injurious processes leading to the breakdown and sudden failure

1.The frequency of fast processes;
(such change processes are fractions of seconds)
2.Average speed processes;
-(Such processes take place in a matter of minutes and hours)
3.Slow process;
(occurring months or even years).

types of friction:

- without lubrication;
- Friction is the boundary between two solids;
- fluid friction



three groups wear

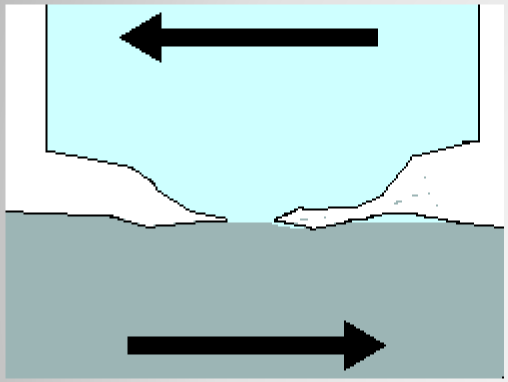
(GOST 16429-70)

Molecular mechanical
(Wear upon setting 1 and 2 kinds)

Mechanical
(Abrasive, hydroabrasive, gas-abrasive, erosive, fatigue, cavitation)

Corrosion-mechanical
(Oxidation at fretting)

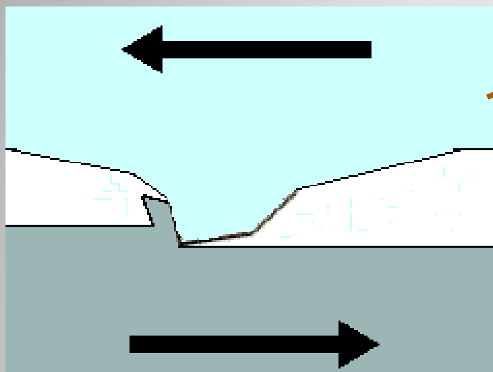
Wear at scuffing



Grasp one kind
It occurs in the absence of lubricant and protective oxide film by friction with low velocities and specific pressures.
The result: a large plastic deformation and formation of metallic bonds between the surfaces

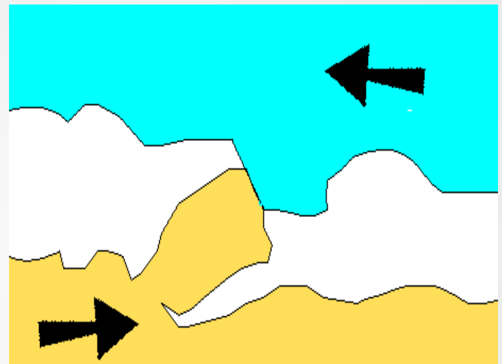
2 Grasp kind
occurs when the sliding friction at high speeds and large specific pressures and temperatures in the contact zone
Result: plastic deformation, adhesion, formation of metallic bonds

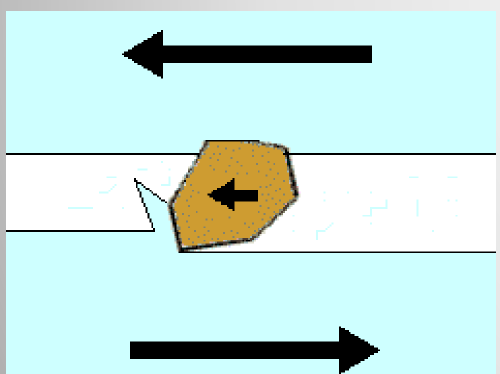
abrasive wear



Cutting metal
as a cutter

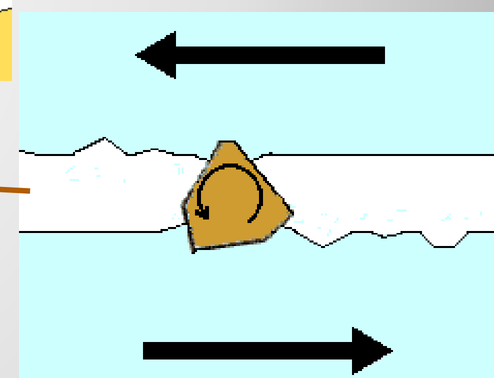
is
in the presence of
gas or water



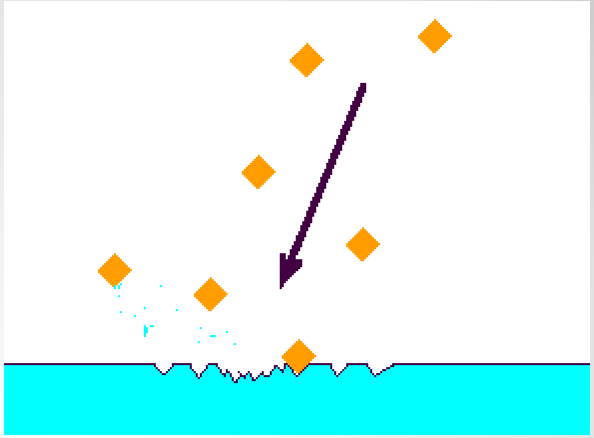


Резание металла
абразивной
частицей

education irregularities
on the metal of the
abrasive particles



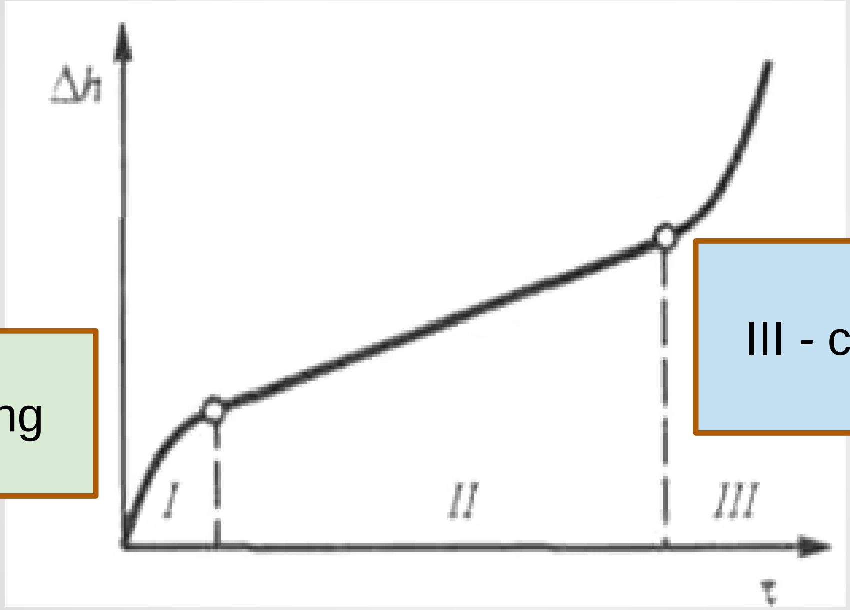
Erosion



Erosion caused by the gas flow, which contains the various solid particles.

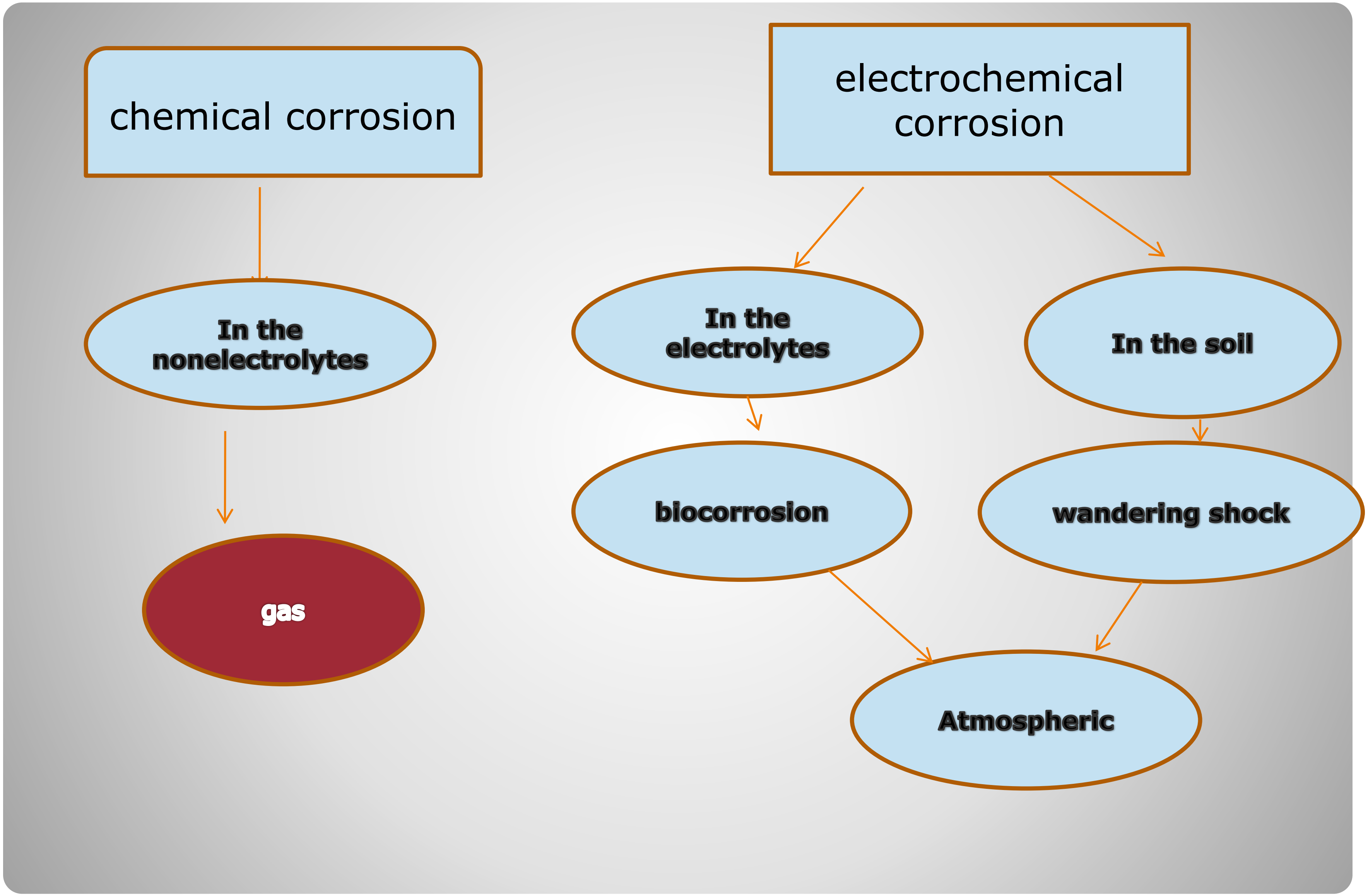
Stage wear

I -bedding



III - catastrophic wear

steady
(Normal) wear

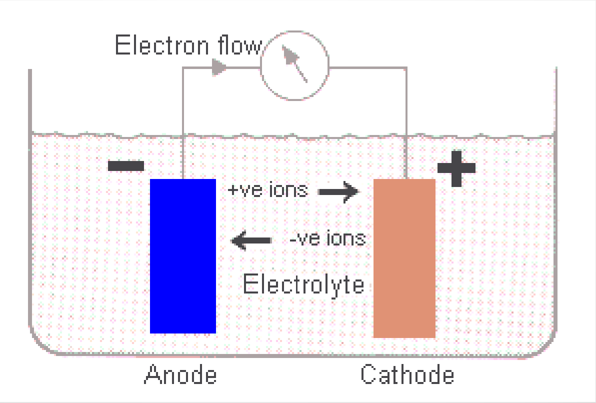

chemical corrosion
electrochemical corrosion
In the nonelectrolytes
In the electrolytes
In the soil
gas
biocorrosion
wandering shock
Atmospheric

electrochemical corrosion
- an process, wherein the metal reacts with the environment to form an oxide or other chemical compound

$2Fe^{+2} \rightarrow 2Fe^{+3} + 2e$ (anodic oxidation reaction)

$1/2O_2 + H_2O + 2e \rightarrow 2OH^-$ (cathodic reduction reaction)

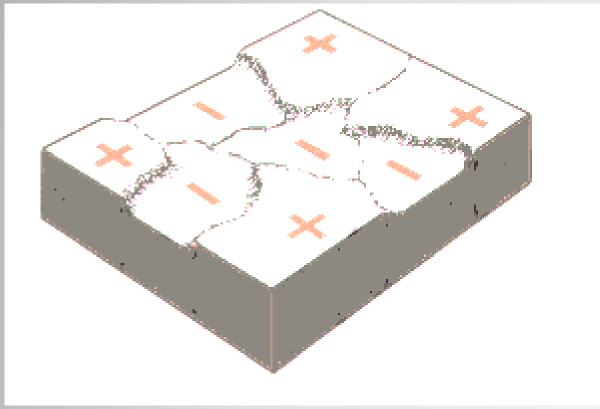
$2Fe^{+2} + 1/2O_2 + H_2O + 2e \rightarrow 2Fe^{+3} + 2e + 2OH^-$

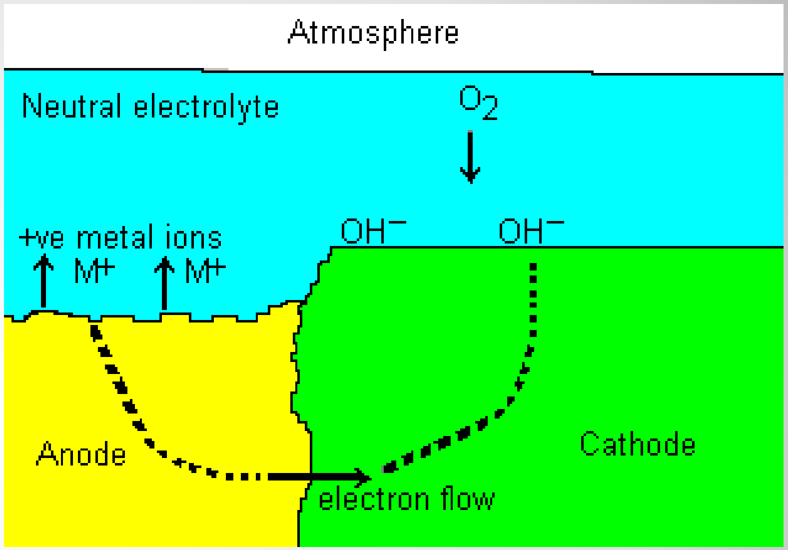


Расходуемый металл

Не расходуется
в процессе коррозии

Galvanic couples on the metal surface





The surface of the metallic article may comprise a plurality of galvanic couples (anode-cathode).
The anode and cathode may occur due to differences in phase composition or from the presence of the coating

Electrochemical series

The surface of the metallic article may comprise a plurality of galvanic couples (anode-cathode).
The anode and cathode may occur due to differences in phase composition or from the presence of the coating

Элемент	Ион	Электродный потенциал, В	Водородный потенциал, В
Магний	Mg2+	-1.87	0.7
Алюминий	Al3+	-1.35	0.5
Цинк	Zn2+	-0.76	0.7
Хром	Cr2+	-0.6	0.32
Железо	Fe2+	-0.44	0.18
Кадмий	Cd2+	-0.4	0.5
Кобальт	Co2+	-0.29	
Никель	Ni2+	-0.22	0.15
Олово	Sn2+	-0.14	0.45
Свинец	Pb	-0.13	0.45
Водород	H+	0.00	
Сурьма	Sb3+	+0.11	0.42
Медь	Cu2+	+0.34	0.25
Серебро	Ag+	+0.8	0.1
Золото	Au3+	+1.3	0.35
Кислород	O -	+0.4	
Хлор	Cl^-	+1.36	

Faster will corrode the metal, which is closer to the beginning of the series. This condition may change, for example in the presence of sea water

Сталь- анод;
Медь-катод

By the nature of destruction corrosion divided:

Равномерная,
Неравномерная
Избирательная

-Язвенная
-Питтинговая
-Межкристаллитная
-Подповерхностная
-Ручейковая
-Нитевидная

corrosion effect can be enhanced
in the presence of stress and different wear mechanisms.

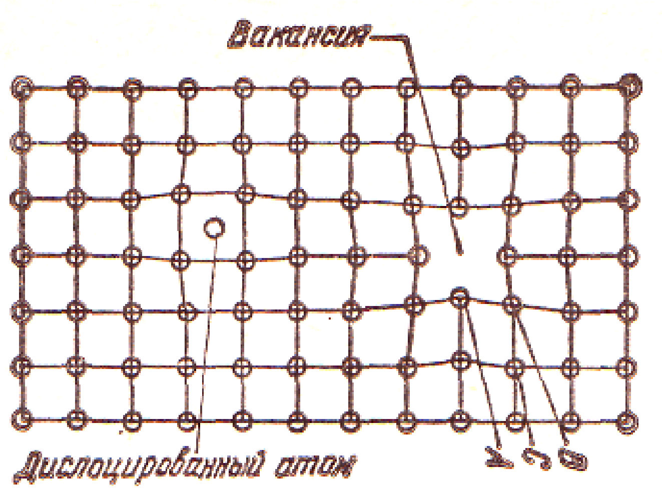
Usually, when the machinery is a constant removal of the oxide film.
Formed products of corrosion may form abrasive particles,
adversely affect the operation of the mechanism.

There are the following mechanical and corrosion damage:

- Fatigue corrosion
- cavitation corrosion
- erosion – Corrosion
-Fretting – Corrosion
- Corrosion under stress

Diffusion hardening surface
(Internal coating)

Diffusion (diffusion from the Latin -. Spread, spreading, scattering) in metals and alloys - it is the process of moving atoms crystalline substance at a distance greater lattice parameter.



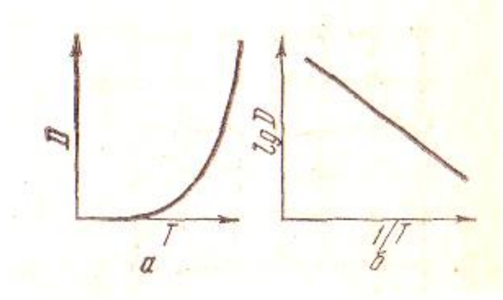
If the directional mass transfer leads to local changes in the concentration moving element atoms dissolved in the solvent, the process is called **heterodiffusion.**
If there is a movement of the main component metal atoms without changing the concentration process called **self-diffusion.**

The first law of diffusion
(Fick's first law)

$$M = -\frac{Ddc}{dx}$$

D - diffusion coefficient characterizes the amount of the substance in grams or moles moving through unit area per unit time at a gradient concentration equal to unity. The minus sign indicates that the diffusion proceeds in the direction of reducing the concentration of the element.

$$D = D_o e^{-Q/(RT)}$$



Do - pre-exponential factor;
Q - diffusion activation energy;
R - gas constant;
T - temperature

The activation energy of diffusion of different elements, giving implementation solutions in α-Fe

Элемент	**Атомный диаметр, Нм**	**Отличие от атомного диаметра железа, Нм**	**Q, Дж/моль**
H	0,56	2	15 700
N	1,42	1,14	76 100
C	1,54	1,02	84 100
B	1,78	0,76	88 400

The values of the activation energy of certain elements in γ-Fe, giving substitution solutions

Элемент	**S**	**Al**	**Mo**	**Cu**	**Mn**
Q, кДж/моль	121	184	247	255	278
Элемент	Ni	Fe	Co	W	Cr
Q, кДж/моль	282	284	366	376	406

The second law of diffusion (Fick's second law)

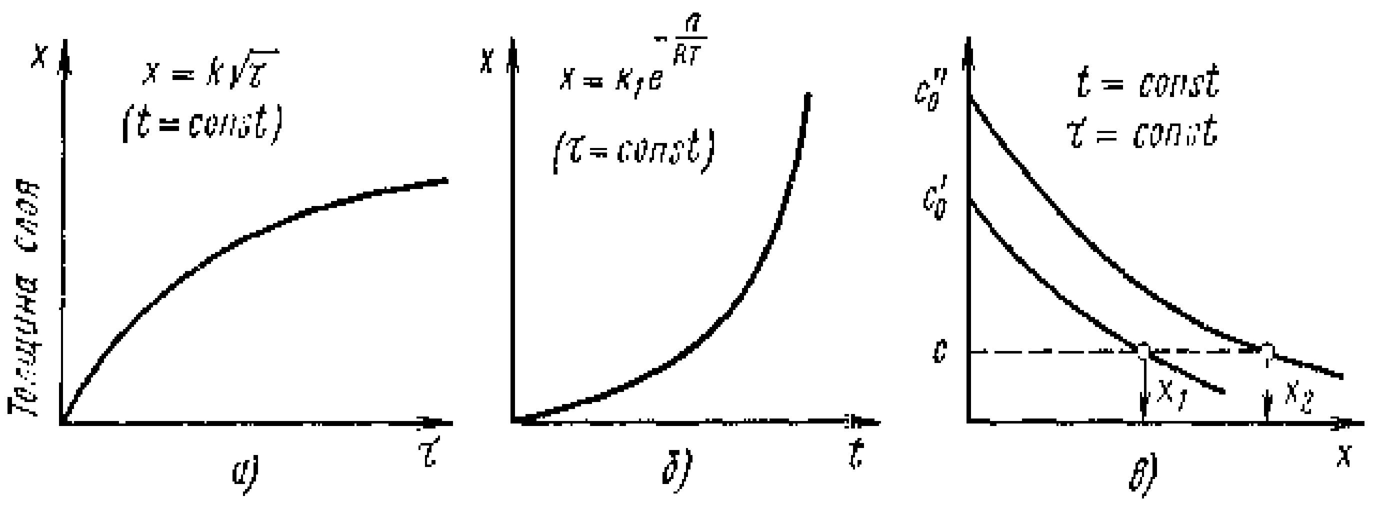
$$\frac{\partial c}{\partial x} = -D\frac{\partial^2 c}{\partial x^2}$$

The expressions used to determine the diffusion coefficient at different temperatures on the basis of experimentally determined values of w, x, and for a time τ.

$$c_{x,\tau} = c_o[1+\Phi\left(\frac{x}{2\sqrt{D\tau}}\right)]$$

Diffusion layer thickness dependence

of the saturation length (on),
the temperature (b)
and the change in concentration of the diffusion layer thickness (c)



Chemical-thermal treatment (HTO) - the saturation of the surface of the metal or an alloy of one or more elements by its diffusion in the atomic state of the environment at a high temperature.

The process of chemical-thermal treatment involves three basic steps:

1. The formation of active element atoms, which is saturated with metal. Such atoms occur at the time of dissociation (decomposition) compounds containing the element.

For example, when carburizing dissociation of carbon monoxide with the formation of active carbon:

$$2CO <=> CO2 + C;$$

When the ammonia dissociation nitriding occurs with the formation of active nitrogen atoms;

$$2N_3 <=> N_2 + 3H_2;$$

2. Adsorption of active atoms on the metal surface. The process depends on the adsorption properties of the surface of the metal atoms adsorbed on the nature, temperature and other conditions.

- 3. The diffusion of adsorbed atoms deep into the base metal.

Main saturation methods used during the chemical-thermal treatment

From powder mixtures

From pastes and suspensions

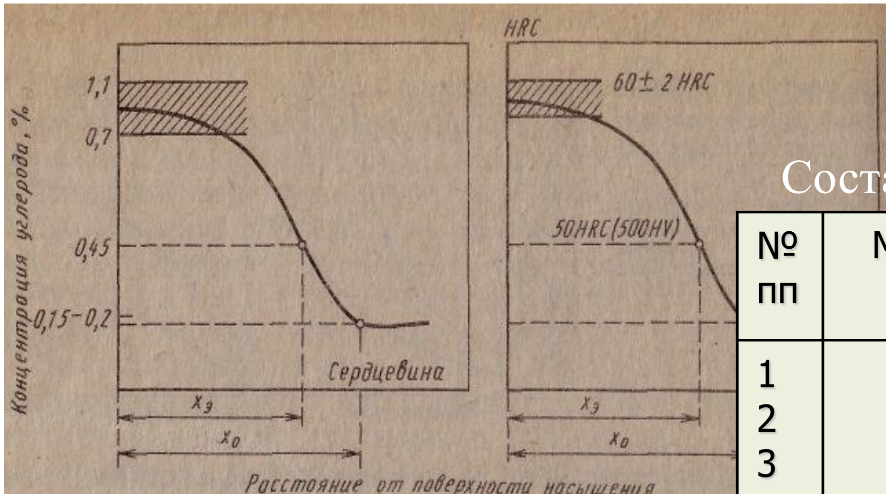
From atmospheres

With the use of a vacuum

From metal melts and salt

Cementation-saturation of the surface with carbon at a temperature 850-950 ° C. Steel subjected to quenching and tempering at low HV = 6000-9500 MPa.

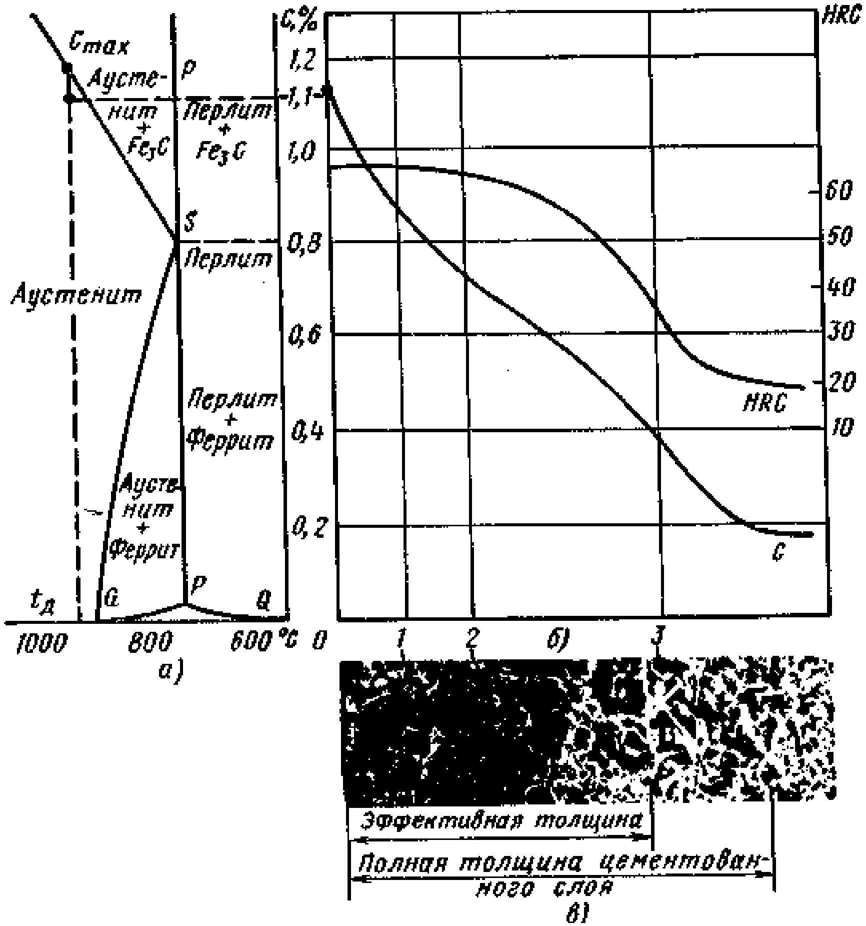
Cementation is carried out in carburizer, pastes, liquid and gaseous media



Соста

№ пп	Марка стали	Химический состав, %			
		C	Cr	Ni	Mn
1	10	0,07-0,13	-	-	-
2	20	0,17-0,24	-	-	-
3	15Х	0,12-0,18	0,8-1	-	-
4	20Х	0,17-0,23	0,7-1,0	-	-
5	15ХР	0,12-0,18	0,7-1,0	-	-
6	20ХН	0,17-0,23	0,45-0,75	1,0-1,4	-
7	20ХГР	0,18-0,24	0,7-1,1	-	0,7-
8	20ХНР	0,16-0,23	0,7-1,1	0,8-1,1	1,0
9	18ХГТ	0,17-0,23	1,0-1,3	-	-
10	30ХГТ	0,24-0,32	1,0-1,3	0,6-0,9	0,8-
11	18ХНМФА	0,16-0,21	0,6-0,9	-	1,1
12	12ХН3	0,09-0,16	0,6-0,9	2,75-3,15	-
13	12Х2Н4	0,09-0,16	1,25-1,65	3,25-3,65	0,8-
14	20Х2Н4	0,16-0,22	1,22-1,65	3,25-3,65	1,1
15	18Х2Н4В	0,14-0,20	1,35-1,65	4,0-4,4,4	-

Марка стали	$\sigma_в$, МПа	$\sigma_{0,2}$, МПа	δ, %	φ, %
10	40	25	35	70
15	43	27	32	65
20	47	30	30	60

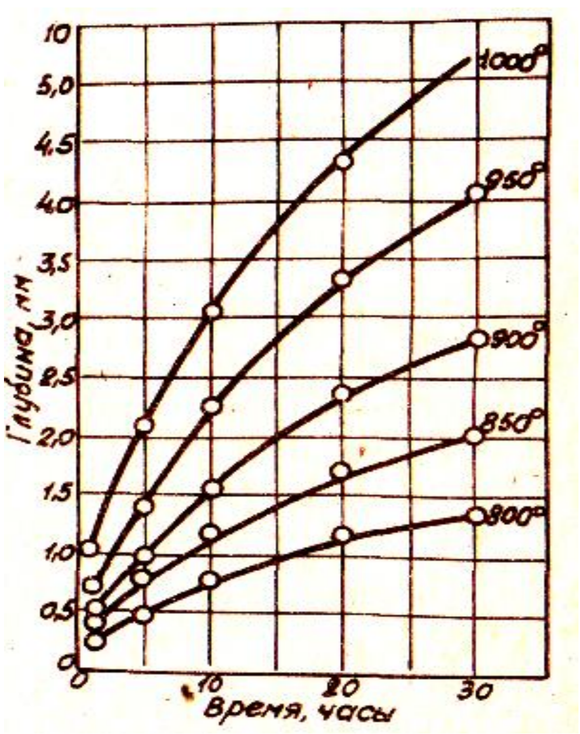


$\delta_{эф}$ = 0,5 – 1,8 мм;
The concentration of carbon – 0,8-1,0%

The effective thickness of the cemented layer:
The amount doevtektoidnoy, eutectoid transition and half (doevtektoidnoy) zones;
Depth control dissemination of hardness above a certain value.
As a control Hardness (after heat treatment) is used:
a) hardness of 50 HRC, which characterizes total depth eutectoid zone and half of the transition zone (up to 0.45% C);
b) hardness HV 540 - 600 (depending on the steel grade) at a load of 1 - 5 kg.

Dependence of depth of cemented layer from the temperature and time of the gas carburizing

1



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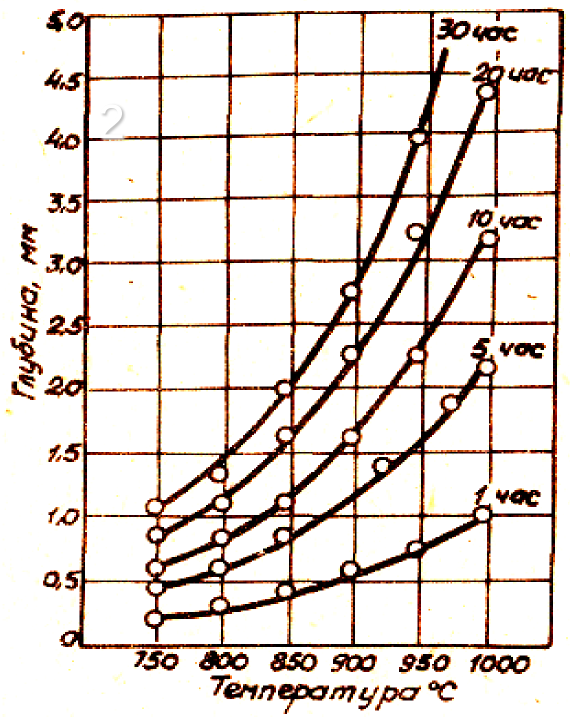


Gas carburizing

$2CO \rightarrow CO_2 + C_{ат}$ or $CH_4 \rightarrow 2H_2 + C_{ат}$

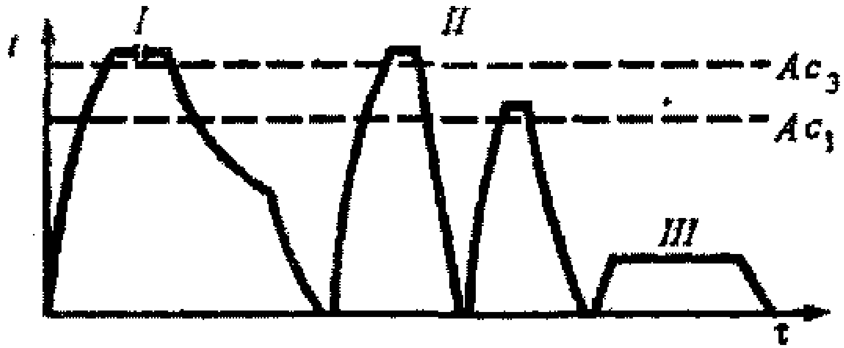
The process is carried out at 910 - 930˚C, 6 – 12 ч (layer thickness 1,0 – 1,7 мм)

in the continuous annealing furnaces and chamber atmosphere is used for the endothermic carburization, which is added to natural gas (92 - 95% endogas and 3 - 5% of the natural gas).

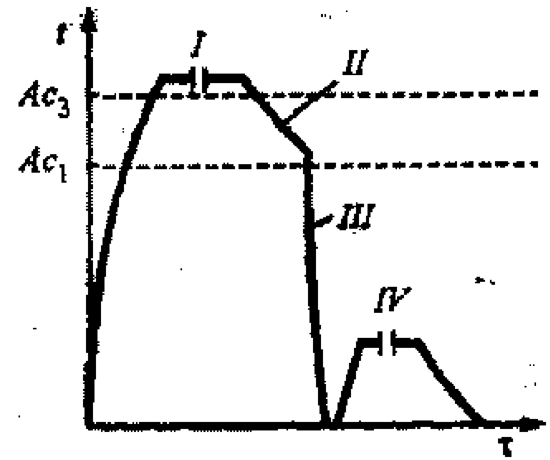
The endothermic atmosphere (20% CO, 40% N_2 and 40% N_2) is obtained by partial combustion of natural gas or another hydrocarbon in an endothermic special generator at 1000 - 1200? C in the presence of a catalyst.

The main advantage of the endothermic atmosphere - the ability to automatically control the carbon potential, which is defined its ability to carbonize, providing a certain concentration on the cemented surface of the layer. Endothermic atmosphere carbon potential set on dew point or the content of CO2 in it, because the concentration of water vapor and CO2 are interrelated.

Heat treatment after the Cementation

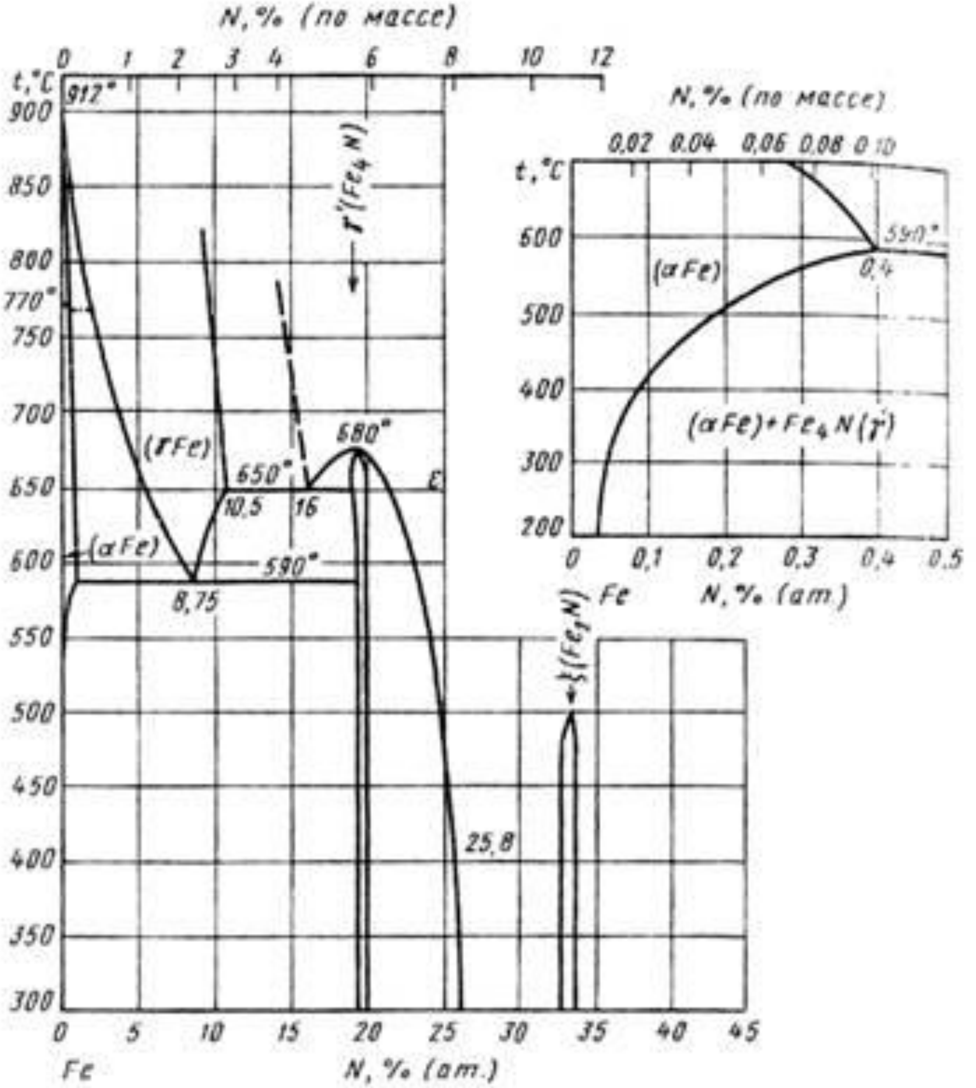


I -cementation
II - double tempering;
III - low vacation



I - -cementation;
II - podstuzhivanie;
III - hardening;
IV - Vacation

Nitration



α-ferrit, γ- exist > 591^0;
γ'- Fe_4N; ε- Fe_2N.
ε- фаза может существовать даже с 8 % N.

Methods of nitriding

gas nitriding in ammonia,
nitriding in a glow discharge (ion)
and nitriding in liquid media.
nitriding process consists :

1. thermal pretreatment blank - to obtain the necessary strength and toughness of the product core (this operation includes high quenching and tempering). To avoid buckling parts tempering temperature should be above the nitridation temperature 20-400S;
2.machining to obtain the desired shape and size;
3.protect areas not subject to nitriding (applying electrolytic method tin layer);
3.nitriding;
5.product finishing

For the layer of high hardness and high thickness must be used a two-step operation:
1) 500-520˚C;
2) 540-560˚C.

ion nitriding

- held in the rarefied nitrogen-containing medium in the glow discharge is excited at the surface of the part (cathode) and the anode is the installation of the container. This gas ions bombard the surface of the part and it is heated to the saturation temperature. nitriding process is carried out in two stages:
- 1 - cleaning the workpiece surface by cathodic spraying for 1 hour at U=1100-1400V and P=0,1 ÷ 0,2 mm Hg. Article .;
- 2 - 470-580˚C nitriding temperature, U= 400-1100V, for 1-24 hours.

Ion nitriding advantages in comparison with gas:
1.reduced processing time;
2.it is possible to control the process to obtain the optimal structure of the nitrided layer;
3.reduced brittleness of the material;
4.articles greatly reduced deformation during processing;
5. ion nitriding cost and non-toxic.

Boriding

Boriding the surface boron-saturation at the temperature
900-1100 ° C in a protective atmosphere of argon,
HV = 17000-19500MPa.
Boriding: in powder fillings, pastes, in a gaseous medium, electrolysis, liquid.

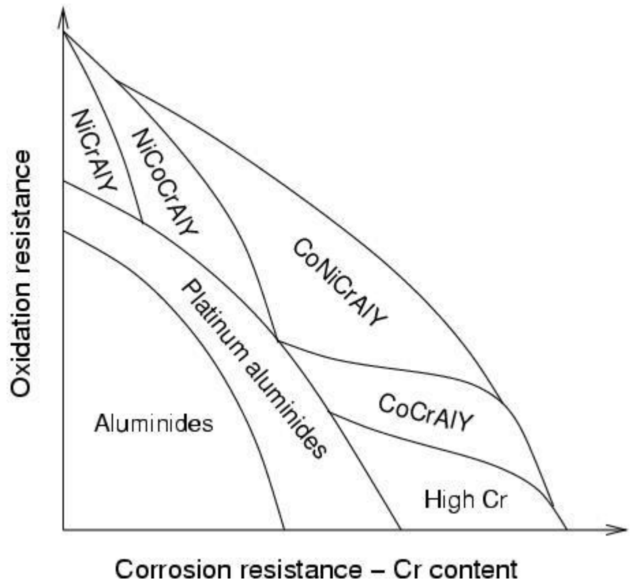
Наименование	Сталь	Режимы борирования		Глубина слоя, мм	Микротвер-дость HV, МПа
		Температура, ºС	Выдержка, ч		
Пуансоны для гибки деталей в холодном состоянии	У8А	900	3	0,04	18000
Резьбонакатные плашки	Х12М	1050	6	0,08	19000
Матрицы формовочных штампов	ХВГ	900	4	0,08	19500
Зажимные цанги	40Х	900	3	0,05	17500
Слесарный инструмент	9ХС	900	4	0,07	18500
Молотовые штампы	5ХНВ	900	6	0,09	18000

Metallization → Heat-resistant coating

Coating base - Ni- Cr - Al and Ni – Cr- Si

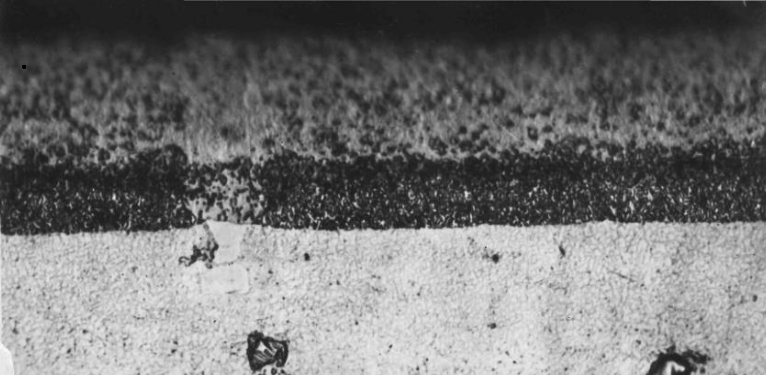
Cr, Al, Si - elements formed on the respective surface oxide composition: Cr_2O_3; Al_2O_3; SiO_2, which have an insulating property of ambient temperatures from 800-900° C (Cr_2O_3) to 1200 ° C (Al_2O_3 and SiO_2). Elements that enhance adhesion to the substrate Al_2O_3: yttrium (0.01%) and hafnium (to 1%), increasing the heat resistance, as well as Pt, Ro, Ta.

Widely known quaternary alloys of the type MCrAlX (M - Fe, Co, Ni), X - Y, Hf, Zr, Si) characterized by high barrier properties at 1200 ° C.



β–NiAl,
γ'–Ni_3Al
γ– a solid solution based on nickel

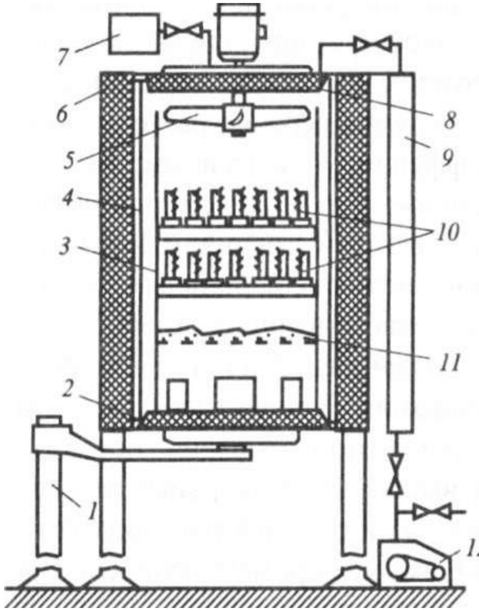
The solid Al_2O_3 film on the surface alloy bases when the content of Al is formed over 40% or 10%, if there is in the composition and 5-10% chromium



Aluminizing - saturation aluminum surface at temperatures in the 700-1100 ° C saturating respective environments.

The aim - increase resistance to scaling products (up to 800-900 ° C), corrosion resistance to the atmospheric conditions and sea water.

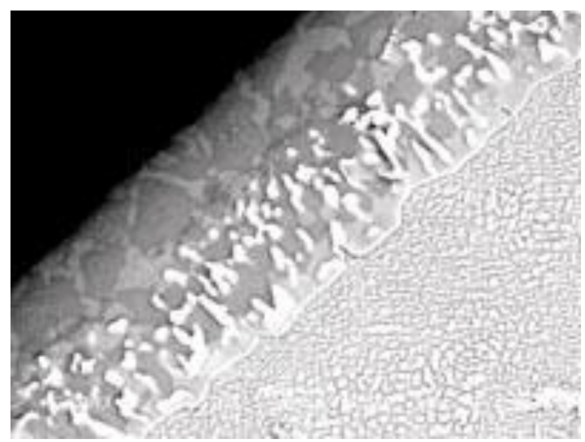
Coatings in mixtures with higher activity is obtained when aluminum is usually 700-900 ° C, low - at 1050-1100°C.
At 700-900 0C in these mixtures a coating to the structure Ni_2Al_3,
at 1100-1150° C, the structure is β -NiAl, nickel-enriched



Circulation method of coating

$3AlCl_2 \leftrightarrow 2AlCl_3 + Al_{ат}$,
$3CrCl_2 \leftrightarrow 2CrCl_3 + Cr_{ат}$
or dissociation of the starting material, for example:
$CrI_2 \leftrightarrow Cr_{ат} + I_2$.
Atoms of aluminum and chromium are deposited on the workpiece surface and form a diffusion coating.

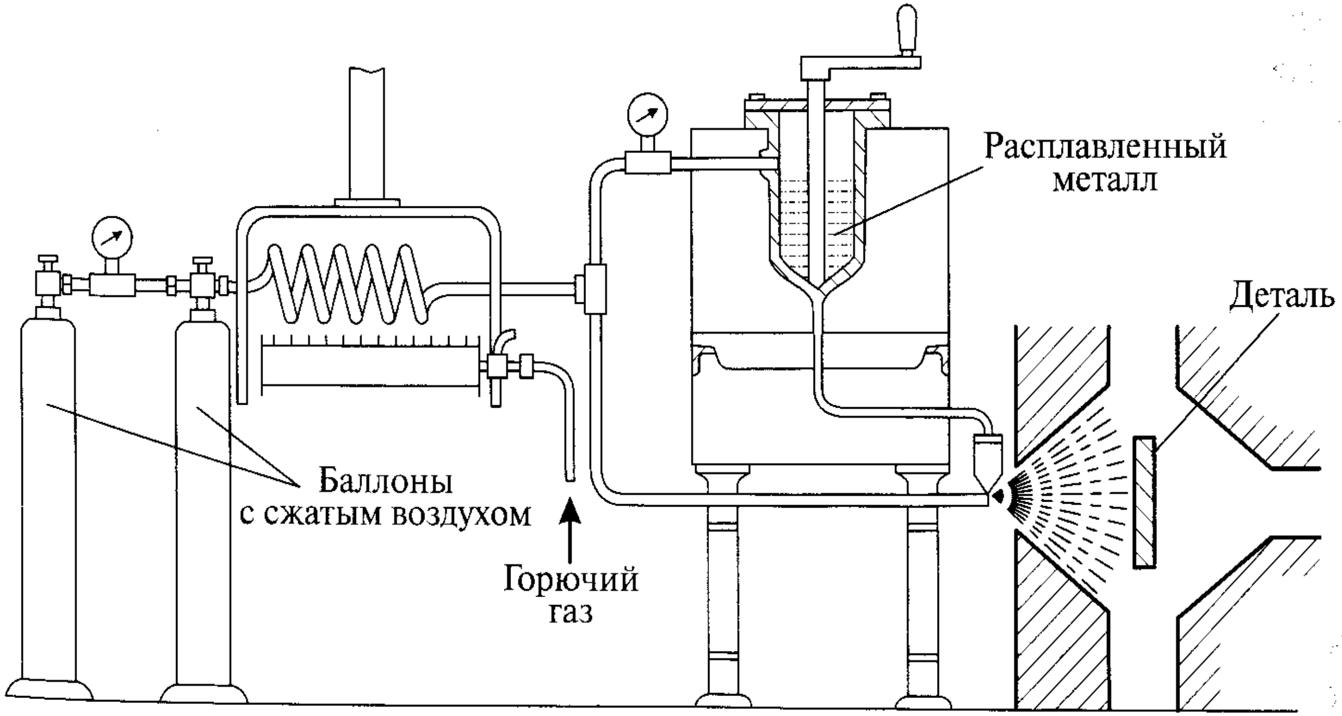
The structure consists of coating chromoaluminizing phases *β* - NiAl and γ- Ni_3Al



Thermal spraying methods:

Electric: plasma (APS), electric;
Gas: detonation (D-gun), flame, high-speed gas-flame (HVOF)

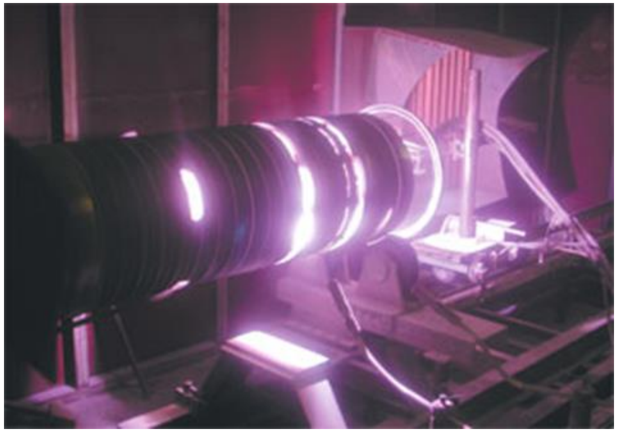
The founder of the thermal spray coating method of obtaining recognized Swiss inventor Max Ulrich Shoop (1870-1956 biennium).



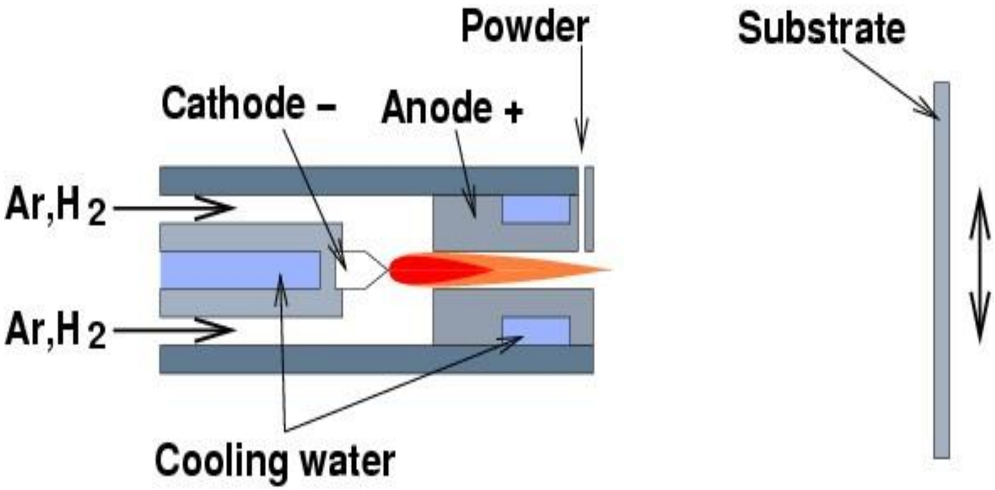
Plasma spraying - the process of coating the surface of the workpiece (product) by the plasma jet. The plasma jet - is partially or fully ionized gas having electric conductivity property and having a high temperature.

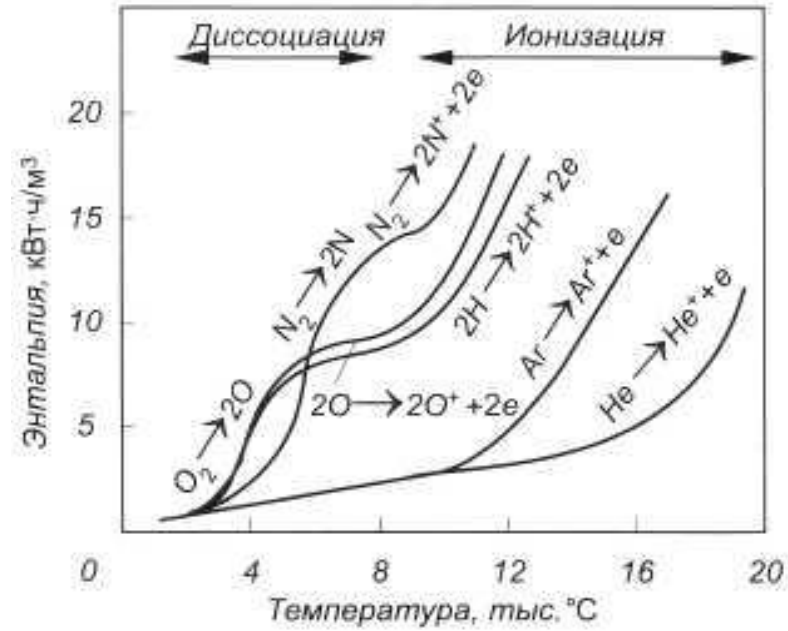
Spraying stages

1. Generation of the plasma jet;
2. entering the spray material into the plasma jet, and its heating acceleration;
3. the interaction of the plasma jet and the molten particles to the base

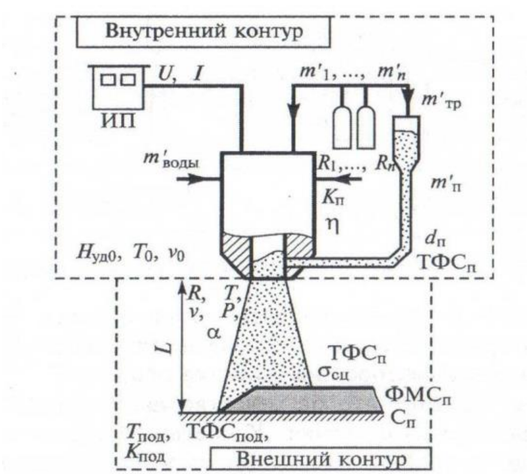


Plasma spraying without protection
Plasma spraying with local protective atmosphere
Plasma spraying with a total protective atmosphere





The scheme of formation of quality of coatings in the process of plasma spraying



Температура -4500^0C;
Скорость частиц
до 6 00 м/с;

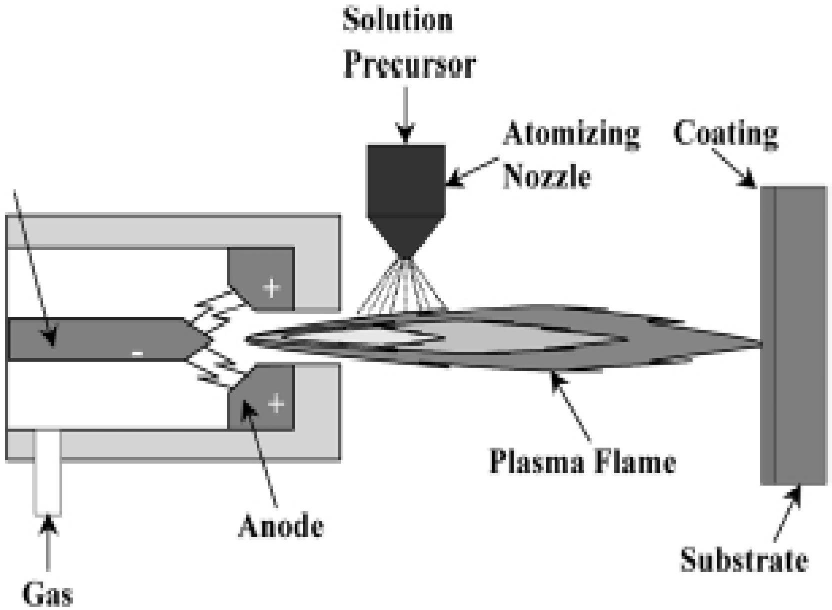
Прочность сцепления –
30- 70 МПа;
Пористость - 3-5%

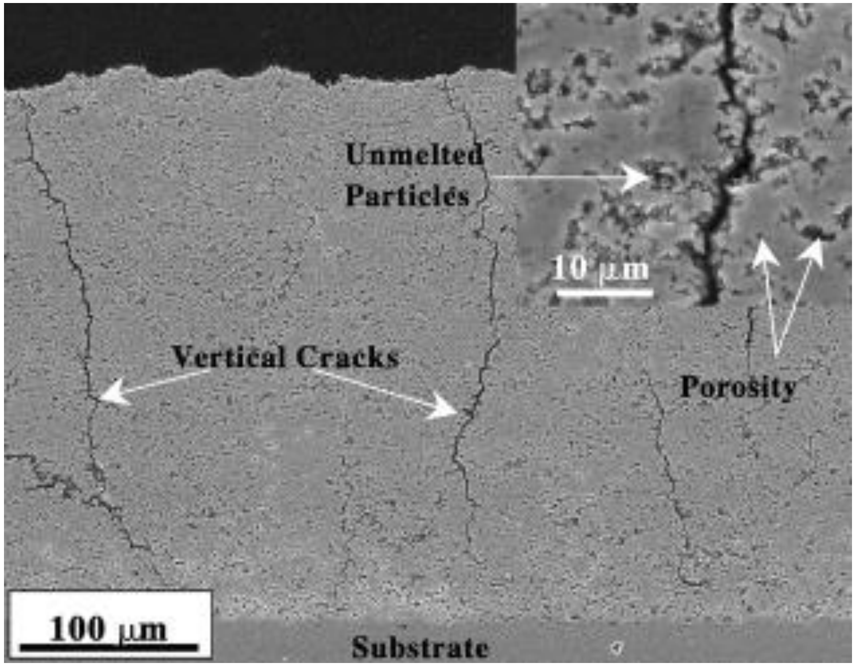
Advantages of Plasma Spraying

- High-performance processor (2-8 kg / h for plasma torches capacity of 20-60 kW to 50-80 kg / h for plasma torches capacity of 150-200 kW); a wide range of types of spray material (wire, powders with different melting points);
- a large number of parameters that provide flexible control of the spraying process;
- High values of the utilization factor of the material (when spraying wire materials-0.7 and spraying -0,3-0,8 powder);
- the possibility of comprehensive mechanization and automation of the process;
- widely available, sufficient efficiency and low cost of basic equipment.

Limitations: low values of energy utilization: the wire spraying 0,02-0,18; powder 0.001-0.02;

Solution precursor plasma spray process (SPPS)



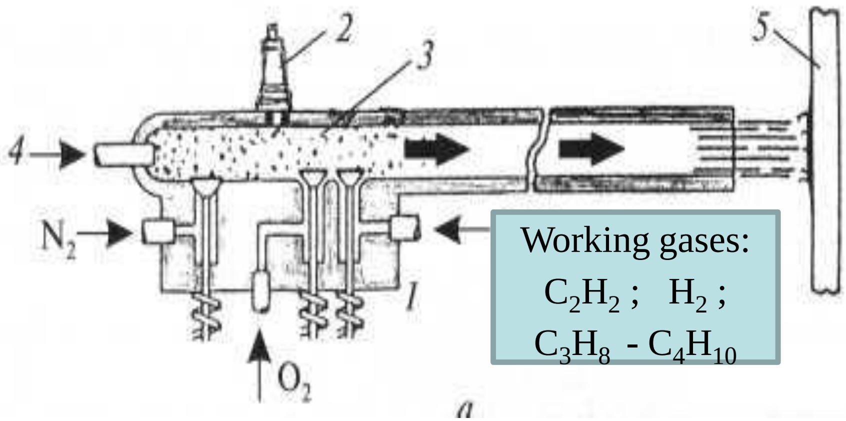


1-SPPS- process creates a coating with high durability in a wide range of microstructures and coating thicknesses.
2. SPPS- coatings have high thermal stability as compared to the APS-, DVC-, EB-PVD- coatings (test mode: 1 hour at 11200C).
3. SPPS coatings have a new mechanism of destruction when on heat resistance test)
fail by large scale buckling of the top ceramic coat, and the failure occurs within the 7YSZ coating, near the 7YSZybond coat interface.

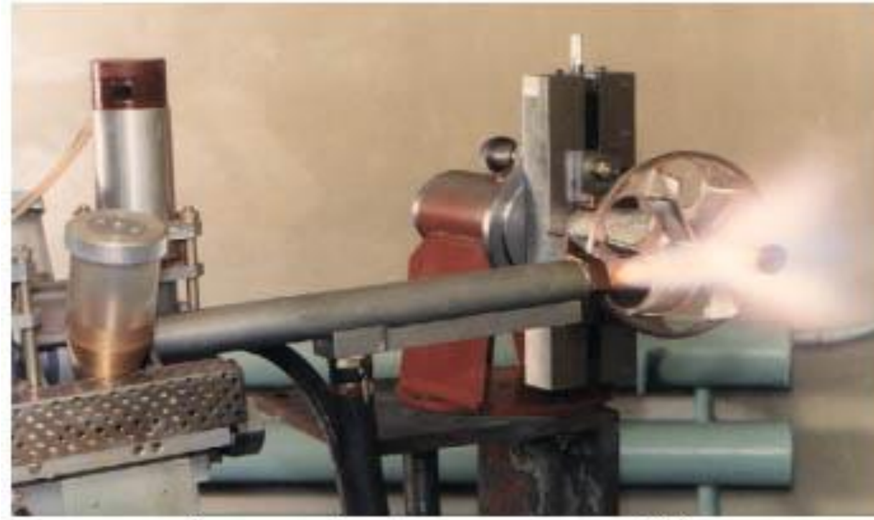
Compare gas spraying methods

Method	Place fuel combustion	Temperature particles ,^{0}C	The particle velocity, m/s	Continuity process
Flame	For the nozzle exit	3300	240	Continuous
D-gun	In the tube	3500	about 1000	pulsed
HVOF	The combustion chamber	2800	1000-1300	Continuous

Detonation-gas spraying

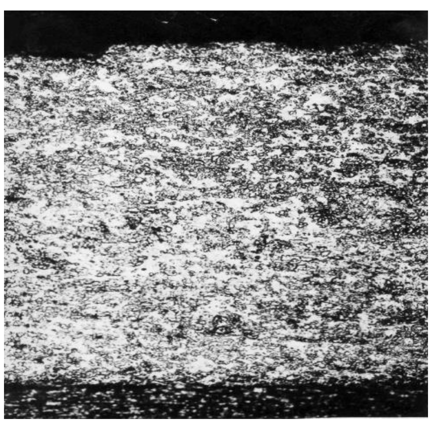


Working gases:
C_2H_2 ; H_2 ;
C_3H_8 - C_4H_{10}

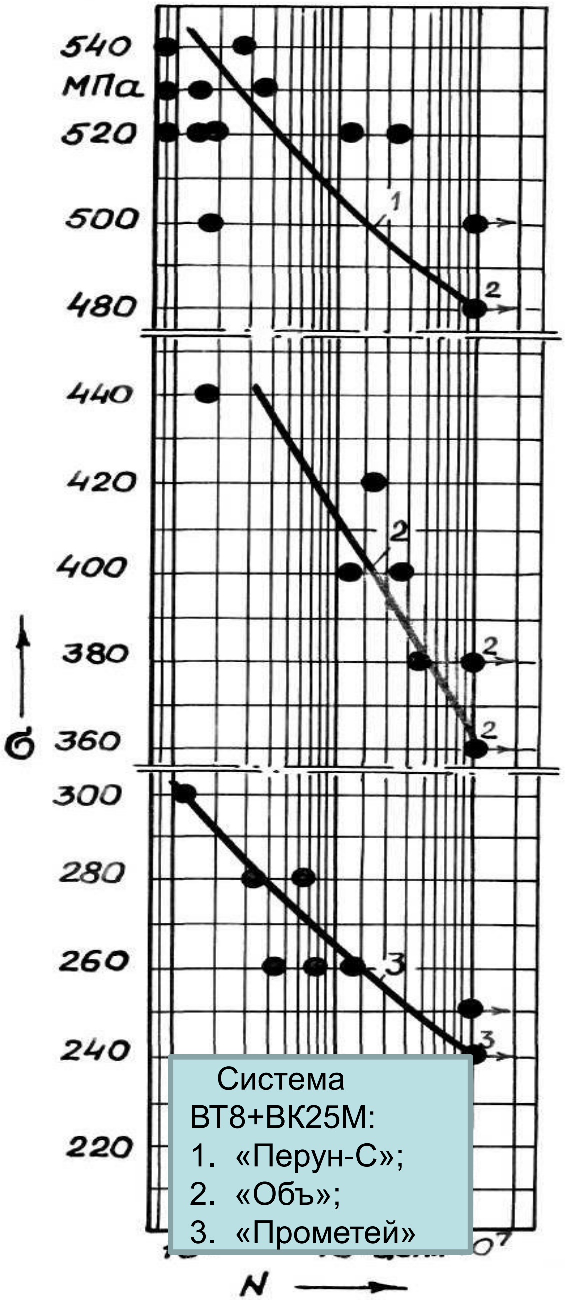


Внешний вид комплекса «Обь»

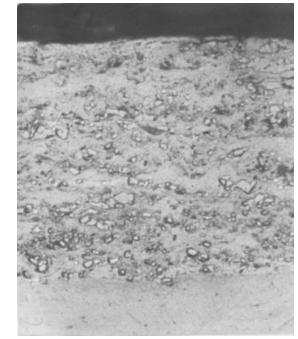
1 metering gas, 2-burning candle, 3 bore,
4 - powder dispenser, 5 – coating



Bond strength >70 MPa;
Porosity - 0-1%

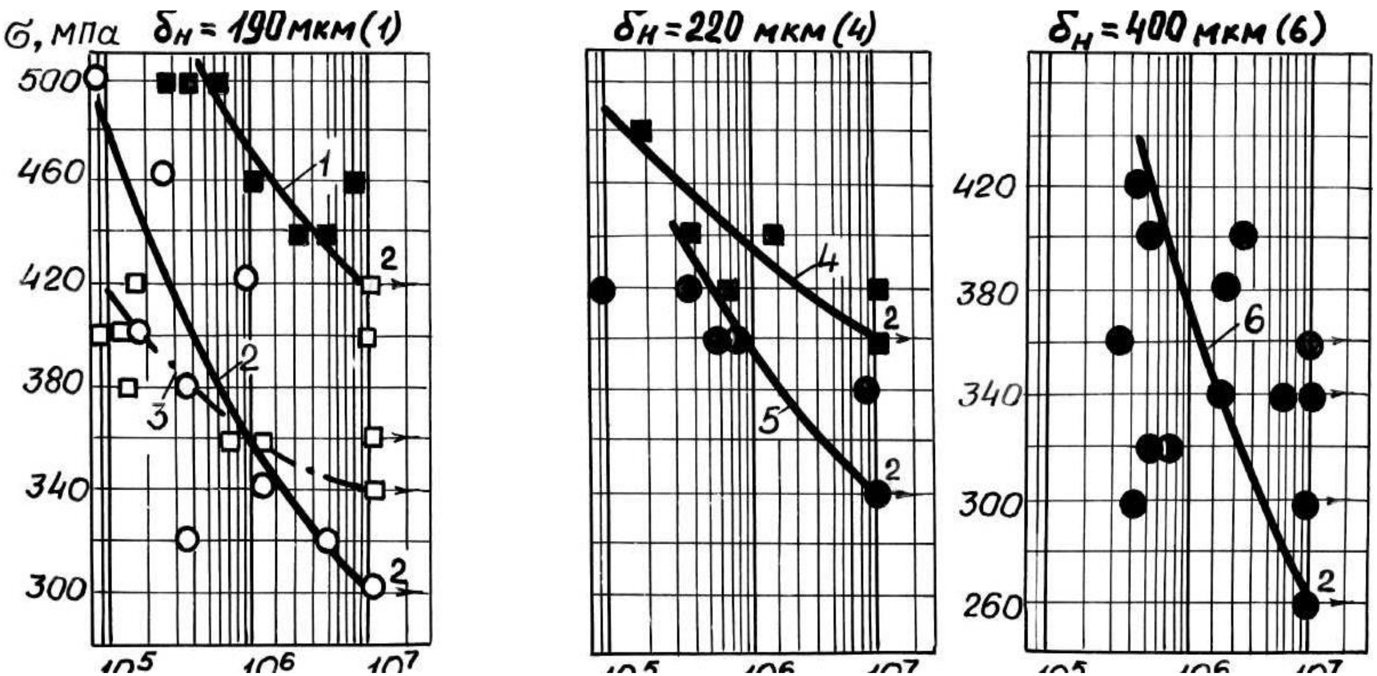


Application DSU improved design, providing increased rate, pulse supply of powder, pressure stabilization, the temperature of the gas flow



ДГУ	Фазовый состав покрытий, вес.%					Механические свойства покрытий	
	WC	W_2C	W	Co	η'-фазы	HV, ГПа	$\sigma_{сц}$, МПа
Перун-С	16-18	1,5	40	25-28	11-14,5	8,5	85,0
Обь	45	7	15	30	3	6,5	110,0
Прометей	45	15	-	36	4	9,4	113,0

WC-Co

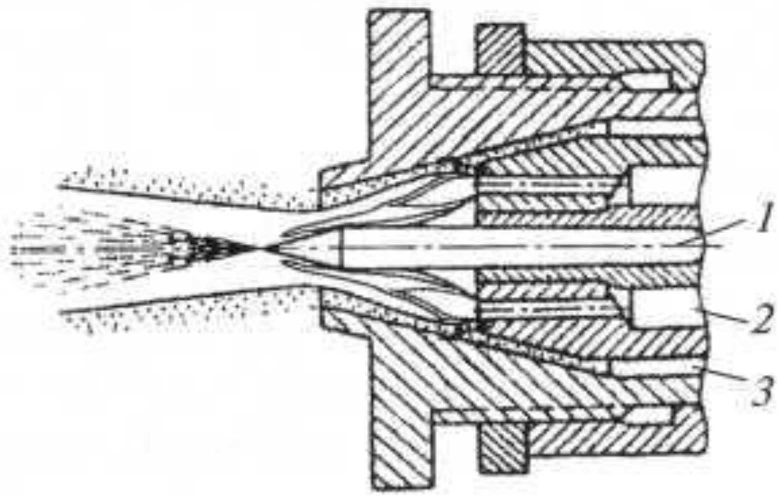


praying mode
(DGS Perun-S):
Rate -6 / c;
Distance - 120 mm;
Filling powder barrel - 0.3-0.8;
the ratio of the working gas
and oxygen: 1: 3.5

Вариант	Thickness unpolished coating, micron	**Kv**
1	190	0,75
4	220	0,71
6	400	0,46

Вари ант	Thickness polished coating, micron	**Kv**
2	190	0,54
5	220	0,60

low-speed flame wire spray gun



Bars 1-, 2- combustible gas (acetylene) with oxygen
3 air

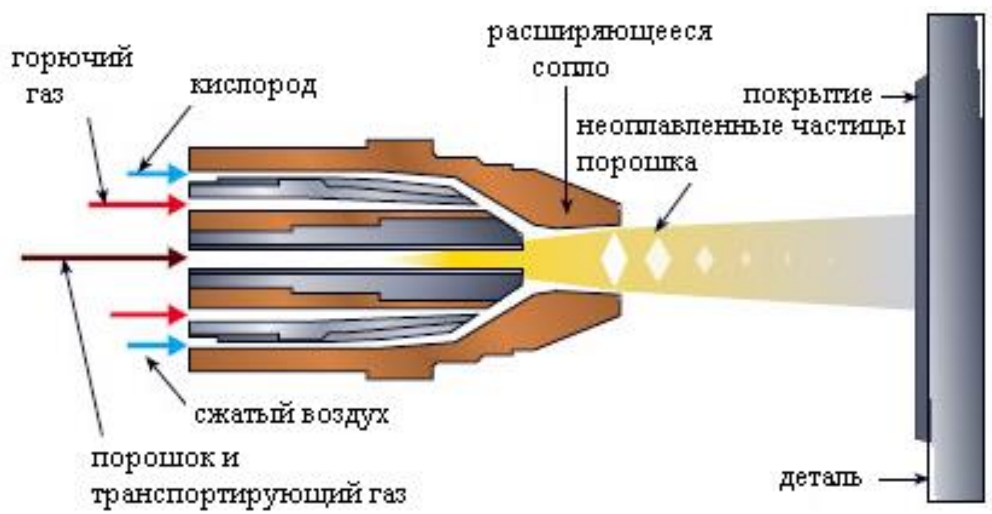
Temperature of powder-gas stream -3300^{O}C;
GWP speed - 240 m/ s

Bond strength -20-30 MPa;
The porosity -10-20%

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O + 1262 \text{ кДж.}$$

in practice, a neutral flame is produced at the ratio of:
$C_2H_2 : O_2 = 1:1,1$

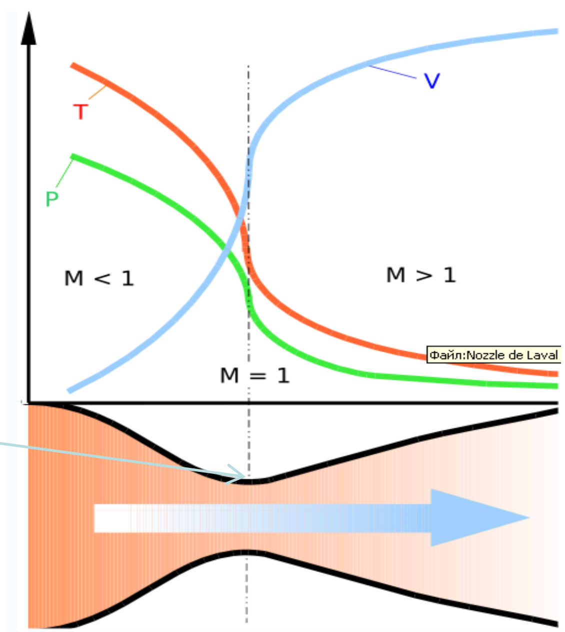
High Velocity Oxygen Fuel (HVOF)

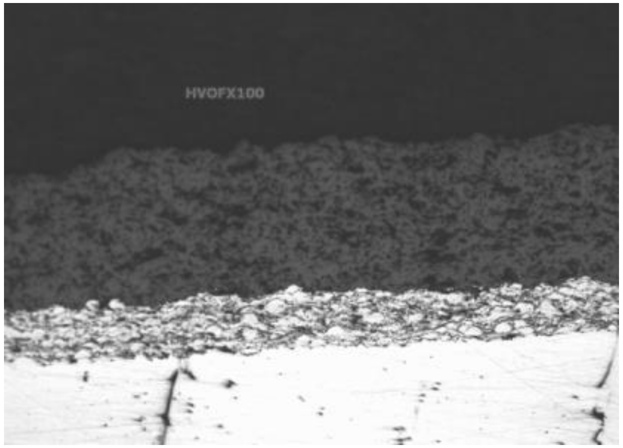


particle speed of 550 ÷ 800 m /s
temperature- 1500-2500°C

Bond strength -40-96 MPa;
Porosity -0,5-2%

Laval nozzle





Advantages HVOF-coatings

- A low level of stress in thick coatings;
- High hardness;
- A high flexural strength;
- Very low porosity;

Low levels of oxides in the coating;

- Excellent safety of carbides during spraying;
- Easy maintenance and low operating cost HVOF - installations.
- However, the effectiveness of HVOF-method depends on the following parameters of the process:
- the powder characteristics,
- the design features of the installation: the method of powder feed nozzle scheme, the efficiency of water-cooling, as well as the parameters of the coating.

Equipment ТСЗП HVOF-2001

включает блок газоподготовки с электронными расходомерами, керосиновую помпу, панель управления с многофункциональным графическим экраном и промышленный контроллер Siemens S7-300.

Управляющая система позволяет задавать и менять, в т. ч. и в процессе напыления, более 100 параметров

installation Features

It runs on a mixture of kerosene fuel - oxygen.

Consumption: oxygen and 1000 l / min? kerosene to 25 l / h

Flow carrier gas (argon, nitrogen) to 30 l / min

Performance: during deposition of carbides - 6 ... 12 kg / h? during deposition of metals and alloys - up to 10kg / h

· The porosity of the coating is less than 1.0%

Adhesion of more than 80 Mpa

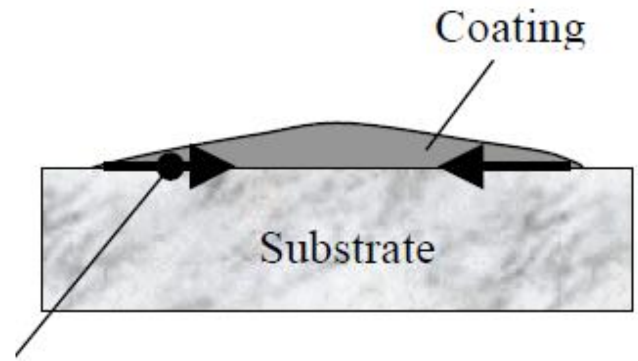
The thickness of the sprayed layer, 0.03 ... 0.5 mm

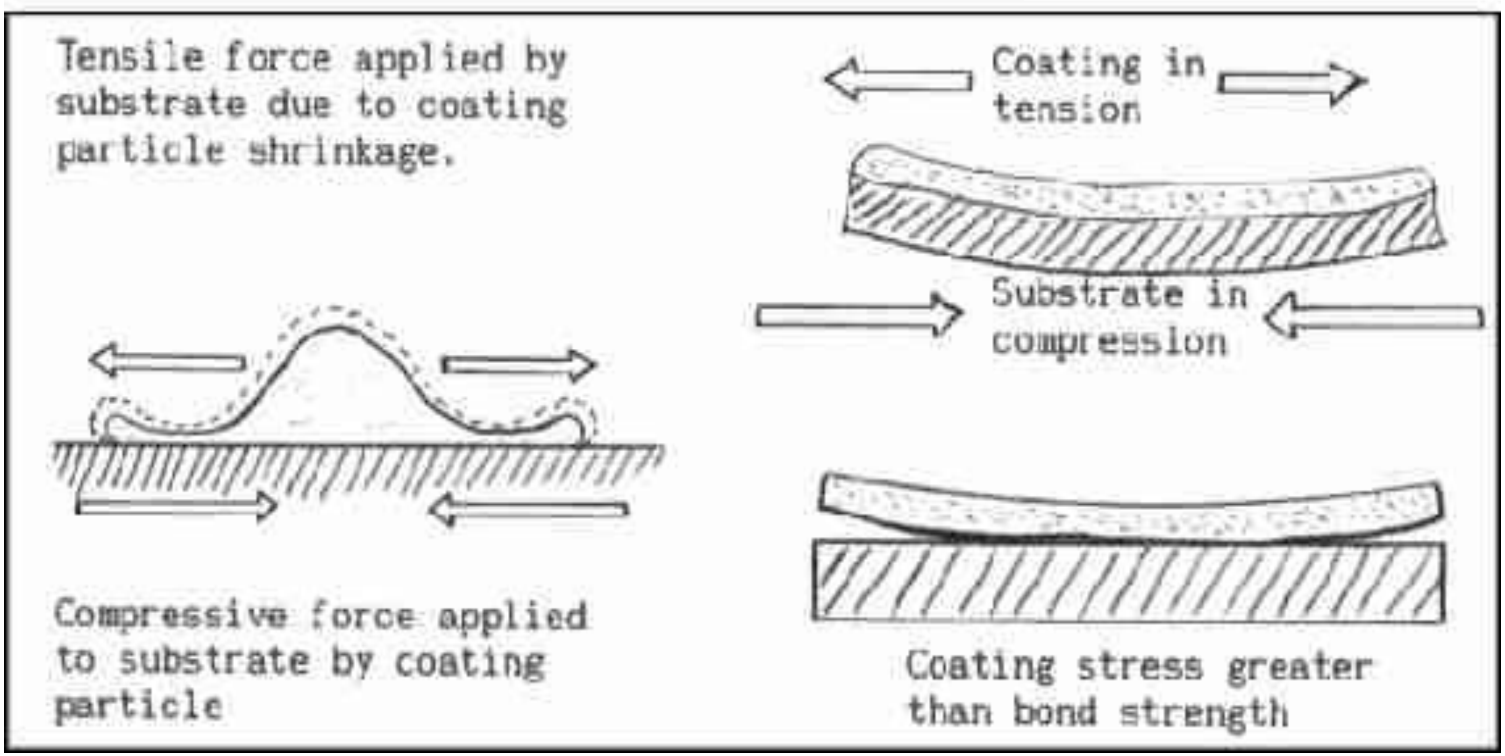
Residual stresses

$\alpha_c < \alpha_s$ stresses in the coating may be either tensile or compressive

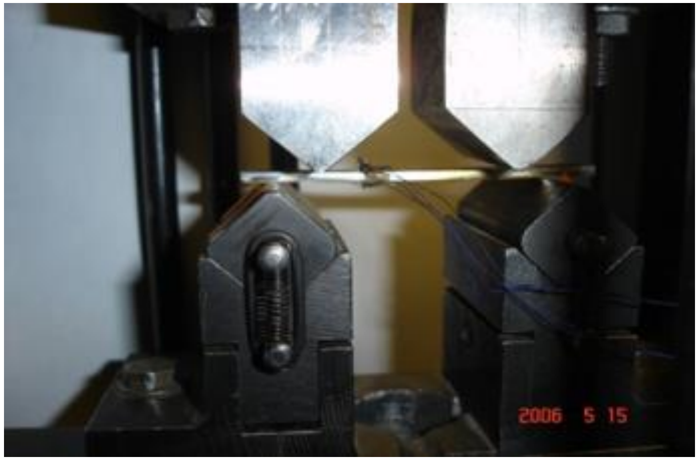
$\alpha_c = \alpha_s$ stresses in the coating are tensile

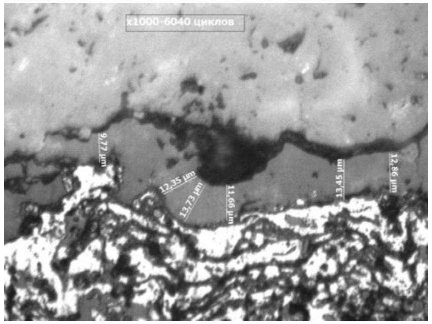
$\alpha_c > \alpha_s$ stresses in the coating are tensile

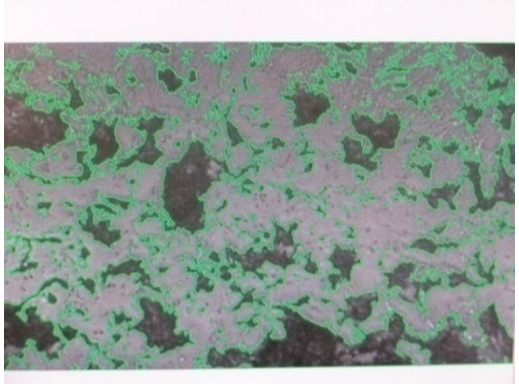




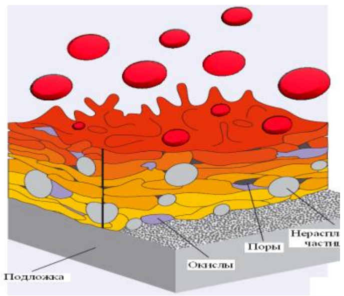
Control of coatings

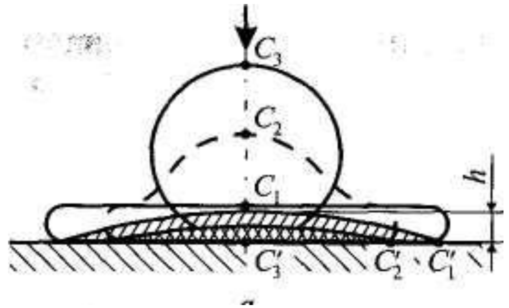


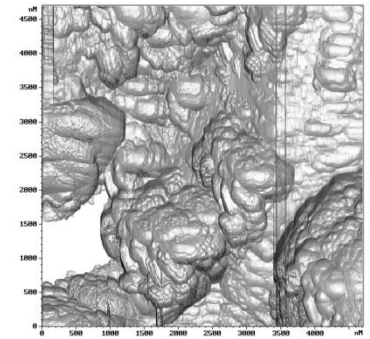


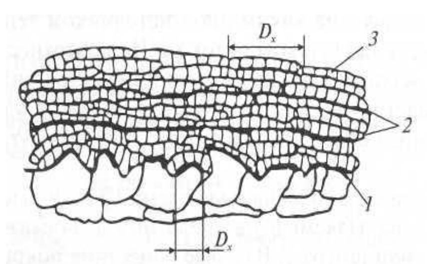


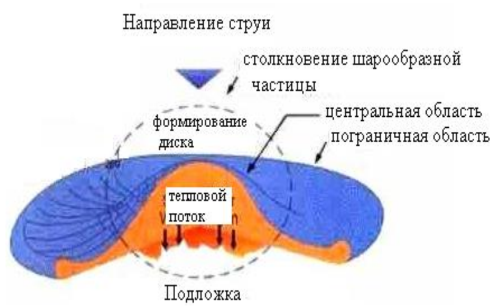
Deformation hardening of the particles and their solidification









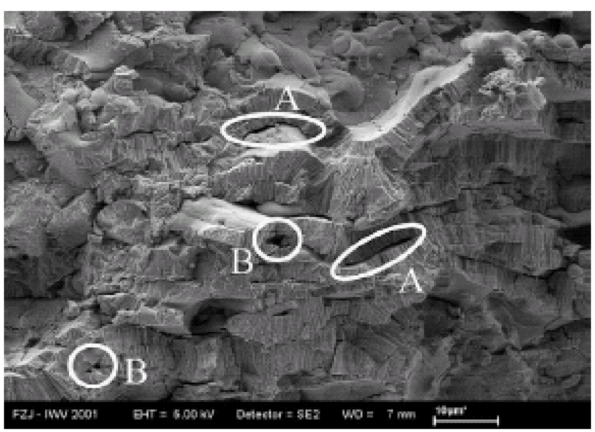


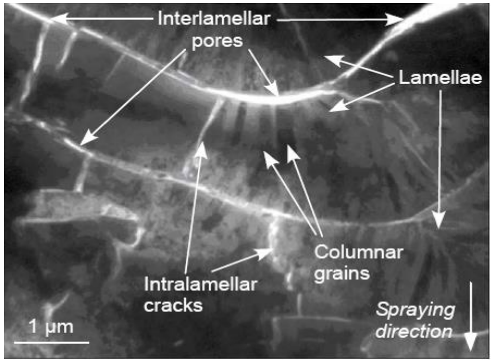
interaction of particles with each other and with the base is carried out by ::

- Mechanical engagement (the so-called anchor);

silyl physical intermolecular interactions (van der Waals forces);

- Chemical interaction forces.

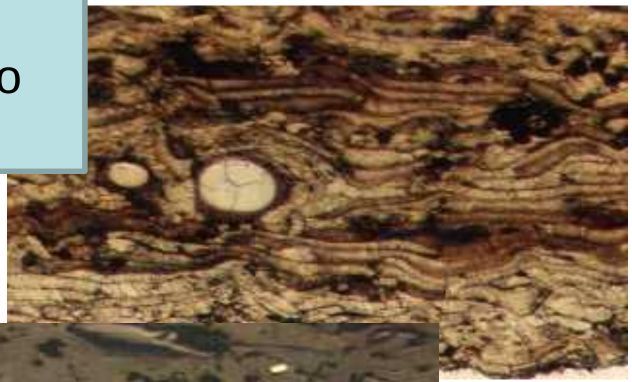




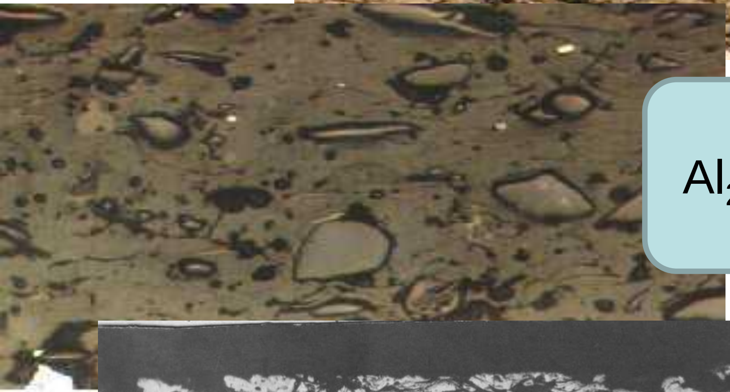
The types of microstructures of Thermal coatings

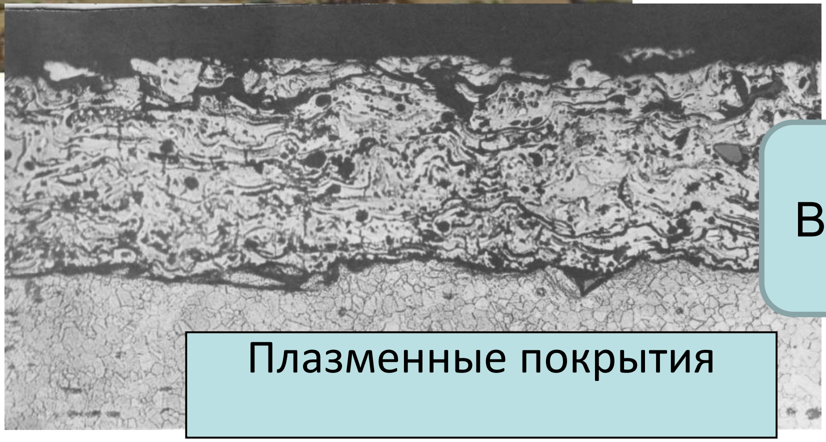
1,Сложно-зернистая

Mo



Al_2O_3

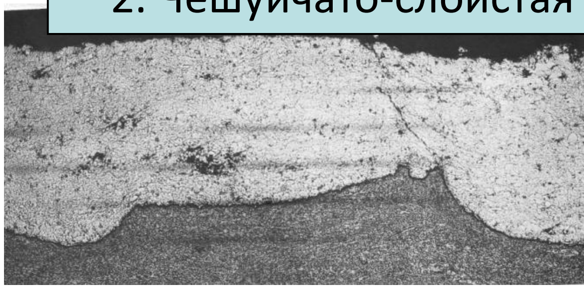




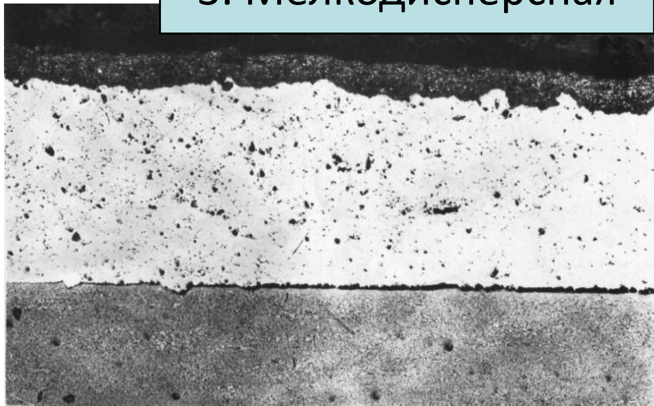
ВКНА

Плазменные покрытия

2. Чешуйчато-слоистая

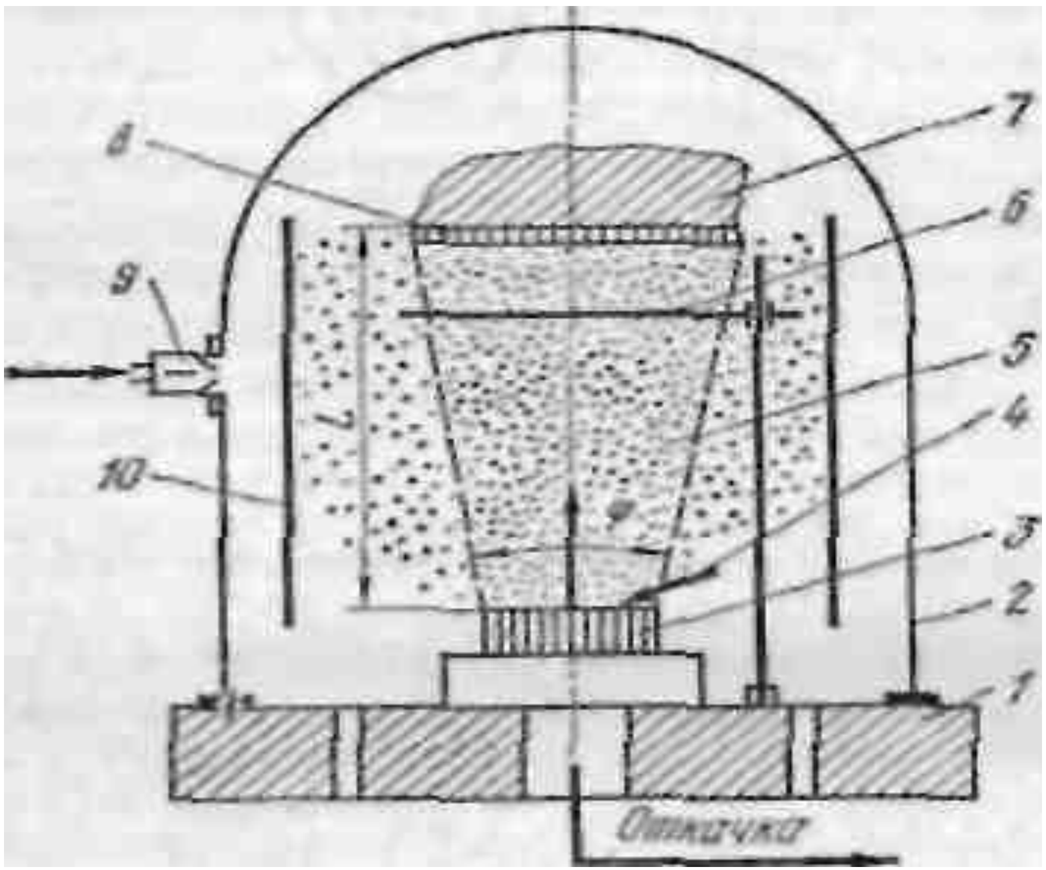


3. Мелкодисперсная



A generalized diagram of vacuum condensation coating deposition

1- Base plate; 2 -Camera; 3 - Sprayed material; 4 - Energy summing spraying material; 5 -Flow of sprayed particles; 6 - Valve; 7 -Detail; 8 - Coating; 9 -Working gas leak valve; 10 - Screen.



-Flux density of the spray particles {N, particle / (cm2-s));
- Energy sputtered particles (W, eV / atom);
-Degree of ionization of sputtered particles (ni,%);
-Rate of particle deposition in the direction of the surface (Vch m / s);
- Flow divergence angle of sputtered particles (φ, °).

Classification of vacuum coatings

Methods for sputtering material deposition and formation of the flow of particles:

- thermal evaporation or solid material;
- explosive (Intensified) evaporation - sputtering;
- sputtering the solid material.

Energy of the spray particles:

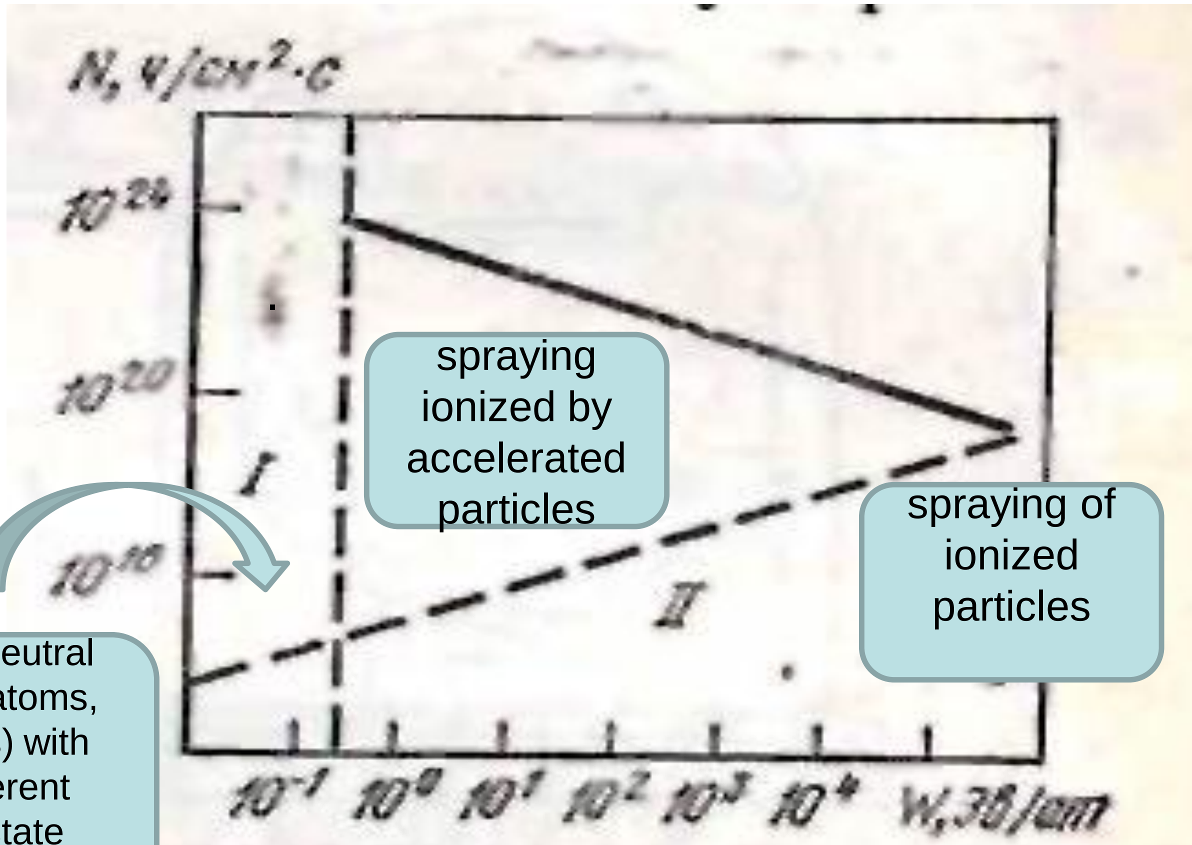
- spraying neutral particles (atoms, molecules) with their different energy state;
- spraying of ionized particles;
- spraying ionized by accelerated particles.

(In real conditions of different particles present in the stream).

By a process of interaction with particles sputtered residual gas chamber:

- spraying in an inert atmosphere or a rarefied high vacuum (133.10^{-3} Pa) - pvd;
- spraying in the active rarefied medium ($133 – 133.10^{-1}$ Pa) - cvd

Particles flux density distribution diagram N and W of energy for different ways

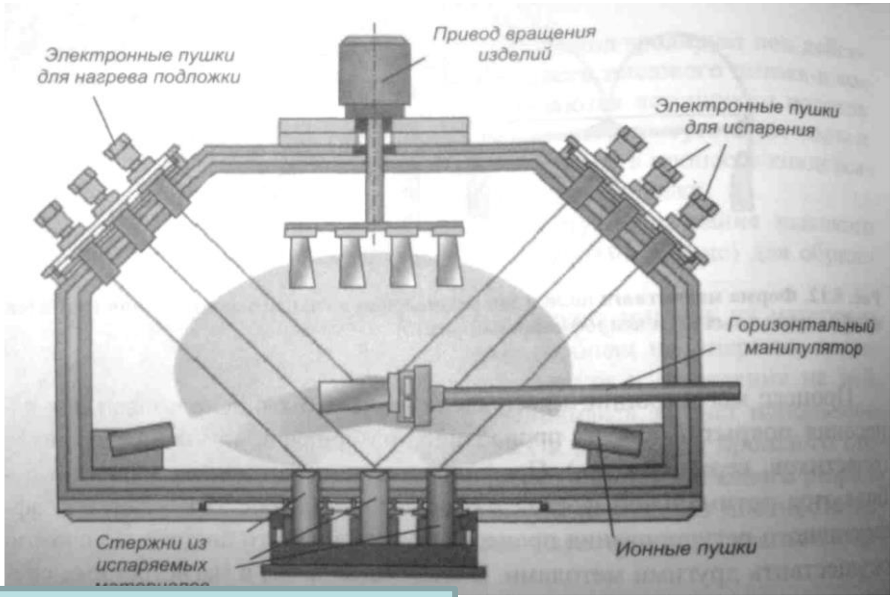


spraying ionized by accelerated particles

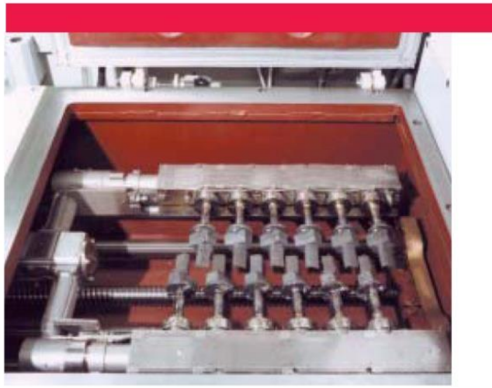
spraying of ionized particles

spraying neutral particles (atoms, molecules) with their different energy state

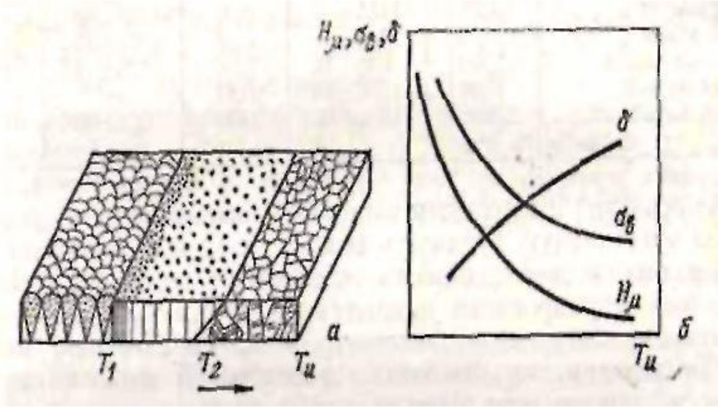
Thermal evaporation of solid material

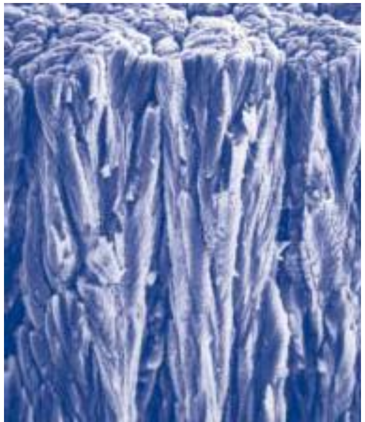


давление не ниже **8,75 • 10^{-3}** Па

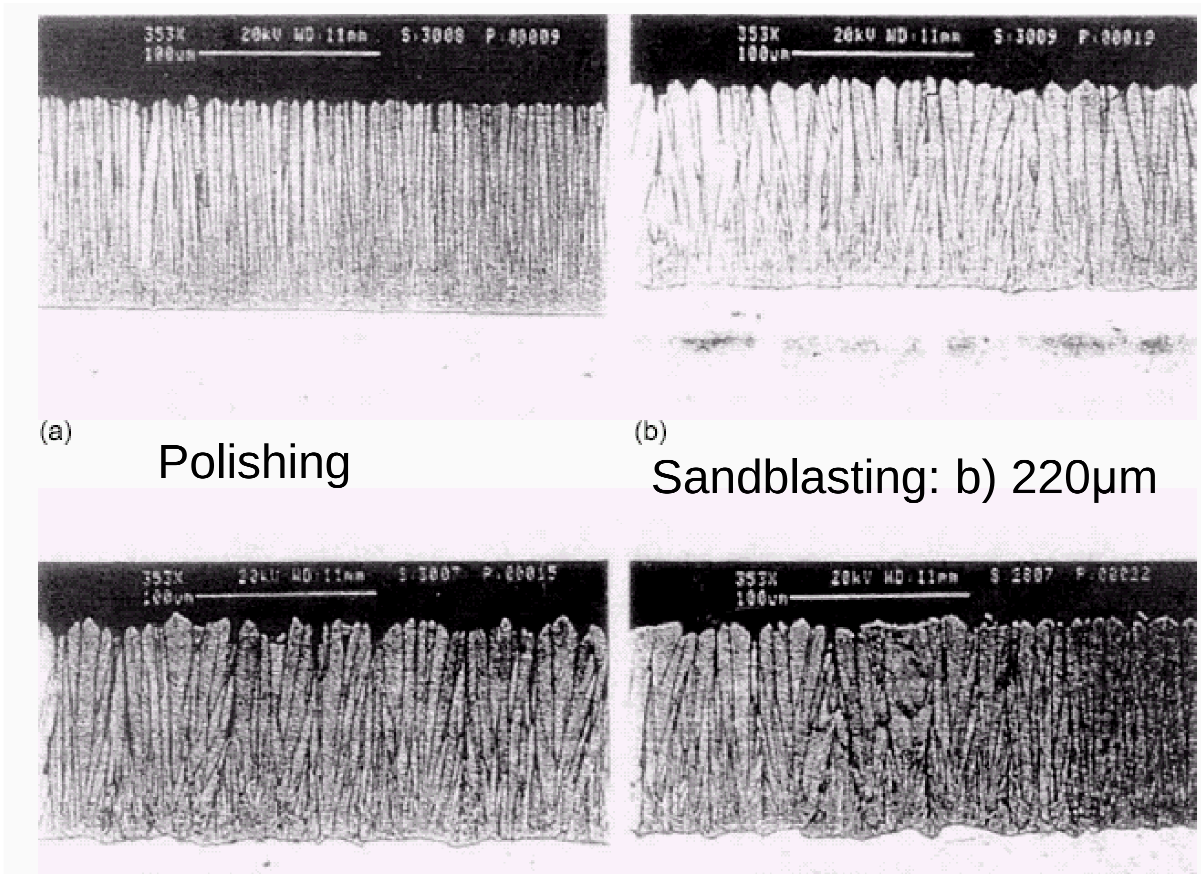


Loading chamber of an EB/PVD system





Influence of surface roughness on the oundations of the microstructure EB-PVD TBC



Polishing

Sandblasting: b) 220µm

Sandblasting:

c) 80 µm

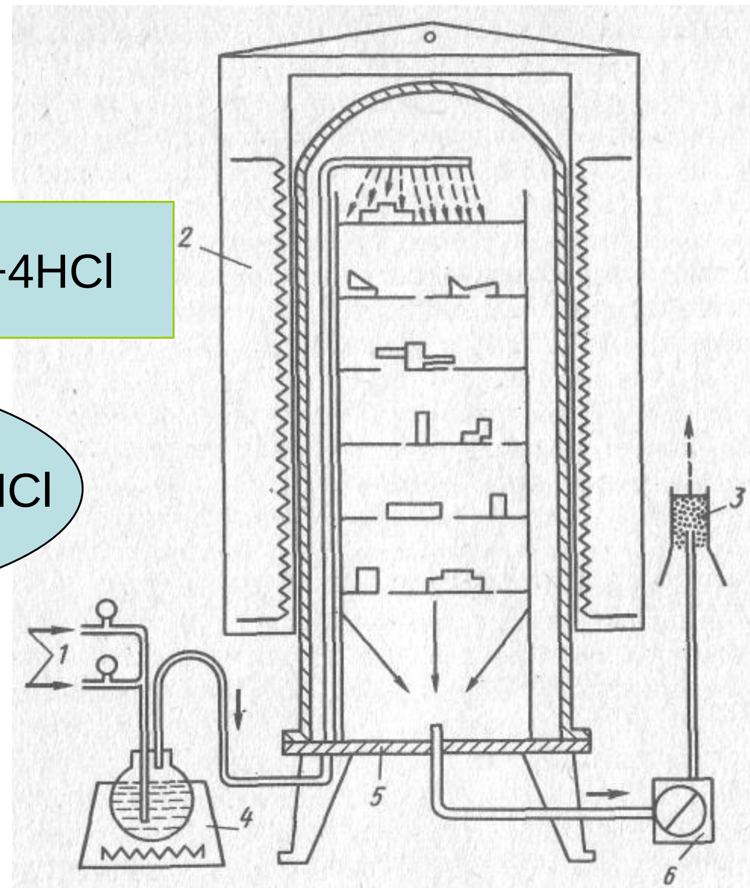
d) 54. µm

CVD Method

650-1700^{0}C

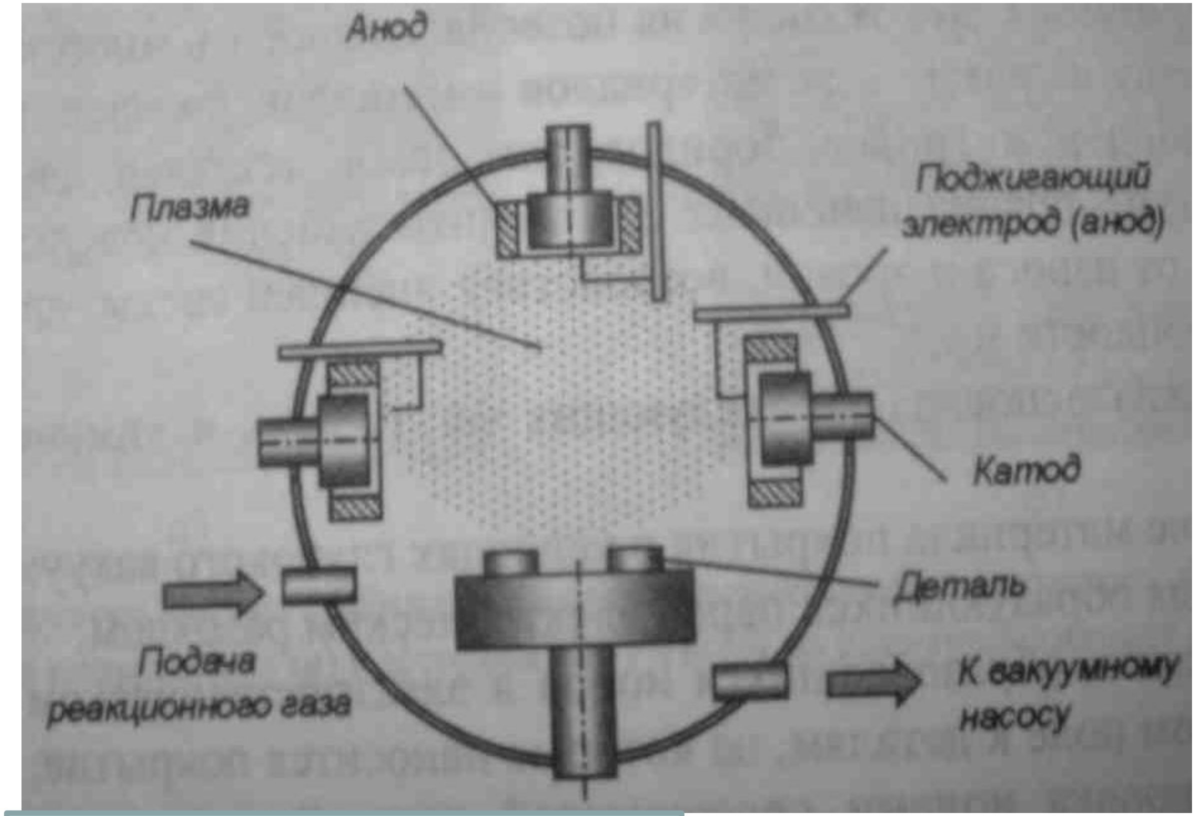
$TiCl_4 + 1/2N_2 + 2H_2 = TiN + 4HCl$

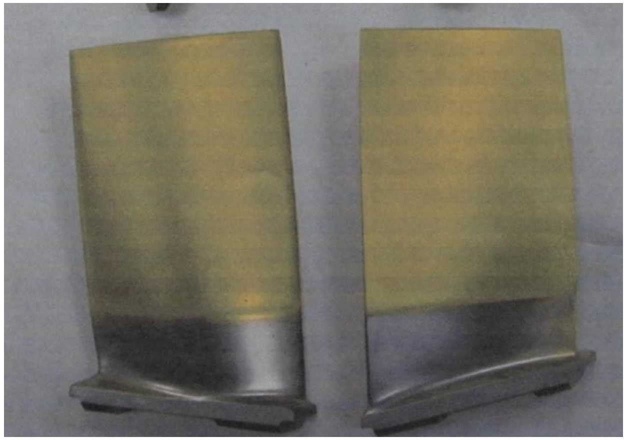
$TiCl_4 + CH_4 + H_2 \rightarrow TiC + 4HCl$



1 – gas; 2 - furnace; 3 - filter; 4 - evaporator; 5 - reactor; 6 pump

Arc evaporation-spraying

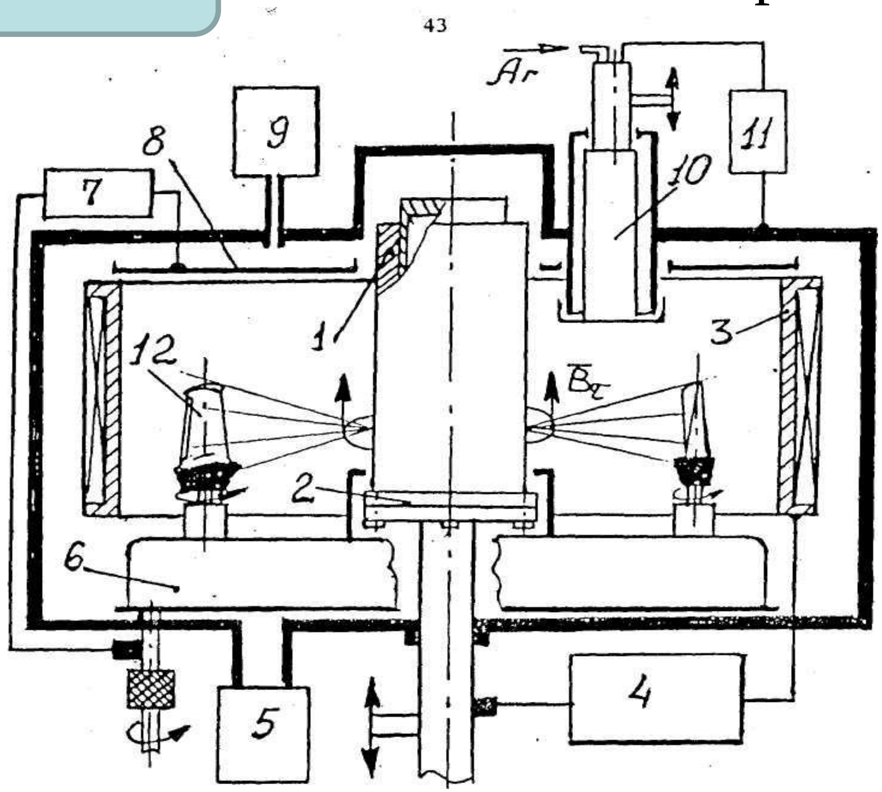




P= 10^{-3} Па

«ВИАМ»

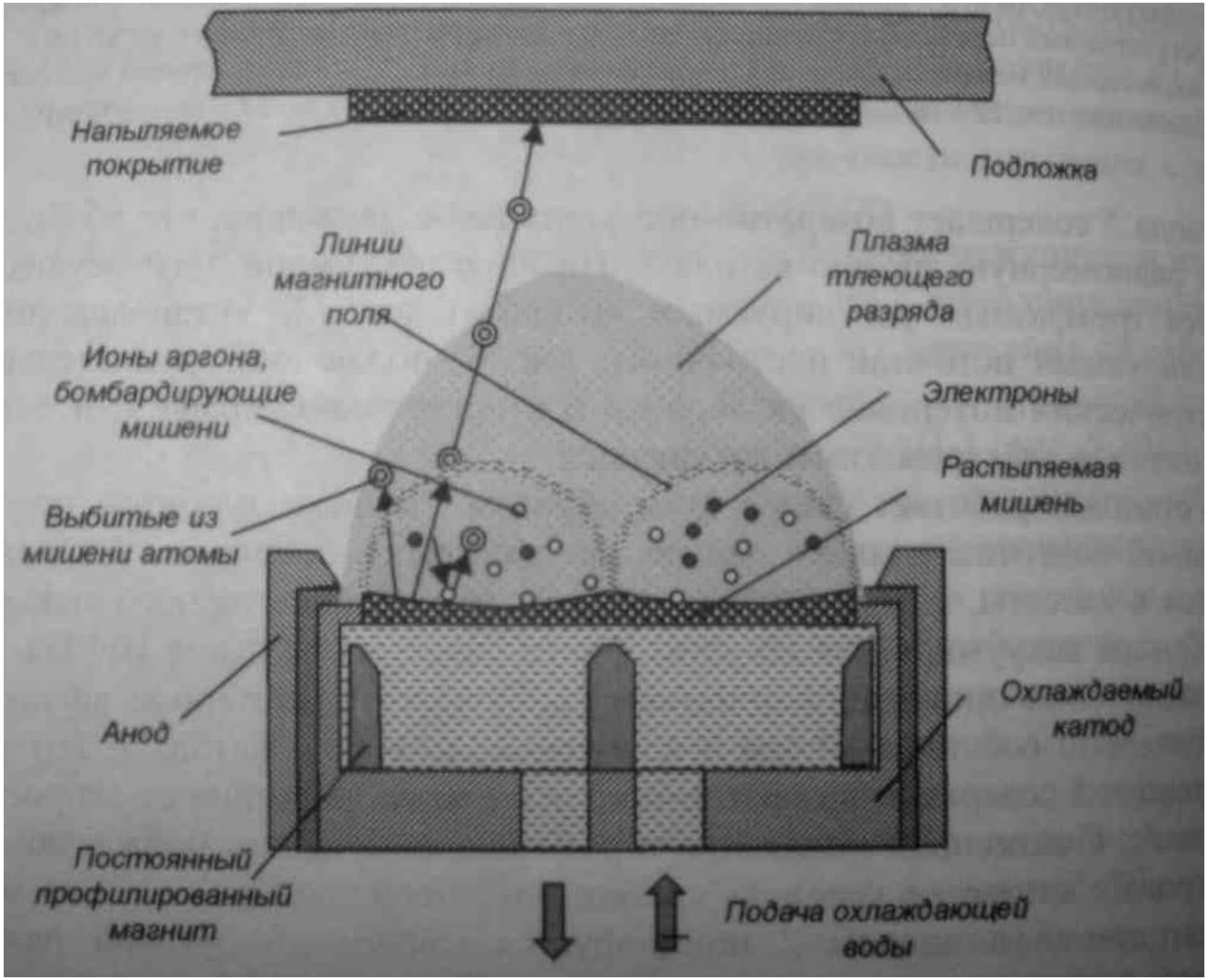
SCHEME of ion-plasma unit MAP-1M

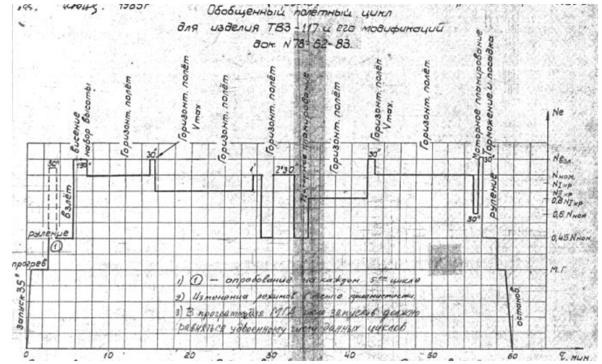


Application area
HP compressor blades of GTE
GTE turbine rotor blades
Cutting tool
Dentures
Cutlery, Jewelry Materials:
Alloys and compounds (Ni-Al, TiN)

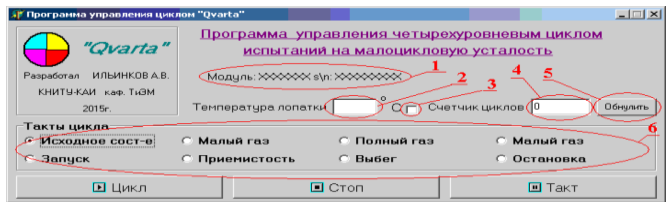
1 CATHODE
2- mandrel CATHODE
3- ANOD
4 POWER GENERATOR PLASMA
5- pumping system VACUUM
6- DRIVE PLANETARY ROTATION
7 POWER SUPPLY FOR BUILDING PRODUCTS OTRICHATELNOGO
8- reference electrode
9 SUPPLY reactive gas
10 gas-discharge ion source with an anode layer
11- HIGH VOLTAGE POWER SUPPLY
12 ITEMS COVERED

Magnetron spraying device

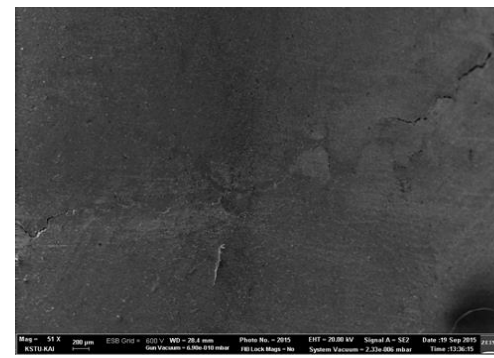


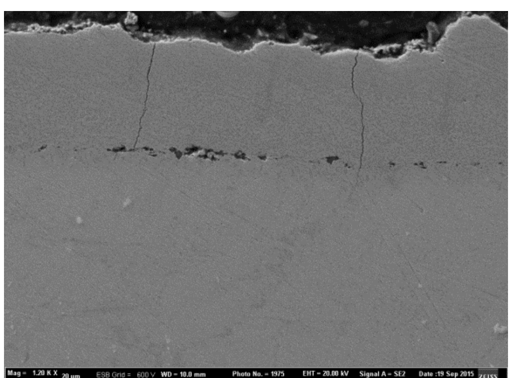


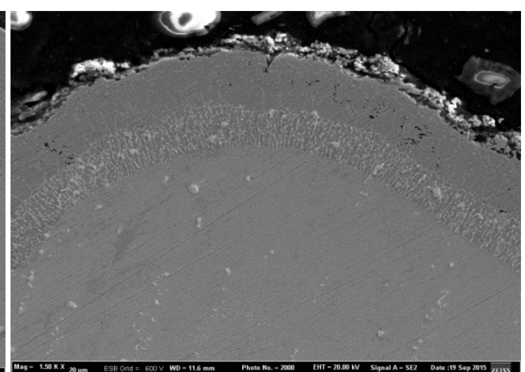
Обобщенный полётный цикл
для изделия ТВ3-117 и его модификаций



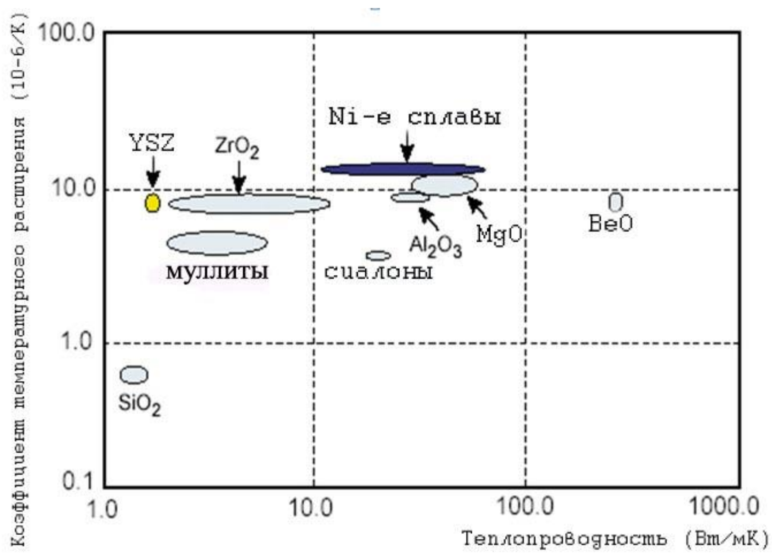
Программа управления циклом "Qvarta"
"Qvarta"
Разработал ИЛЬИНКОВ А.В.
КНИТУ-КАИ каф. ТиЭМ
2015г.
Программа управления четырехуровневым циклом
испытаний на малоцикловую усталость
1
2
3
4
5
6
Температура лопатки
С
Счетчик циклов
0
Обнулить
Такты цикла
Исходное сост-е
Малый газ
Полный газ
Малый газ
Запуск
Приемистость
Выбег
Остановка
Цикл
Стоп
Такт

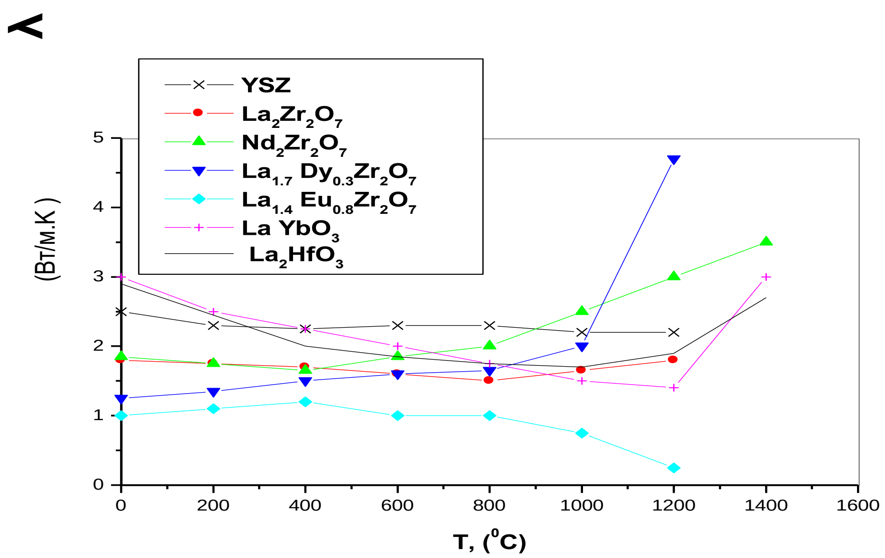


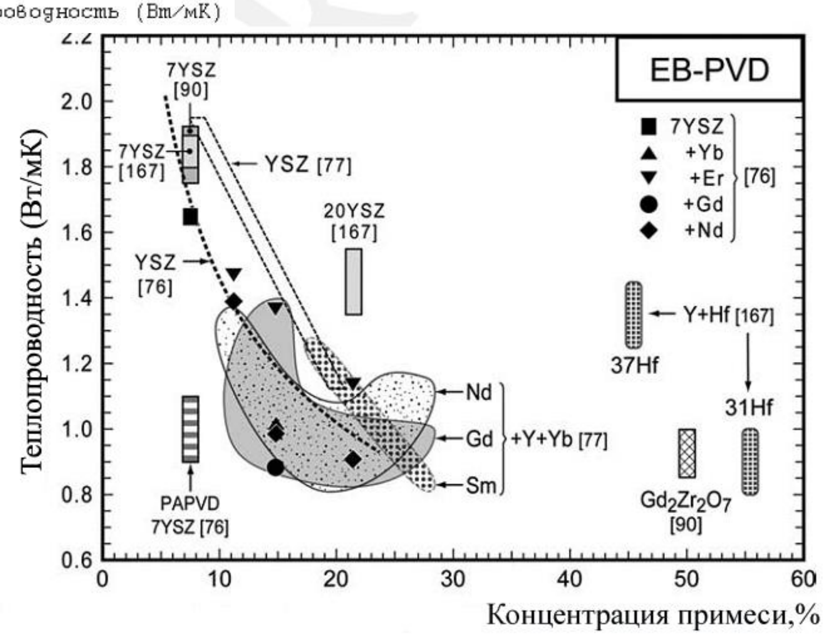




Materials with low thermal

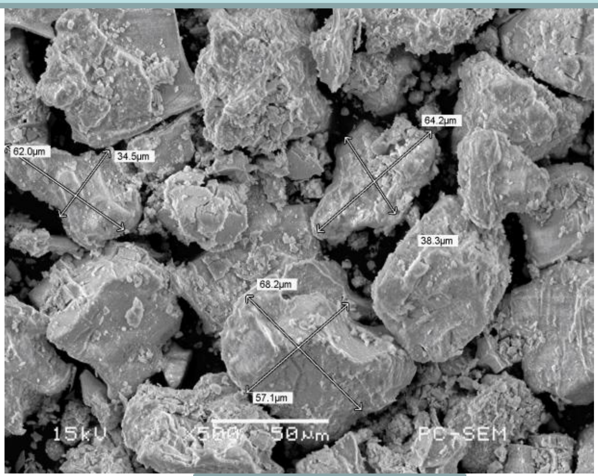






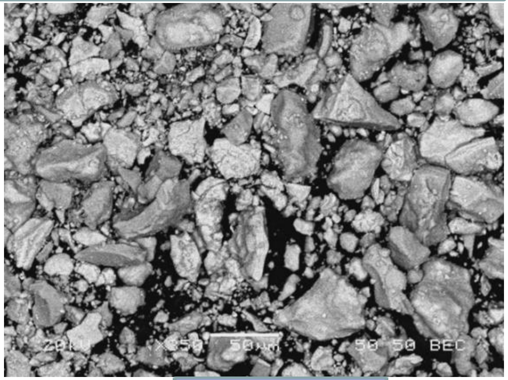
conglomeration

Solid-phase process



ZrO_2 - 8% Y_2O_3 (8YSZ)

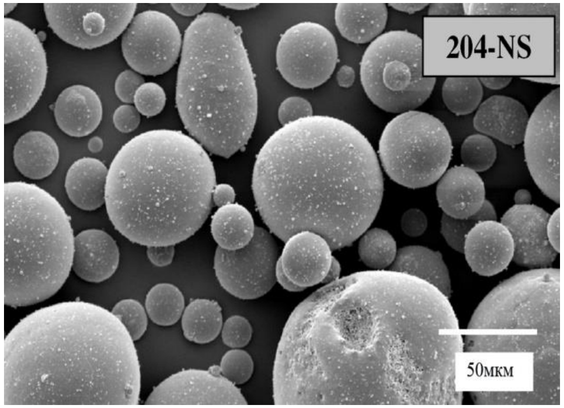
The liquid-phase process

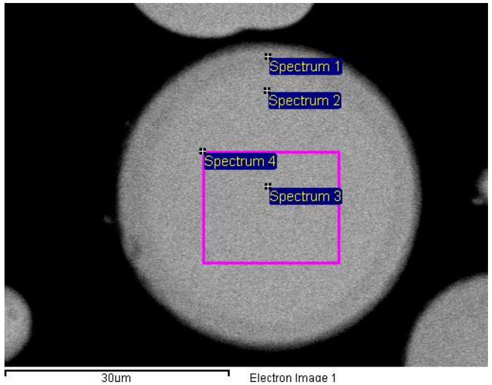


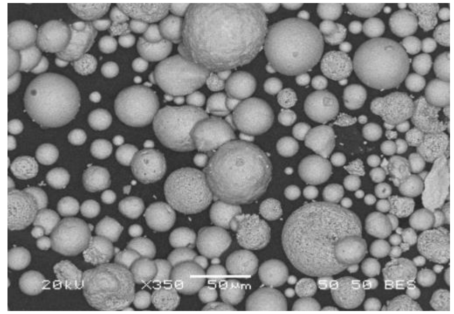
BK25M

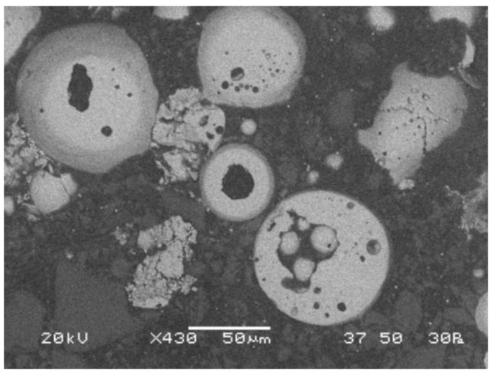
Disadvantages:
- The duration of the process;
- Chemical heterogeneity and grading

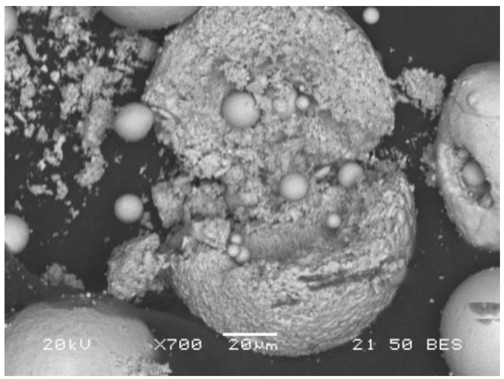
Spheroidal Spray Dried

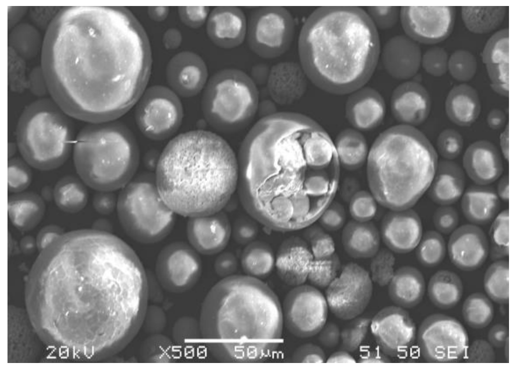




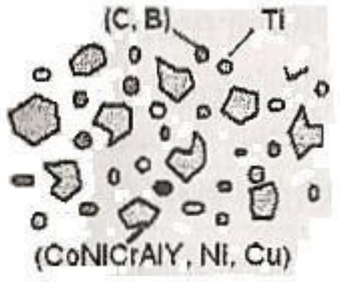




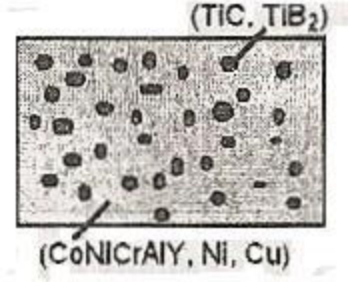




Hollow – процесс создания композиционных порошков для напыления покрытий

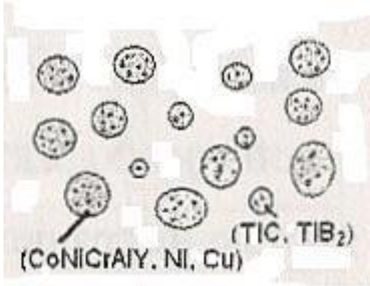


Мехактивация в планетарной центробежной мельнице



Проведение СВС - реакции

Дробление композита



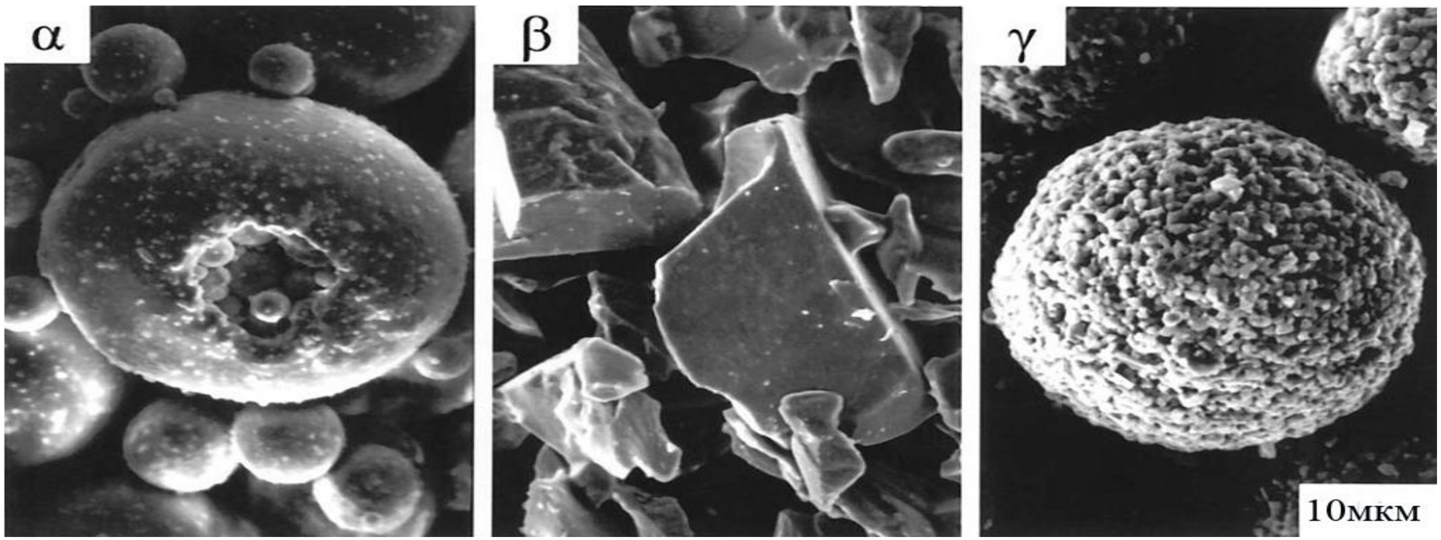
Модифицирование

Результат процессов: интенсивная поверхностная сорбция рабочего газа на поверхности частиц исходных порошков и его замешиване в агрегируемые частицы при дальнейшей обработке.

Плазменная обработка частиц модифицированных частиц CoNiCrAlY

Результат процесса: формирование полых сферических капель. Формирование сплэтов при соударении таких капель с основой обеспечивает плотную границу раздела «покрытие – основа» и, соответственно, высокие функциональные характеристики покрытий.

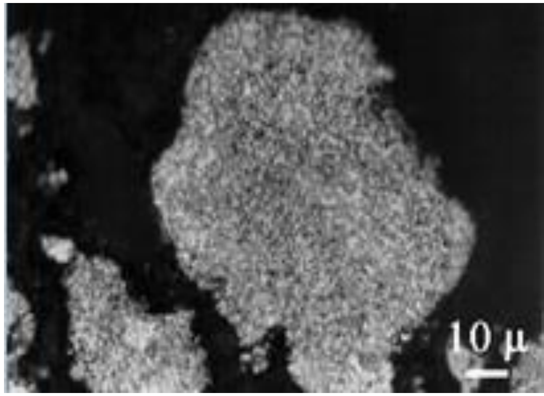
Форма и текучесть порошков различных способах получения



α-полая сфера(плазменный метод);
β- осколочная(сплавление и размол);
γ- сферическая(конгломерирование)
Δ- монолитная сферическая(золь-гель процесс

Текучесть порошков:
α- 34 с
β- 40 с
γ- 40 с
Δ- 22 с

SVS method

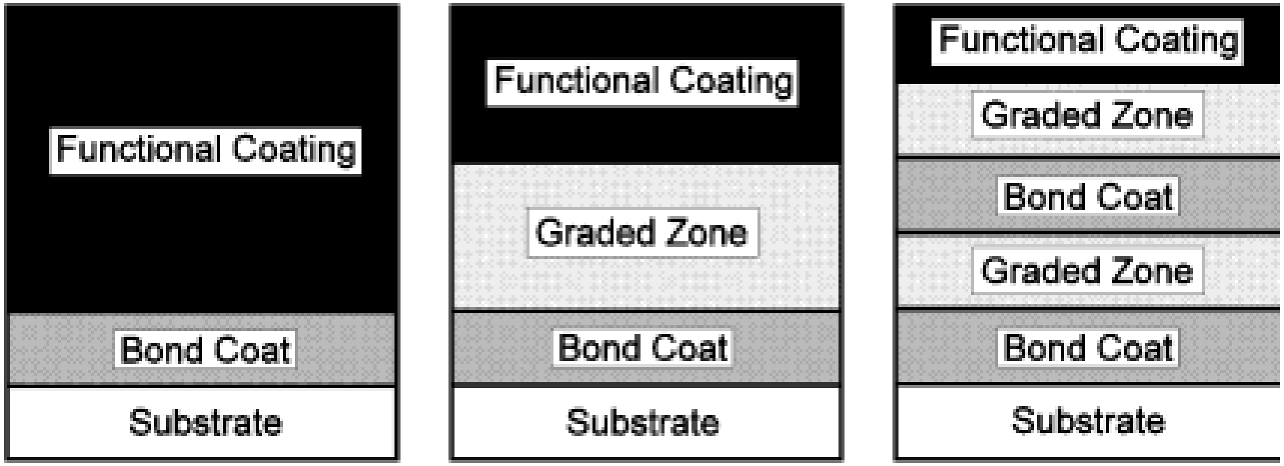


Process scheme:
SHS synthesis - grinding - classification by fractions

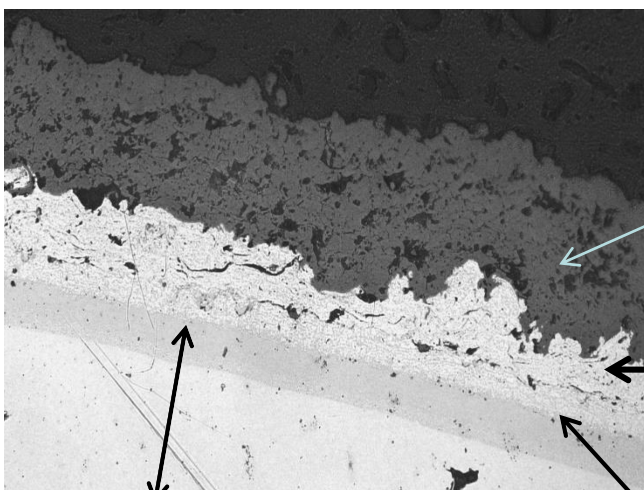
- Composite powders of type
- "Metal alloy / refractory compound"
- metal alloys:
- The iron-based - Fe, FeCr;
- nickel-based - Ni20Cr, Ni40Cr, NiCrAl;
- based on aluminum - Al, Al12Si;
- intermetallic compounds - NixAly, FexAly, TixNiy;
- refractory compounds:
- carbide - TiC, Cr3C2, Cr7C3, SiCP and combinations there of.

Advantages of the method:
thin solid volume distribution (grain size refractory components 0.5-10 microns);
high cohesive strength of the composite;
the constancy of the phase composition of the powder and coating;
CMMs increase by 10-30%;
uniform distribution of solids in the coating amount.

Combined technologies



The blades of the turbine section of the nozzle,
Rotor blades 1 and 2 stages



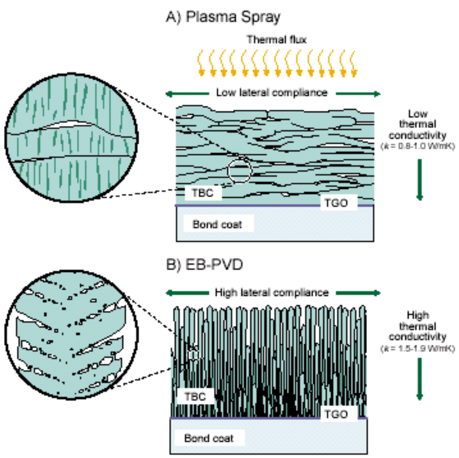
APS
YSZ

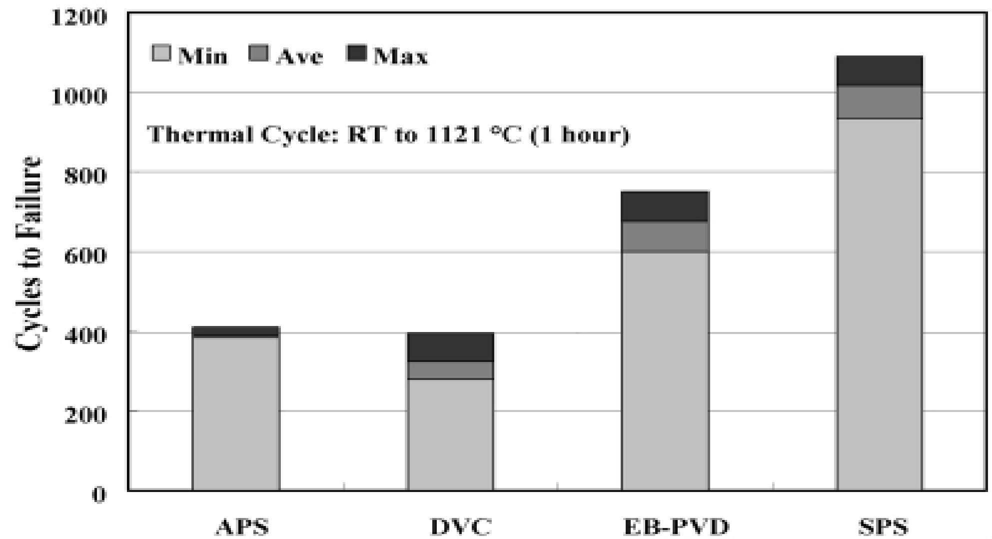
APS of bond coat
NiCoCrAlY

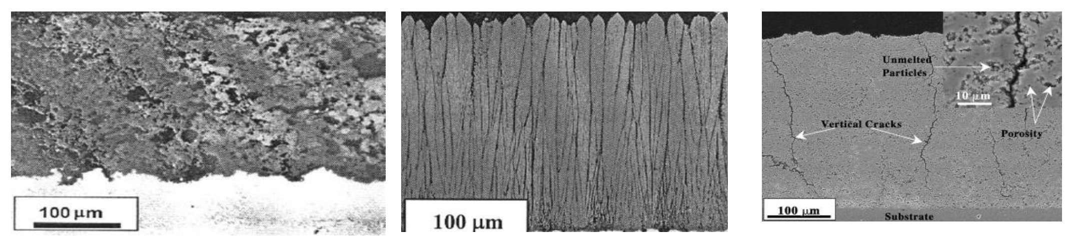
Ионно-плазменное напыление
NiCoCrAlY
(ВСДП-16)

Powder aluminizing

Methods for producing a ceramic layer thermal barrier coatings







Termal tests