Lithuanian Energy Institute

http://www.lei.lt

3 Breslaujos,

LT – 44403 Kaunas,

Lithuania

Lithuanian Energy Institute

Institute was founded in 1956
as the Institute of Energy and Power Engineering
of the Lithuanian Academy of Sciences.

In 1967-1991 it became known among local and foreign scientific society interested in fundamental research in hydrodynamics, thermal physics, material science, simulation and control of power supply systems, hydrology as the Institute for Physical and Engineering Problems of Energy Research.

In January 1992 the Government of Republic of Lithuania granted the state science institution status to the institute which became independent from the Academy of Sciences and was named the Lithuanian Energy Institute.

Lithuanian Energy Institute

INSTITUTE is a state scientific research institution, certificated on ISO 9001:2000 – quality management system

CERTIFICATE OF COMPLIANCE

Sert

CERTIFICATION DIVISION

LITHUANIAN STANDARDS BOARD
UNDER THE MINISTRY OF ENVIRONMENT
OF THE REPUBLIC OF LITHUANIA

This is to certify
that the Quality Management System of

LIETUVOS ENERGETIKOS INSTITUTAS

LIETUVOS ENERGETIKOS INSTITUTAS

Breslaujos g. 3, LT-44403 Kaunas Lithuania (Lietuva)

has been assessed
and found to be in compliance
with the following quality standard

LST EN ISO 9001:2001

The Quality Management System is applicable to:

SCIENTIFIC RESEARCH, APPLIED RESEARCH, DESIGN AND EXPERIMENTAL DEVELOPMENT ACTIVITIES IN THE FIELD OF TECHNOLOGICAL, SOCIAL AND PHYSICAL SCIENCES*

The compliance was assessed during the initial assessment
(Report number 2002-018-1)
Quality Management System has been certified since 2004-02-17
LST Sert will regularly undertake inspections
and grants recognition for the period

2004-02-17 - 2007-02-17

Certificate number 9000-046

VILNIUS, 2004-02-17

LST Sert
T. Kosciuškos g. 30, LT-01100 Vilnius, Lithuania (Lietuva)

*Further clarifications regarding the scope of this certificate
and the applicability of LST EN ISO 9001:2001 requirements may be obtained by consulting the organization

SCIENTIFIC RESEARCH ACTIVITY OF THE INSTITUTE

- **Research in the fields of thermal physics, fluid and gas dynamics, and metrology;**
- **Materials, processes and technologies research for the management of renewable energy sources, hydrogen energy, effective use of energy resources and reduction of environmental pollution;**
- **Safety and reliability of nuclear, thermonuclear energy and other industrial objects;**
- **Radioactive waste management and decommissioning of the Ignalina Nuclear Power Plant;**
- **Modeling and control of energy systems; energy economy**

- **PART 1. PLASMA PROCESSING LABORATORY OF LITHUANIAN ENERGY INSTITUTE**

- **PART 2. PLASMA SYNTHESIS, CHARACTERIZATION AND CATALYTICALLY EVALUATION OF HARD OXIDE CATALYSTS FOR CO, NOX REDUCTION OF COMBUSTION GASES**

PLASMA PROCESSING LABORATORY OF LITHUANIAN ENERGY INSTITUTE

Plasma processing laboratory was founded in 1968

The stuf of laboratory:

Senior research associate -	**7**
Research associate –	**1**
Junior research associate -	**2**
PhD studentt -	**1**
Engineer -	**1**
Technician -	**2**

PLASMA PROCESSING LABORATORY OF LITHUANIAN ENERGY INSTITUTE

Main research areas:

- **Research and development of plasma torches and arc-plasma reactors,**
- **Heat and mass transfer at high temperature gas flow in tubes, channels and plasma chemical reactors**
- **Ceramic coatings for advanced applications;**
- **DLC and carbon coatings for surface modification**
- **Research and implementation of plasma neutralization process of hazardous substances;**
- **Generation of water vapour plasma and its application for fuel conversion and neutralization of hazardous waste.**
- **Catalytic coatings for CO and NOx reduction in exhaust gases;**
- **Plasma processing of high temperature resistance mineral fibre from local raw materials and waste**

EXPERIENCE AND RESOURCES OF LABORATORY

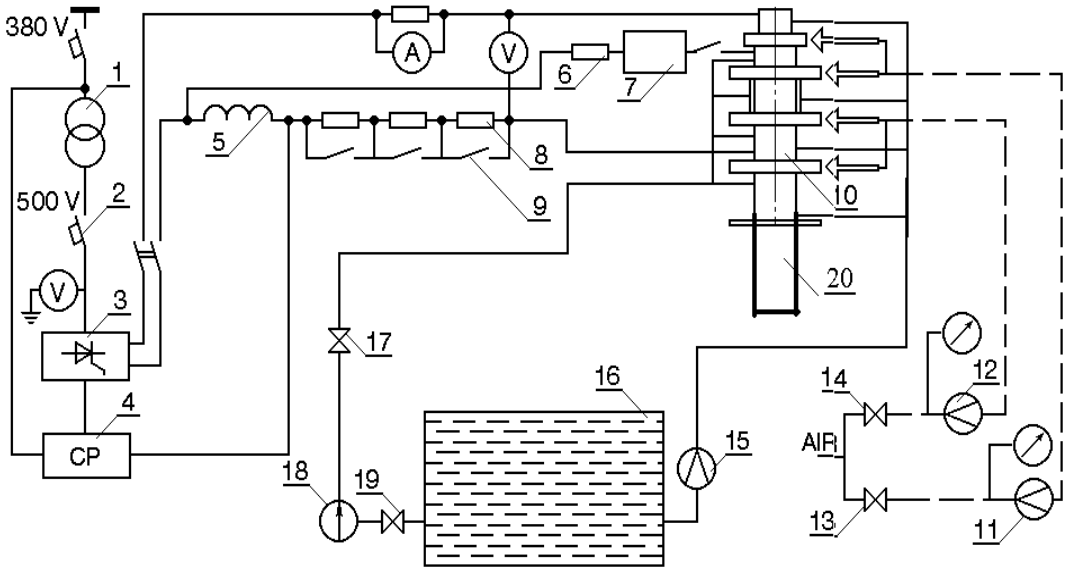
- DC plazma torches (30 – 300 kW) and supplying equipment
- Equipment for coating technology
- Equipment for hard ceramic processing
- Equipment for $CO/CO_2/C_3H_8/NO/NO_2/SO_2//H$ analyze
- Cooled Langmuir probe for electron/ion densities, temperature and floating potential measurements in plasma jet
- Cooled Pitot probe for local plasma jet temperature and velocity measurements
- Equipment for measurement of specific surface area of a material (BET method)
- High speed camera for plasma jet visualization (650 000 fps)

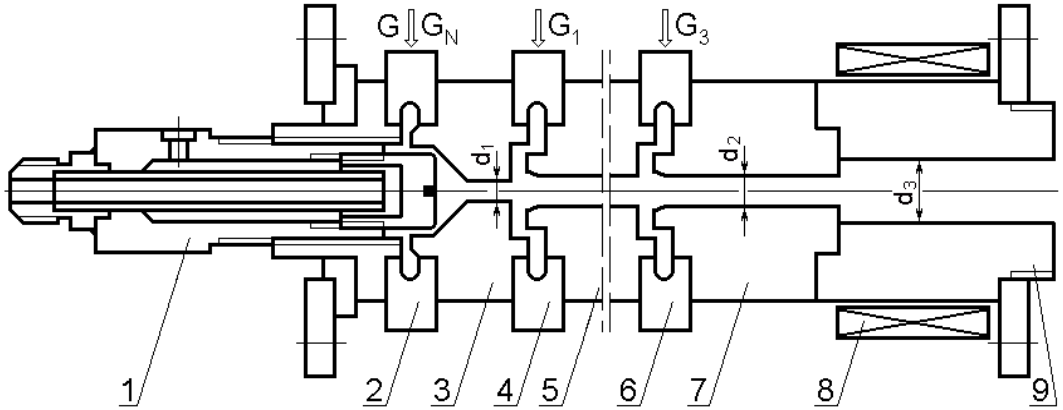
MAIN RESEARCH AREAS:

- Research and development of plasma torches and arc-plasma reactors,

The experimental equipment consists of these main systems: electricity supplies (3), plasma torch (10), a stream reactor with a processing chamber (20), gas supply and monitoring system (11-14), cooling system (15,16) and operation control and data monitoring system (4-8). Continual data monitoring of operating plasma torch allows the test bench functioning.

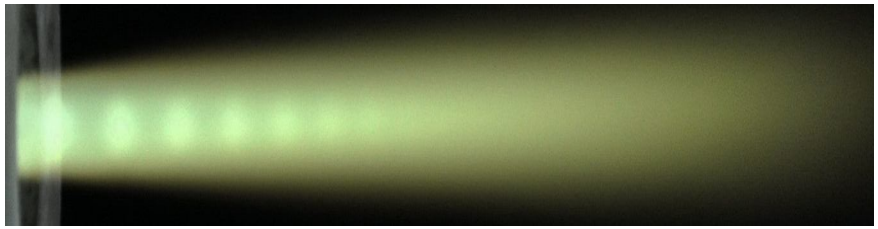
Plasma torch power	**30 - 300 kW (3 MW)**
Total gas flow rate	**0, 5 – 30 g/s (150)**
Temperature	**1000 – 4000 K**
Velocity	**100 – 1500 m/s**
Gas	**air , nitrogen**

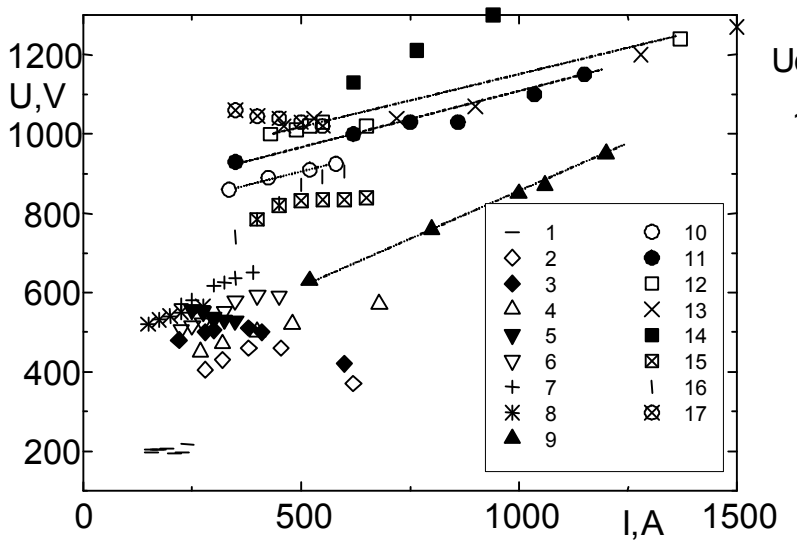




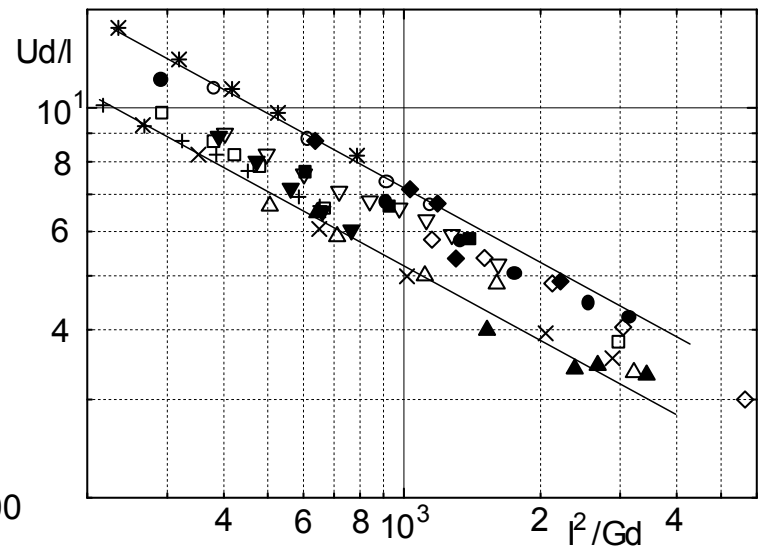
A schematic representation of linear single-chamber plasma torch with intermediate neutral sections.

G,GN – air or N2 supply G1 – main air supply,G3 – air supply.

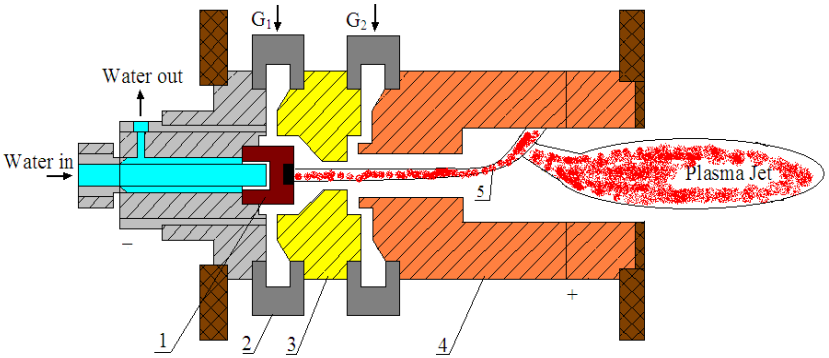




Linear plasma torch VAX



Generalized plasma torch VAX

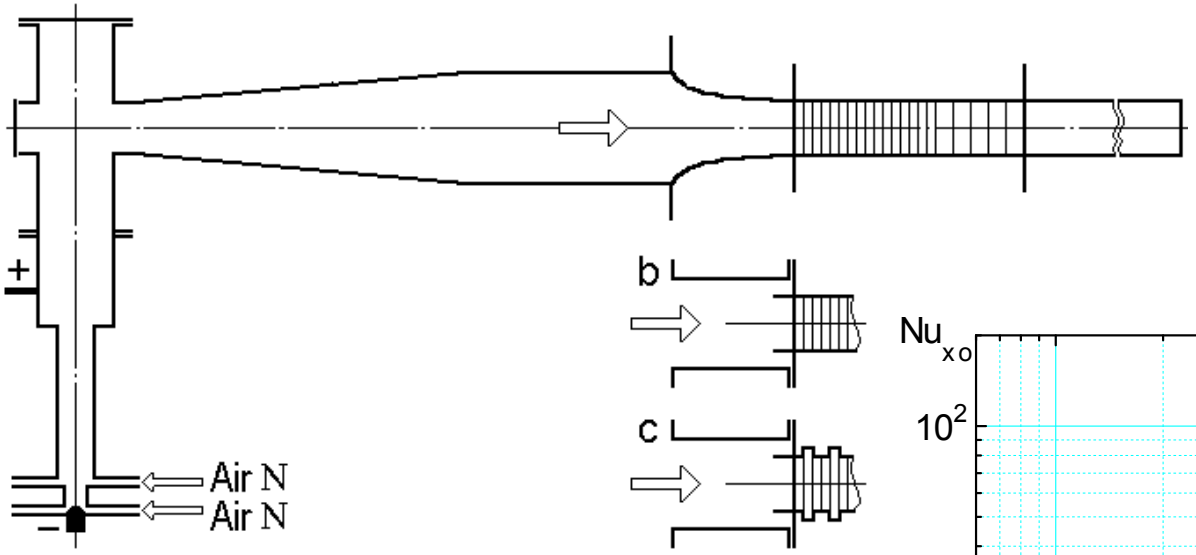


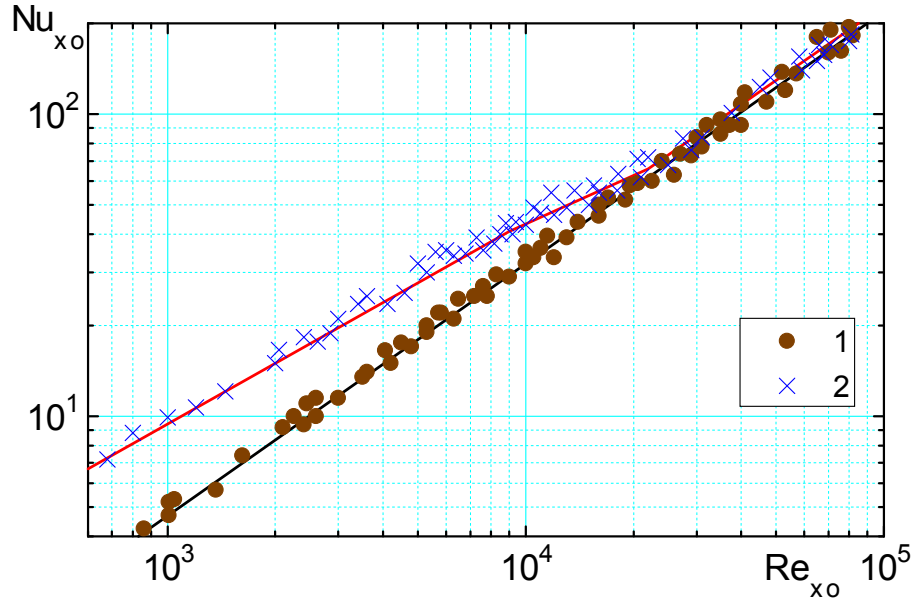
A scheme of water vapour plasma torch. 1 – cathode, 2 – insulating rings, 3 – neutral section, 4 – anode, 5 – electric arc.

Arc current (A)	130 – 210
Arc voltage (V)	230 – 330
Arc power (kW)	30 – 53
Power loss to the cooling water (kW)	8 – 18
Output power (kW)	24 – 36
Plasma torch efficiency, η	0.58 – 0.78
Argon gas flow rate, G_1 (10^{-4} kg · s^{-1})	5.2
Water vapor flow rate, G_2 (10^{-3} kg · s^{-1})	1.48 – 4.48
Total mass flow rate, G (10^{-3} kg · s^{-1})	2 – 5
Mean temperature of plasma jet at the torch outlet nozzle (K)	2300 – 2900
Mean velocity of plasma jet at the torch outlet nozzle (m · s^{-1})	340 – 700

MAIN RESEARCH AREAS:

- **Heat and mass transfer at high temperature gas flow in tubes, channels and plasma chemical reactors**





T = 1000 – 5000 K
Re = 2 • 10 3 – 0, 5 • 10 6

1 – smooth inlet, 2 – sharp inlet

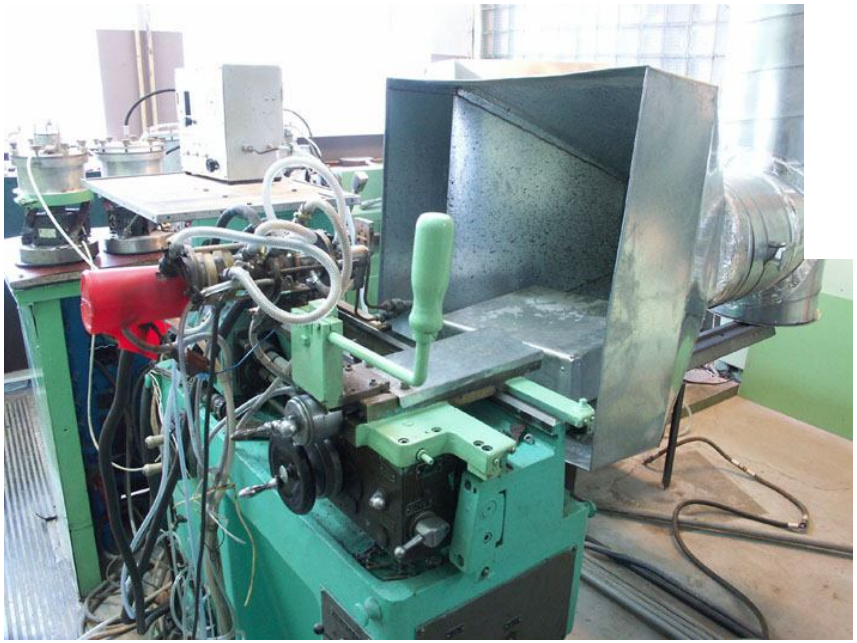
MAIN RESEARCH AREAS:

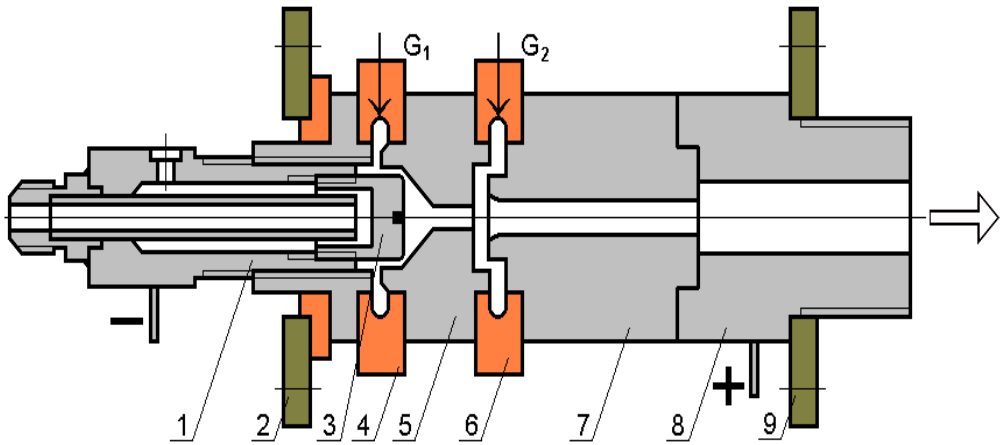
- **Ceramic coatings for advanced applications;**

Plasma spray deposition of thin ceramics layers for:

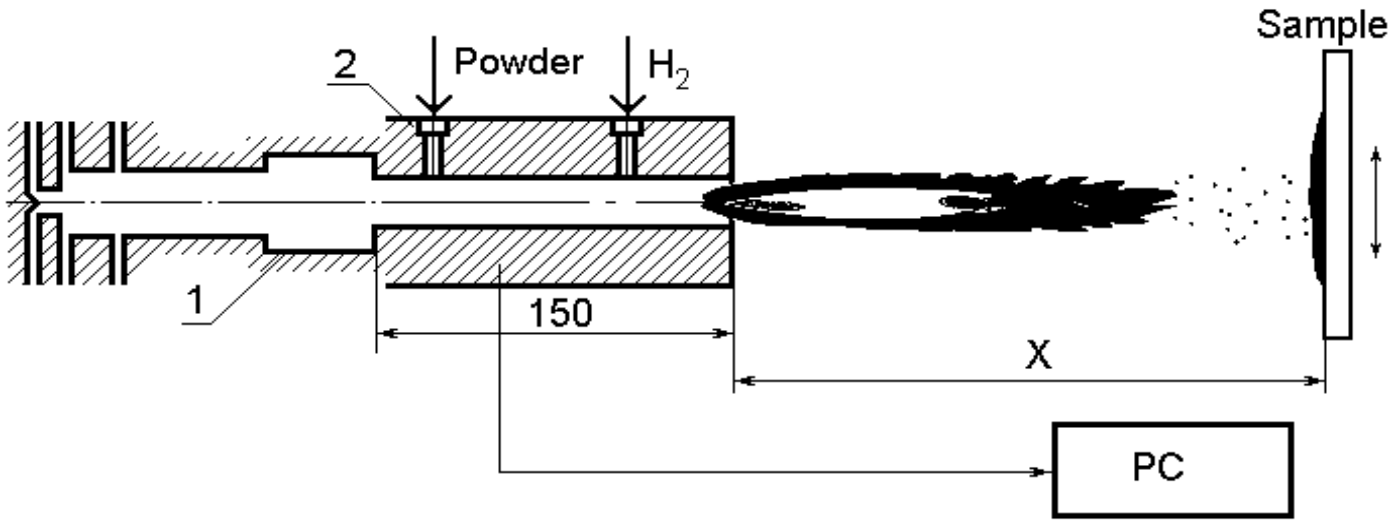
SOFC electrolyte layer - Yttria stabilized zirconia oxide
Hard bio ceramics for prosthetic application - Al, Ti, Zr oxides

Plasma equipment for catalytic and tribology coatings synthesis at atmospheric pressure



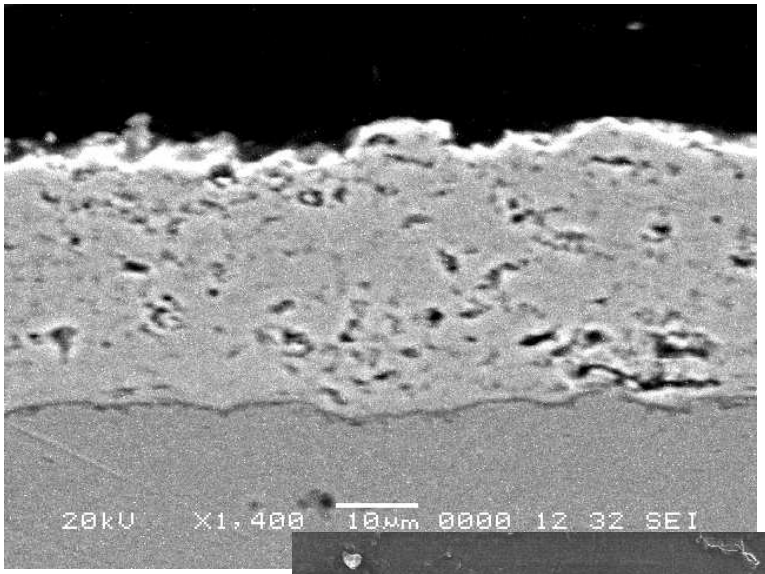


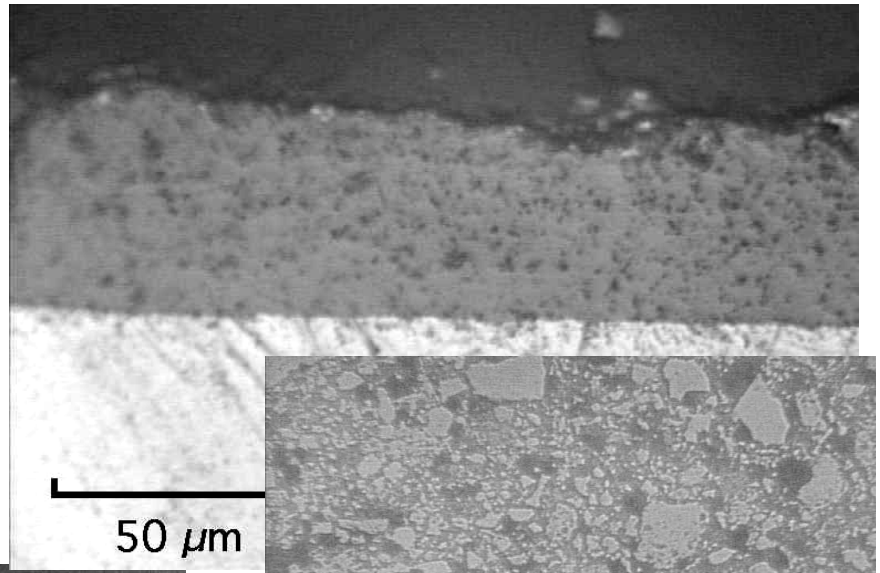
A schematic representation
of linear single-chamber plasma torch.
1 – cathode holder, 2, 9 – flange, 3 – cathode,
4, 6 – insulate and air input rings,
5 – intermediate section, 7, 8 – step-wise anode.

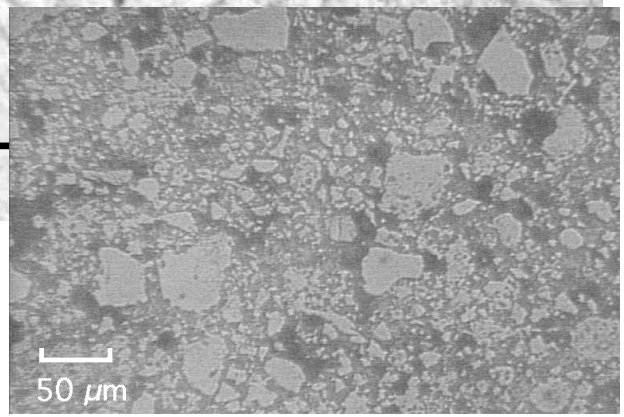


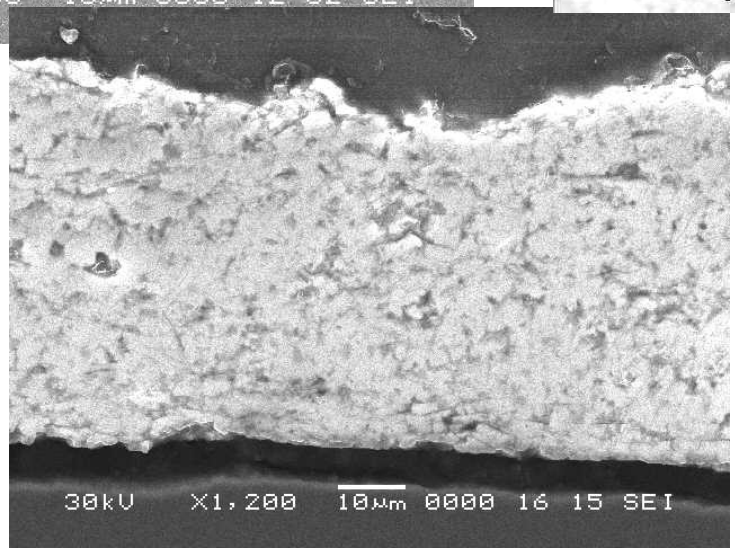
The scheme of experimental set-up: 1 – plasma torch, 2 – reactor,, X – sample location distance

Plasma sprayed ceramics

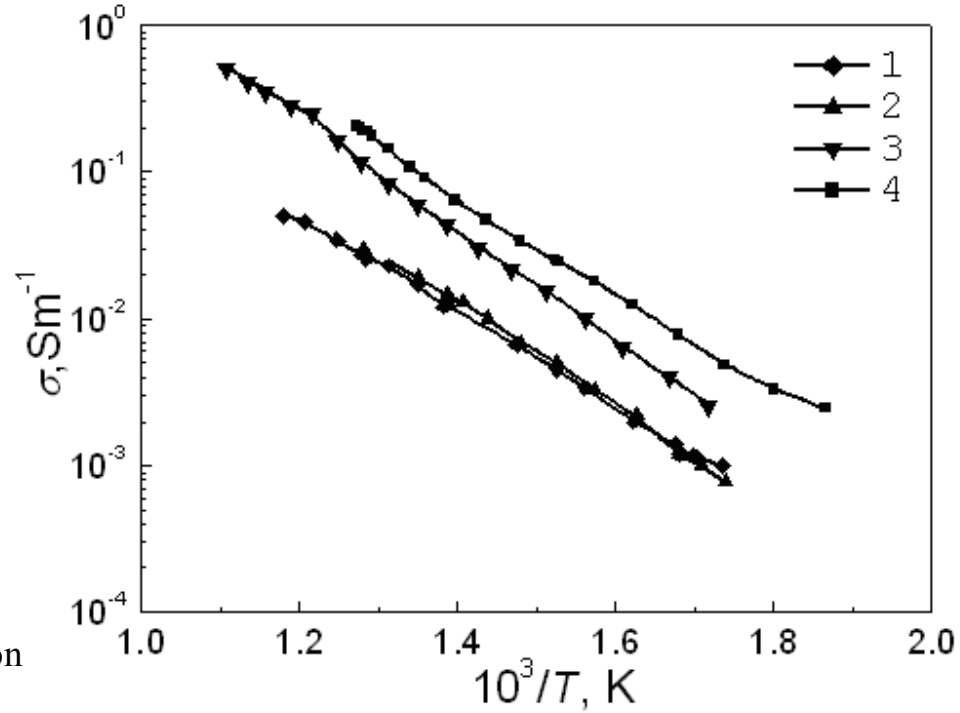








Plasma sprayed Zirconia coatings.
Typical thickness ~50 mm.

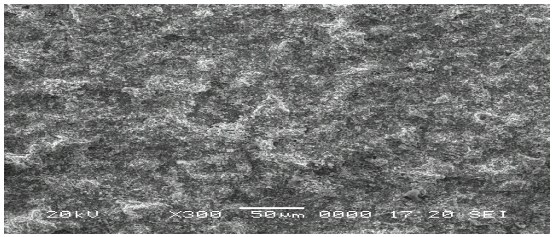


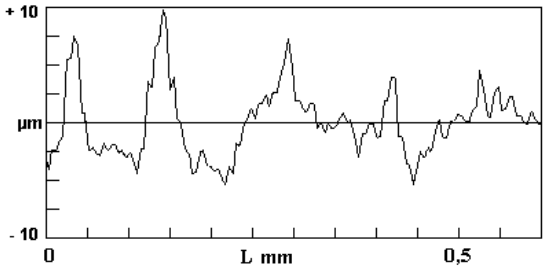
Plasma spraying regimes for YSZ films deposition

Regimes	1	2
Capacity of plasma torch *P*, kW	47,5	47
Total mass flow of air *G*, gs^{-1}	4.73	4.73
Total mass flow of hydrogen *G* (H_2), gs^{-1}	0.1	0.1
Plasma jet temperature *T*, °C	3460	3380
Spray duration *t*, s	30	30
Spray distance *x*, mm	70	70

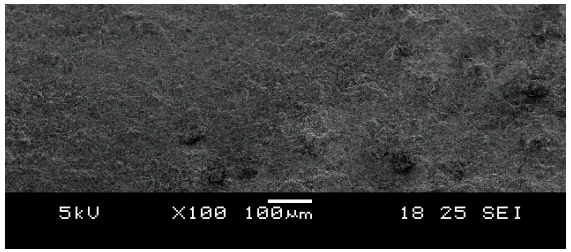
Ionic conductivity of plasma sprayed YSZ

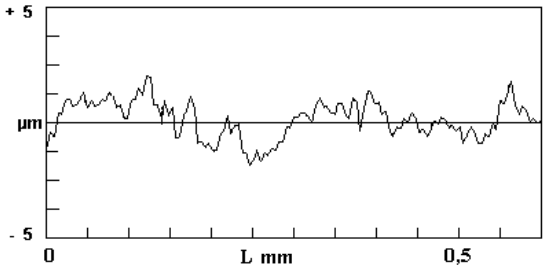
Tribological characteristics plasma sprayed ceramics coatings



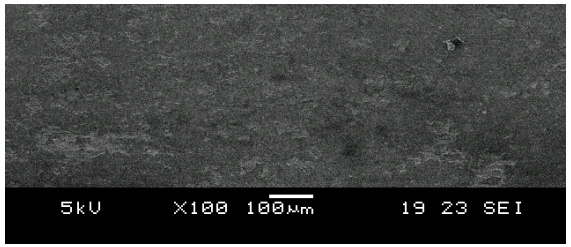


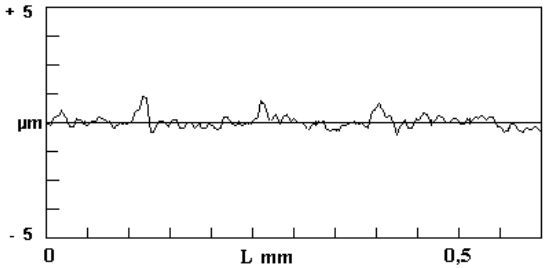
As sprayed





After polishing



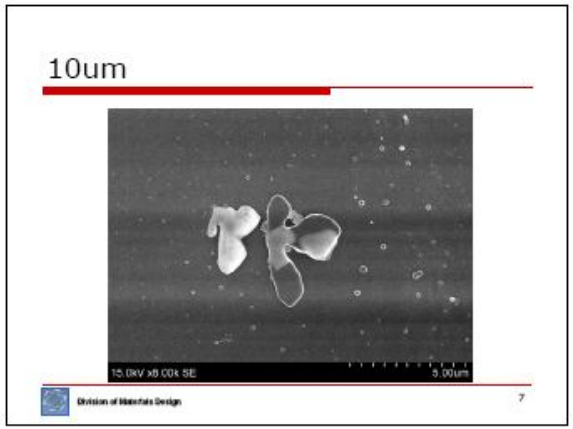


After wear test

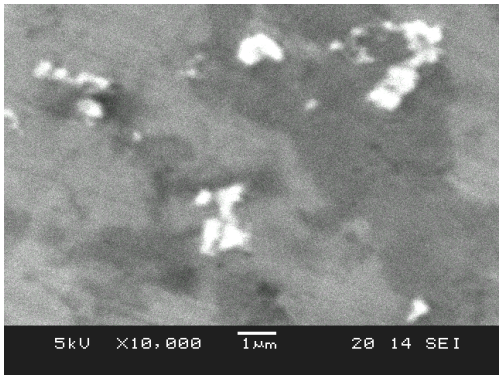
Average surface roughness parameters and Vickers micro hardness value of plasma sprayed zirconias

Parameter	Plasma sprayed coatings				
	ZA5	ZA15	ZA20	ZA85	Z100
Ra (µm)	1.14	1.36	1.32	0.8	1.14
Rz (µm)	6.0	7.72	6.44	6.0	6.68
Vickers micro hardness, MPa	5220	5740	6658	7250	4669

Wear debris of polyethylene



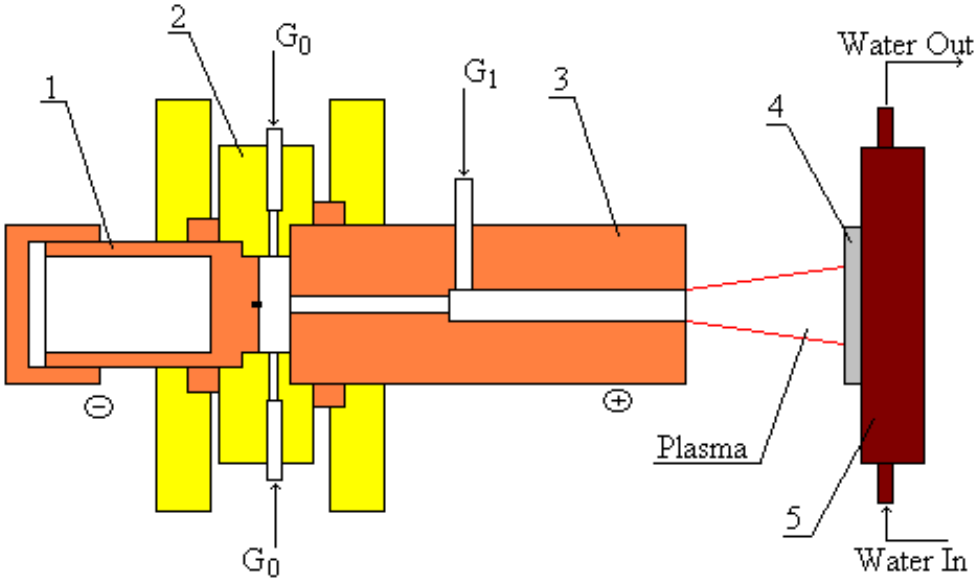
Wear debris of zirconia - alumina coatings under the load of 3 N

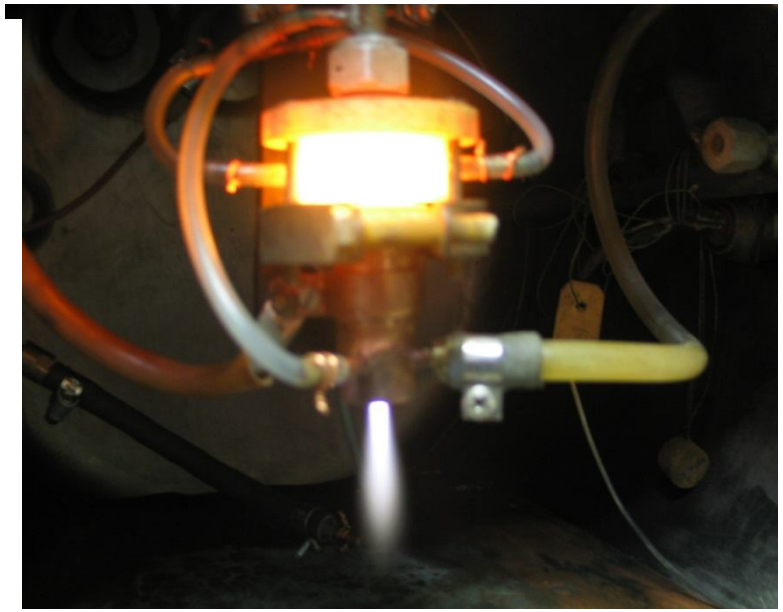


MAIN RESEARCH AREAS:

- **DLC and carbon coatings for surface modification**

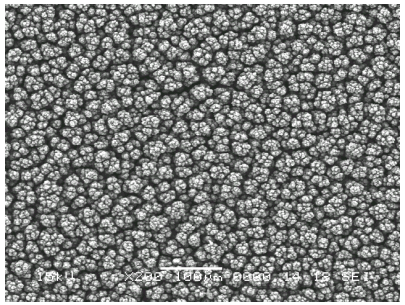
Production of carbon films at reduced (1000 Pa)

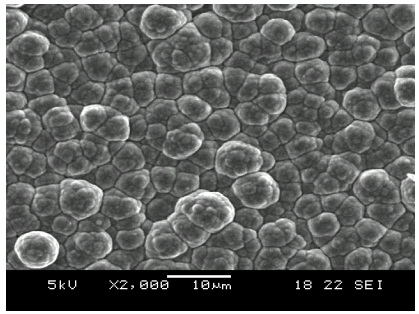


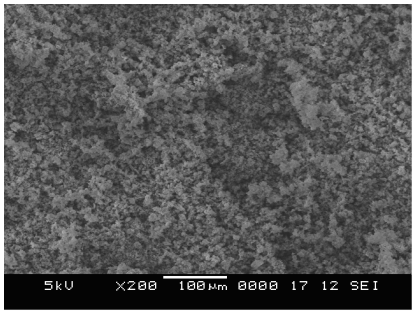


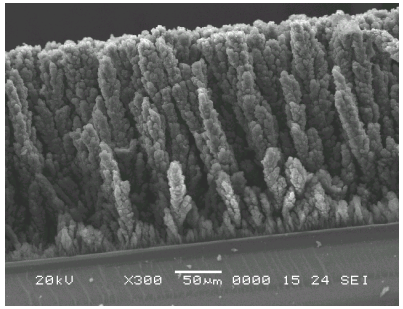
Schematic diagram of the plasma torch: 1-cathode, 2-working gas injecting ring, 3–anode, 4–sample, 5–sample holder, G_0–working gas (Ar, H_2) injection places, G_1 – precursor (C_2H_2) injection place.

Carbon films structure (SEM, Raman and FTIR spectroscopy)

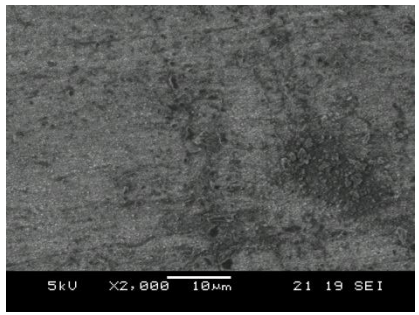




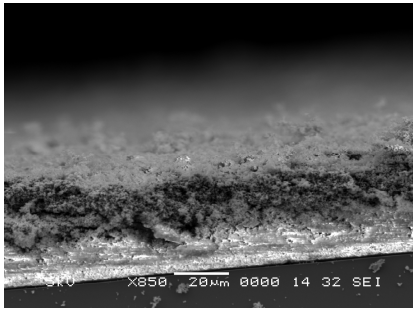




Ar/C_2H_2=60, d=0.005 m



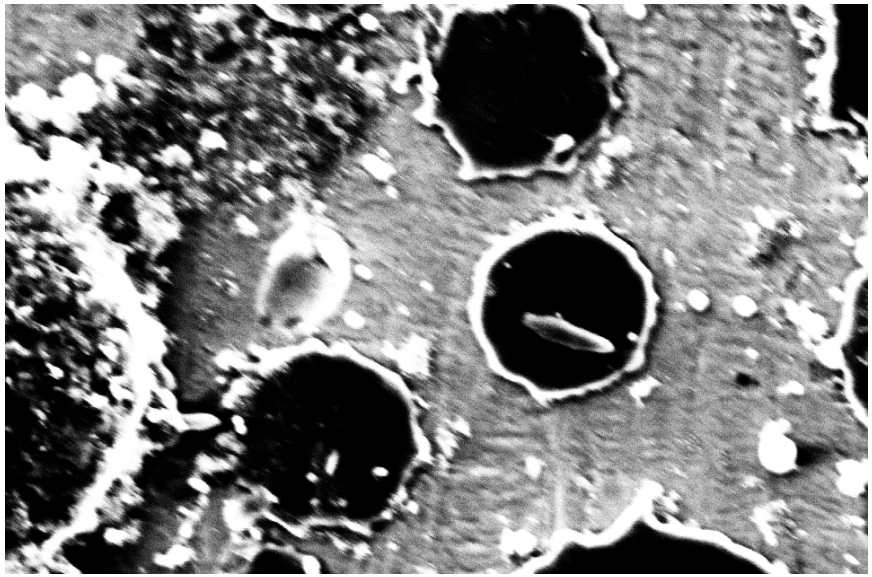
$Ar/H_2/C_2H_2$=60/2/1, d=0.01 m



Ar/C_2H_2=8, d=0.06 m

Thickness of carbon coatings from 0.5 up to 50 µm.
Substrate temperature from 200 up to 1300 ^{o}C.
Substrate material - silicon, steel, and glass.

Production of carbon films at atmospheric pressures from graphite.

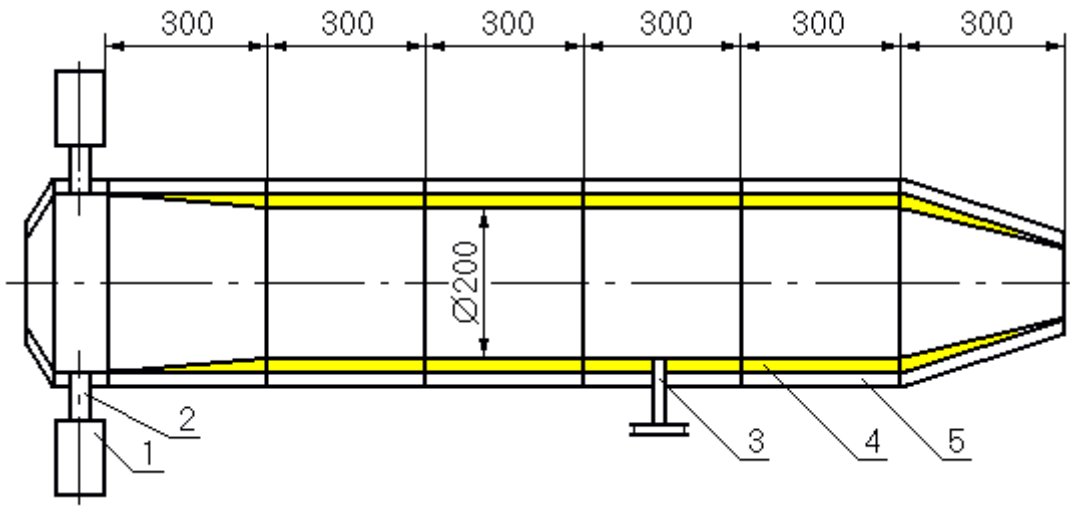


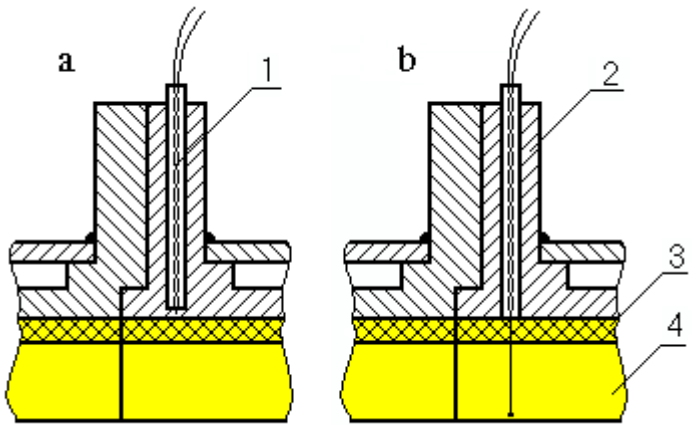
Spray regime	
P, kW	30.8
G, g/s^{-1}	5.03
v, m/s	818
T, ºC	2264
Spray distance, mm	70
Spray duration, s	20

Thickness of carbon coatings from 10 up to 1000 µm.
Substrate temperature from 50 - 70 oC.
Substrate material - steel.

MAIN RESEARCH AREAS:

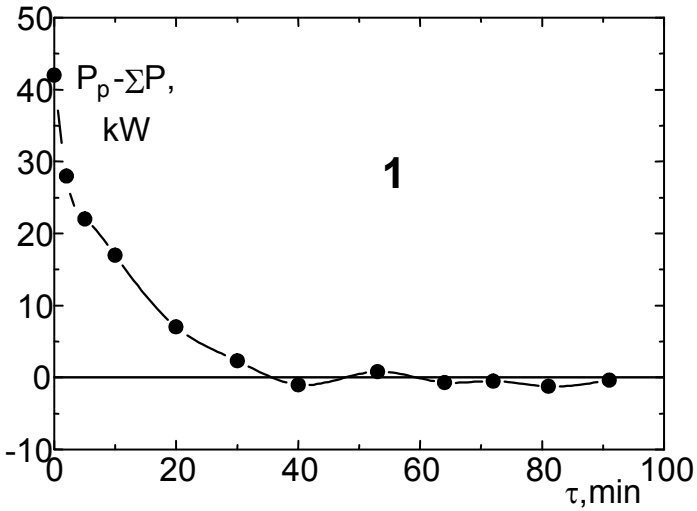
- **Research and implementation of plasma neutralization process of hazardous substances;**

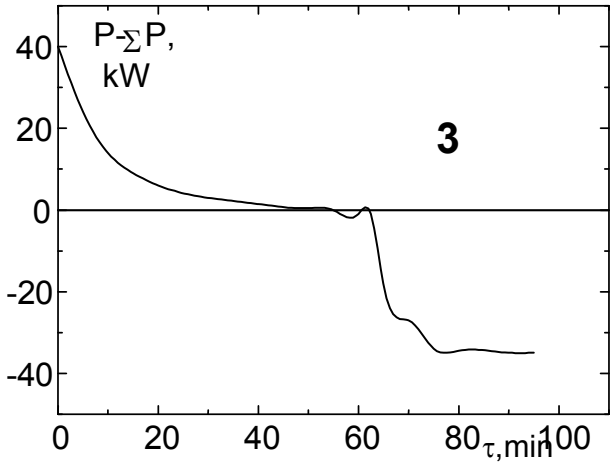


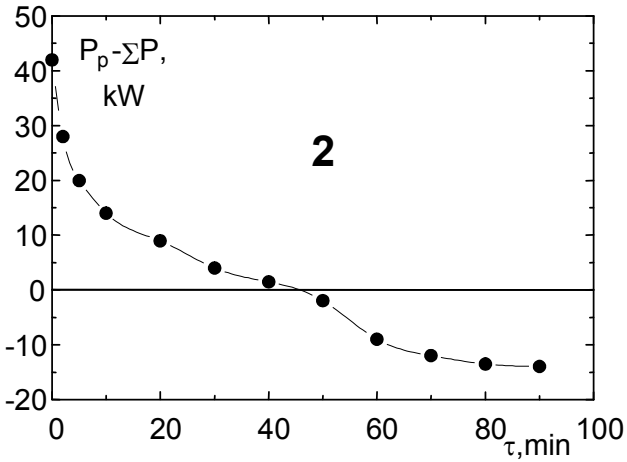


Stream reactor. 1 – plasma torch, 2 - plasma torch and feeder connection section, 3 – window for pyrometer observation, 4 – insulating layer, 5 – section (five units).

Thermocouple preparation place.
1 – thermocouple, 2 – frame, 3 – layer of asbestos cover
4 - layer of ceramic cover







1 – Heat balance

2 - Heat balance when destroying acetic acid

3 - Heat balance when destroying toluene

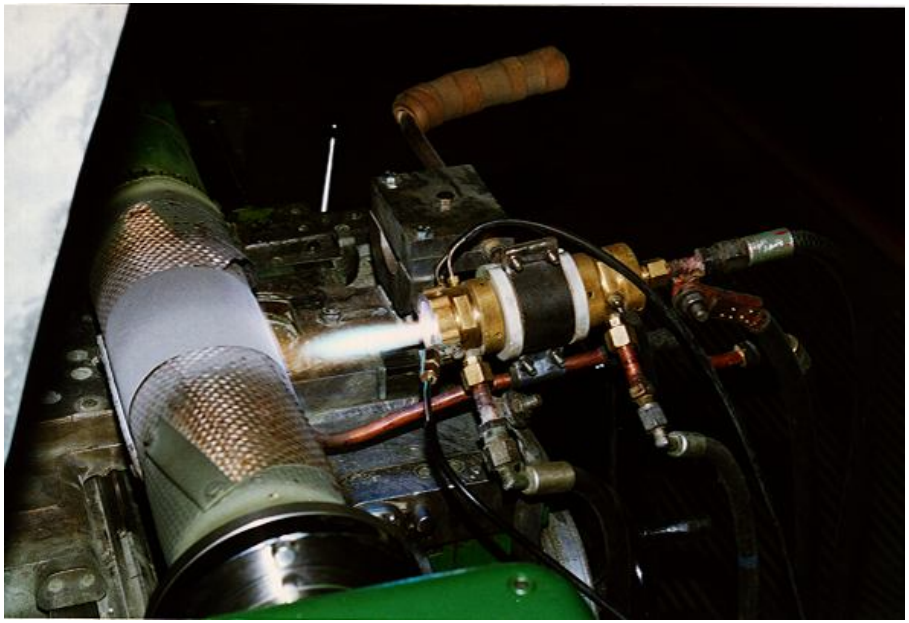
MAIN RESEARCH AREAS:

- **Catalytic coatings for CO and NOx reduction in exhaust gases.**

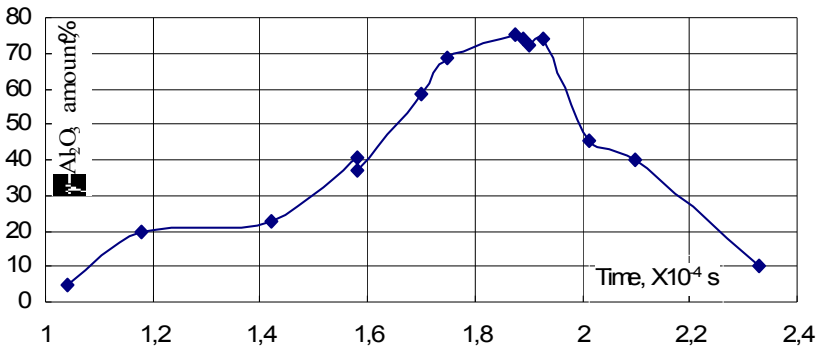
Most of catalysts now used for reduction CO, NOX and other hazardous substances in exhaust gases are based on platinum group metals. Materials used for monoliths or sheets for catalytic converters usually are ceramics or special steel doped with rare earth elements.

Limitation for wide application of such catalysts is low resistance to thermal shock, low thermal conductivity and high costs.

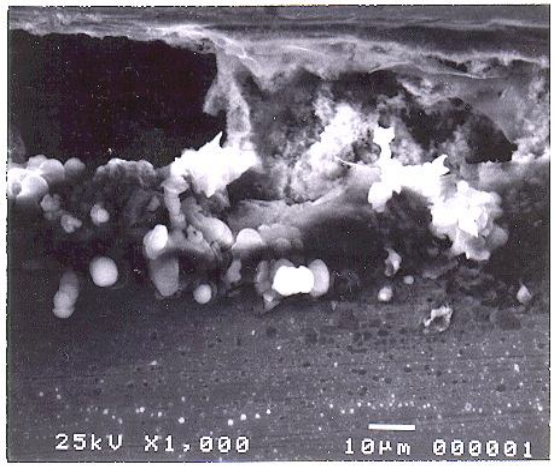
Alternative to platinum group metals - development of new, environmentally friendly and cheep catalysts for exhaust gas treatment based on metal oxides (Al_2O_3 doped with CuO, Cr_2O_3 and etc.).

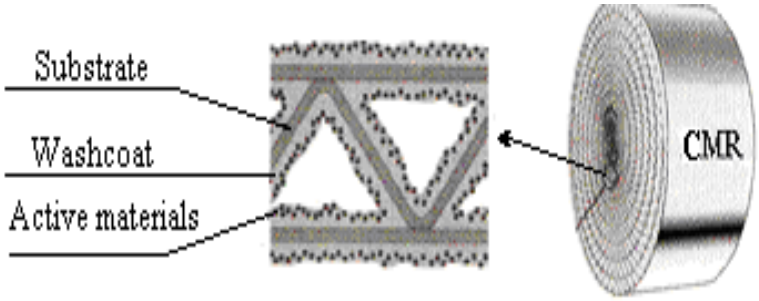


Plasma equipment for ceramics
coatings deposition

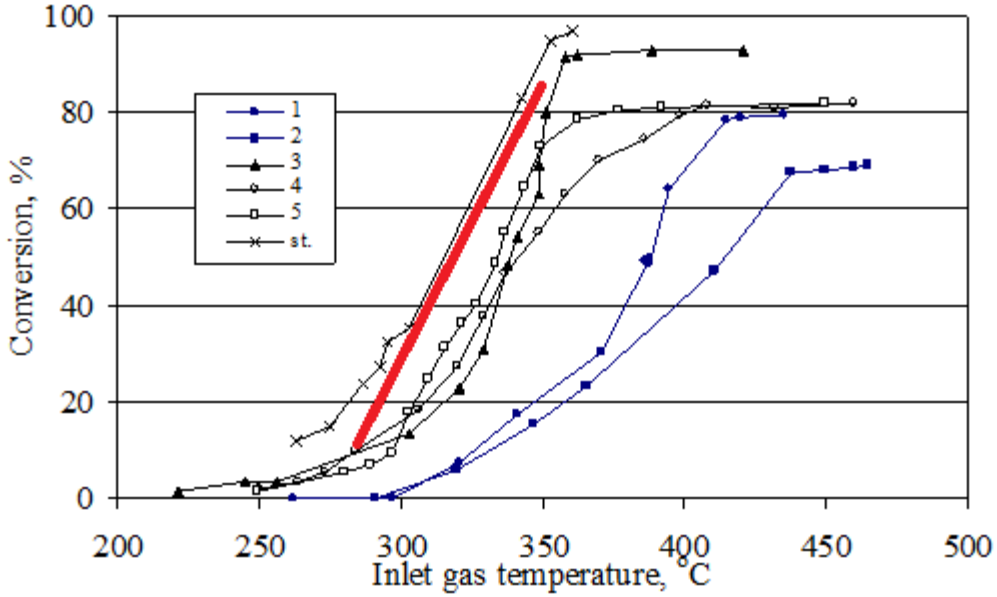


. The amount of γAl2O3 on the coating surface as function of presence time in plasma jet.





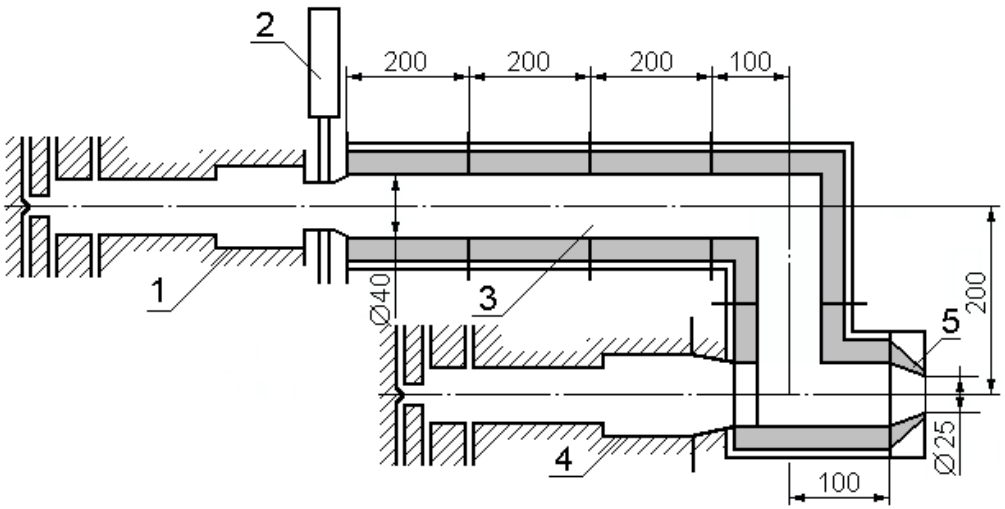
Coating thickness - 20- 50µm



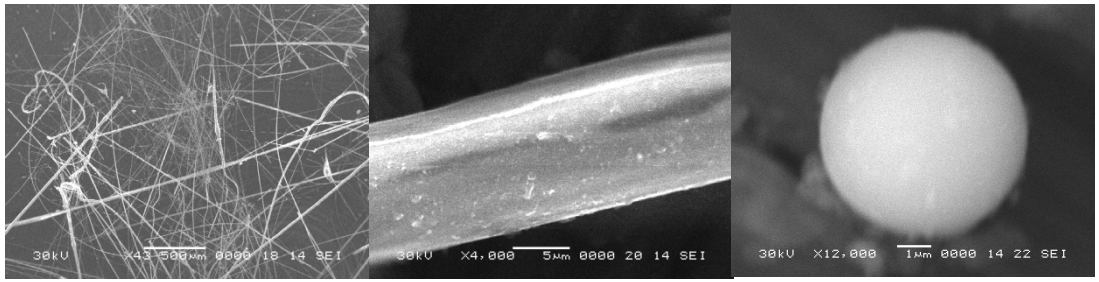
CO conversion versus inlet temperature for
a CO feed concentration of 3% .

MAIN RESEARCH AREAS:

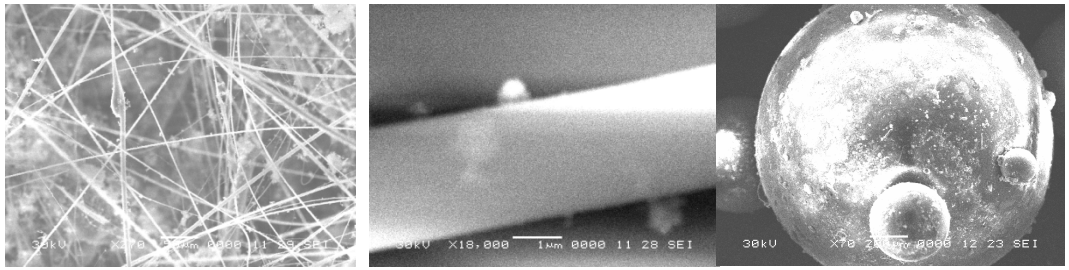
- **Plasma processing of high temperature resistance mineral fibre from local raw materials and waste**



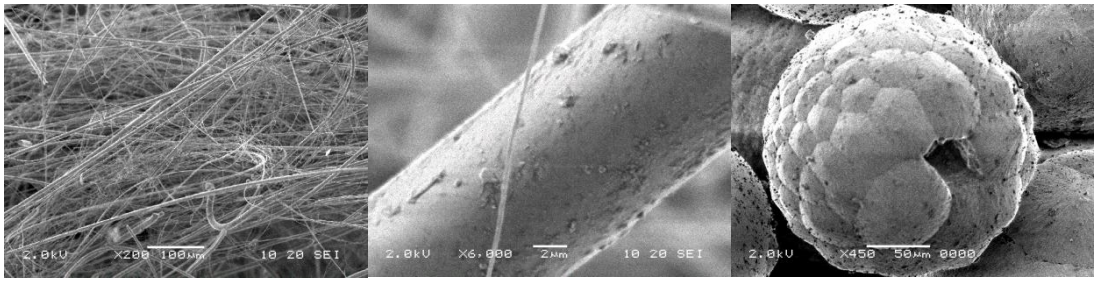
Schematic view of the experimental set-up.
1, 4 – plasma torch; 2 – connected section and batcher of powder settling; 3 – plasmachemical reactor; 5 – discharge section



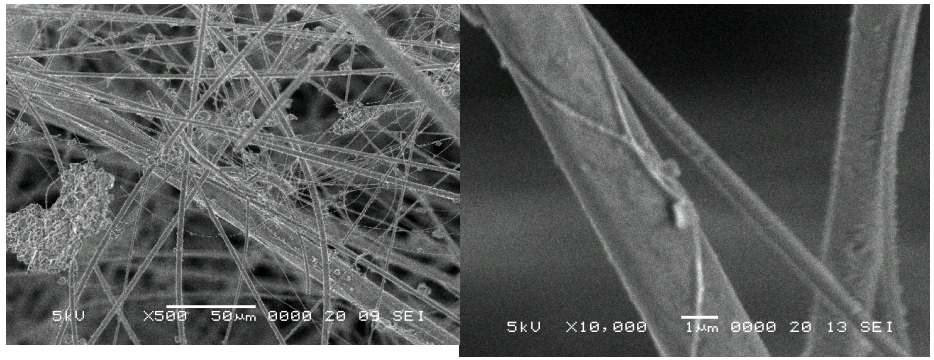
Kaoline



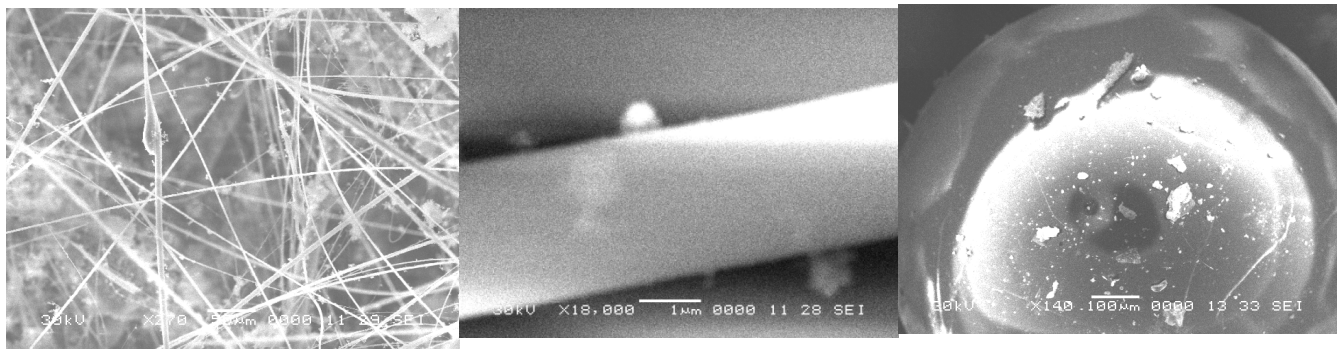
Mg oxide



Al oxide

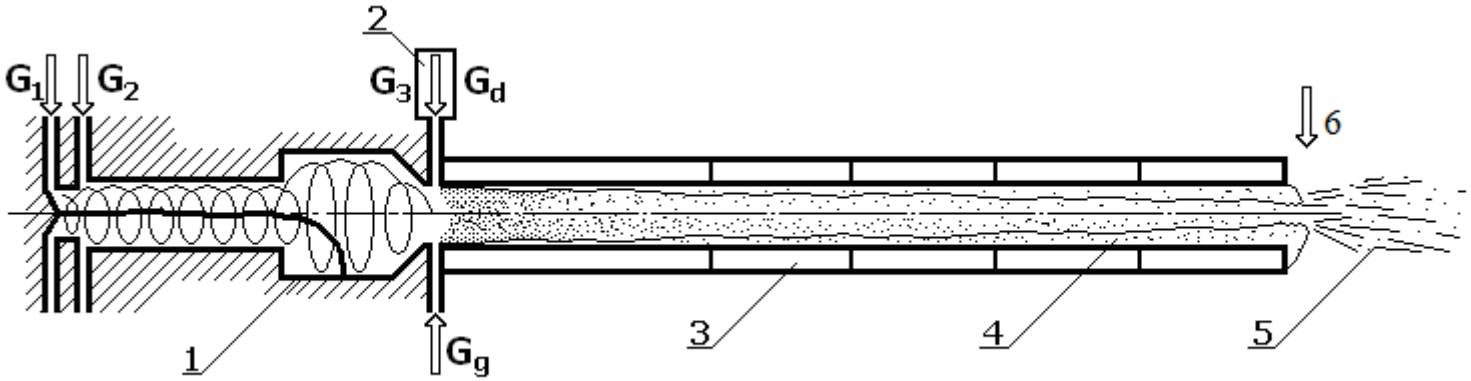


Dolomite

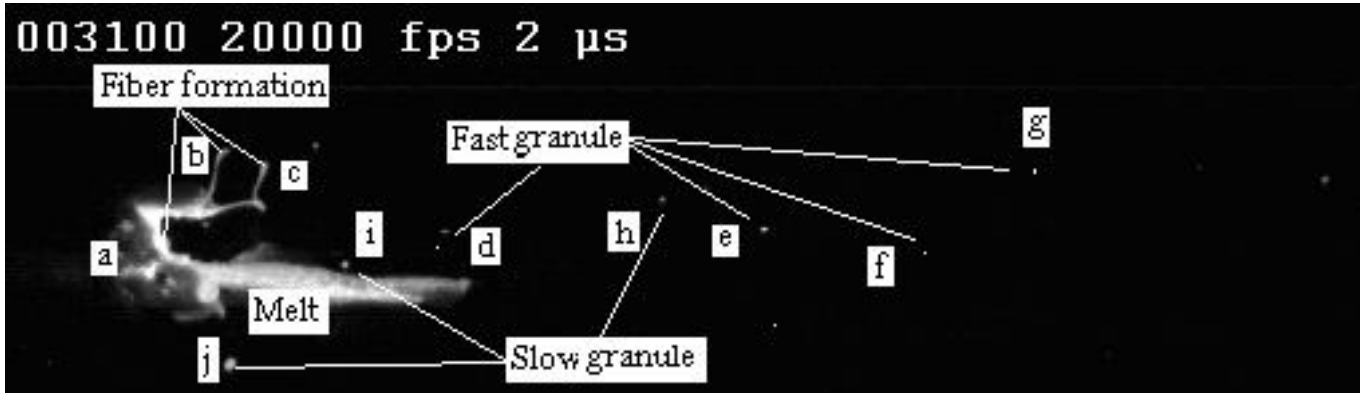


Ti oxide

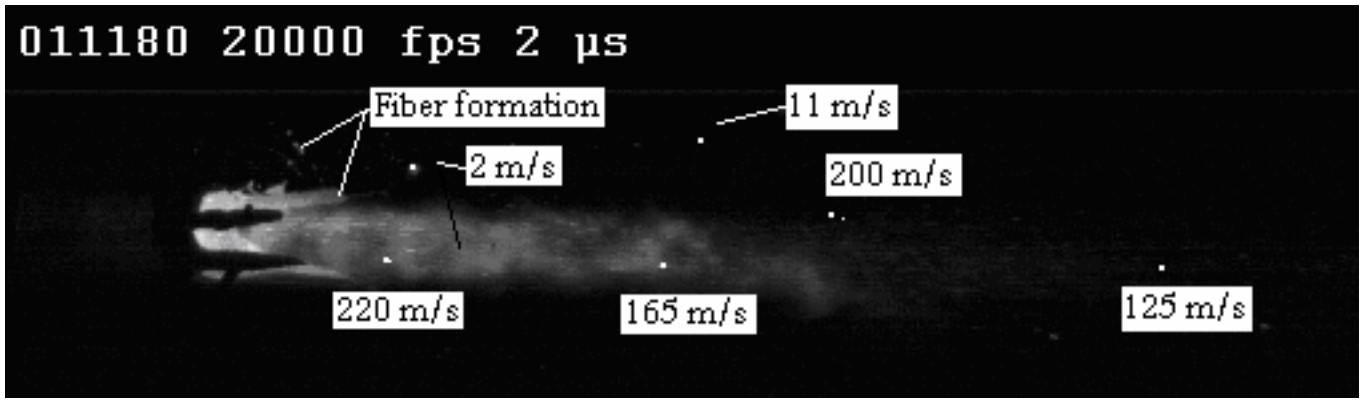
PLASMA SYNTHESIS, CHARACTERIZATION AND CATALYTICALLY EVALUATION OF HARD OXIDE CATALYSTS FOR CO, NOX REDUCTION OF COMBUSTION GASES



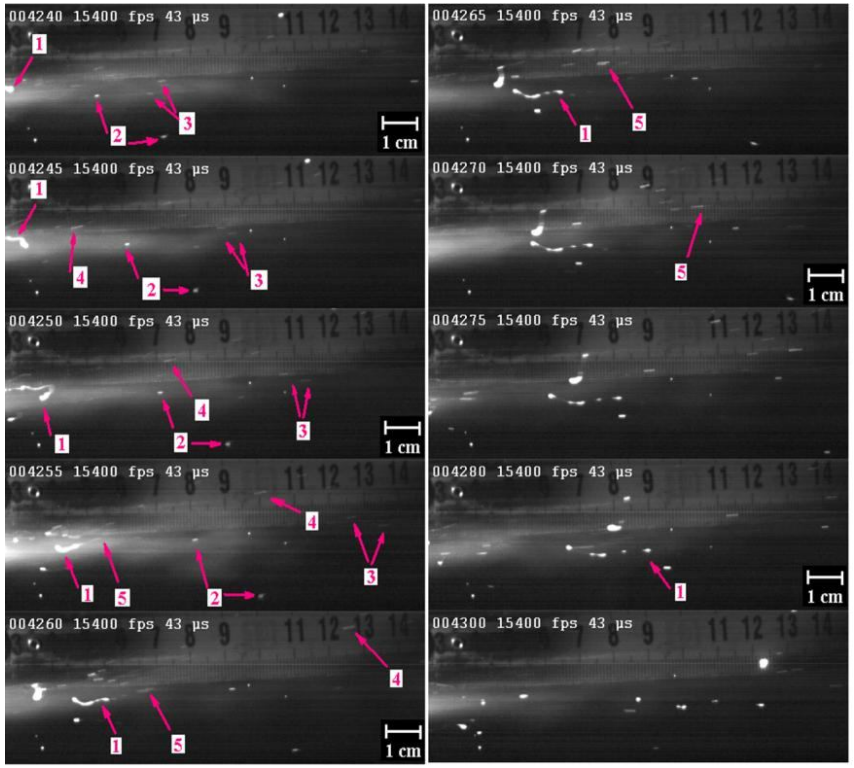
. Plasma-chemical reactor: 1 – plasma torch, 2 – feeding of dispersed particles, 3 – section of the reactor, 4 – melt flow, 5 – fibre and granules, 6 – catalyst powder injection



Behaviour of melted granules of zeolites in subsonic air plasma jet

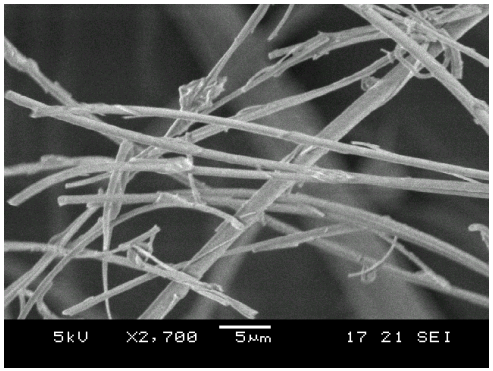


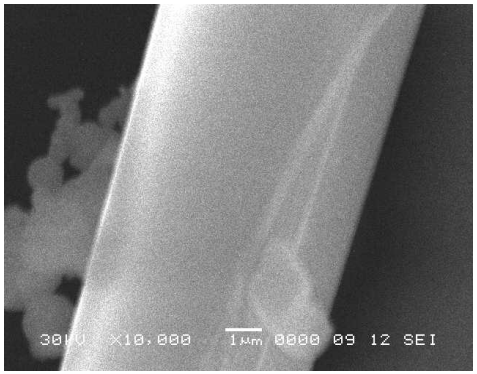
Behaviour of melted granules of zeolites in supersonic air plasma jet



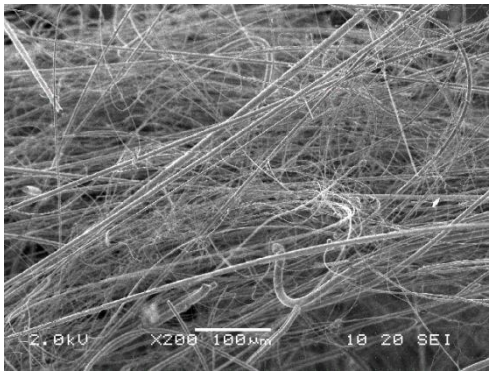
Behavior of melted granules and fibre of zeolites in supersonic air plasma jet

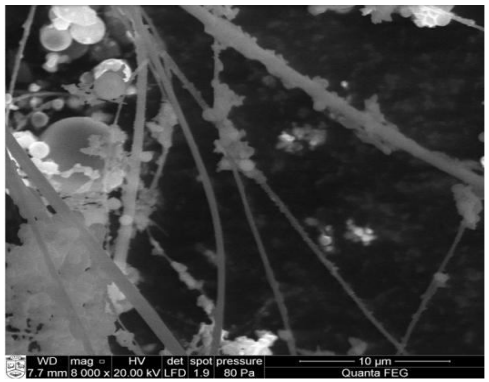
Zeolite fibre





Clean

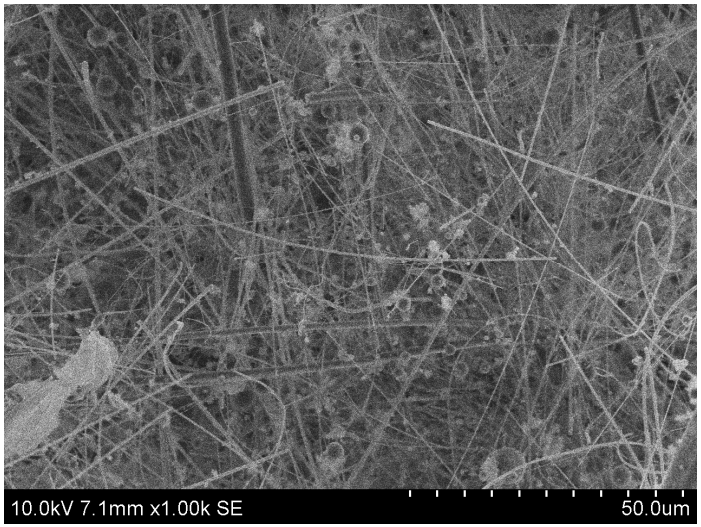


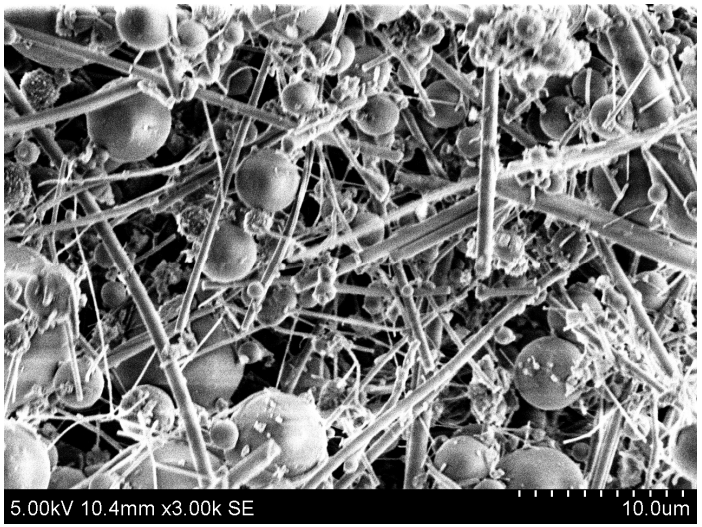


With melt droplets

Chemical composition [mass %]: Al2O3 – 40.9, SiO2 – 55.2, Fe2O3 – 0.9, TiO2 – 1.4, CaO – 0.5, MgO – 0.49, Na2O – 0.2. The particle size - 50µm, density - 830 kg·m-3,

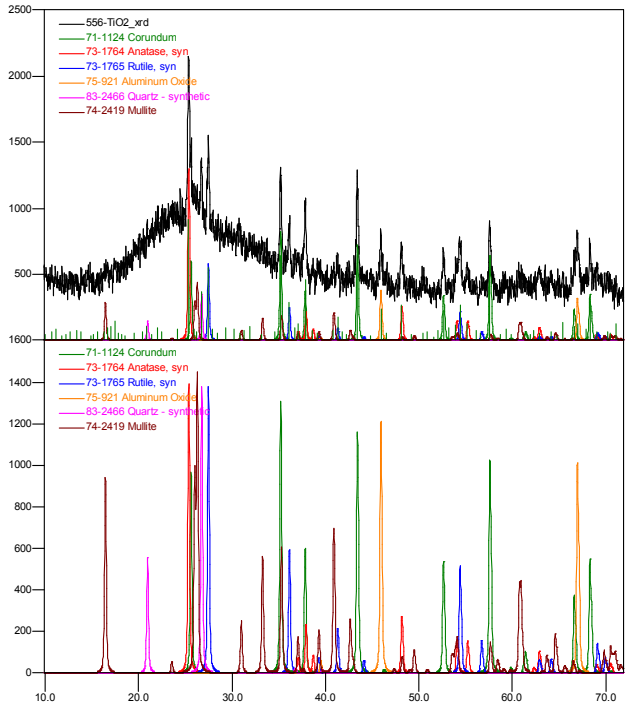
XRD of zeolite fibre with Cu addition



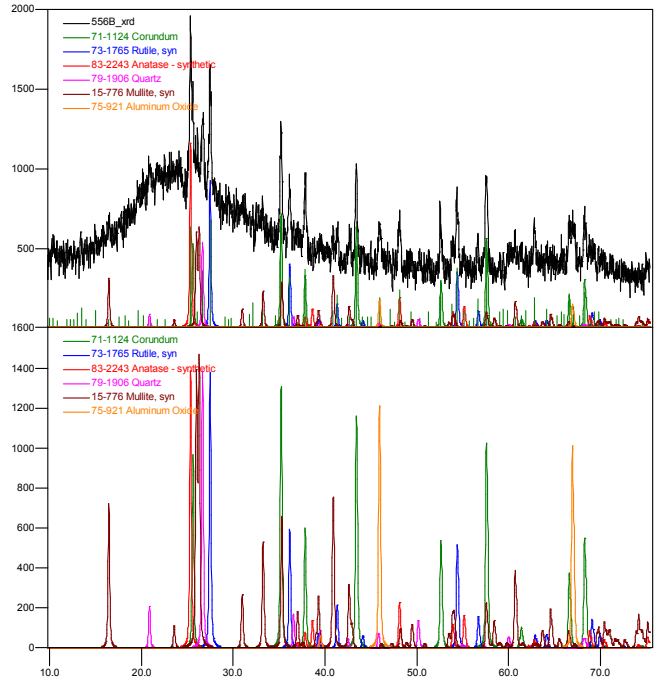


Free surface area - 18,46 m2/g

XRD of zeolite fibre with Cu addition

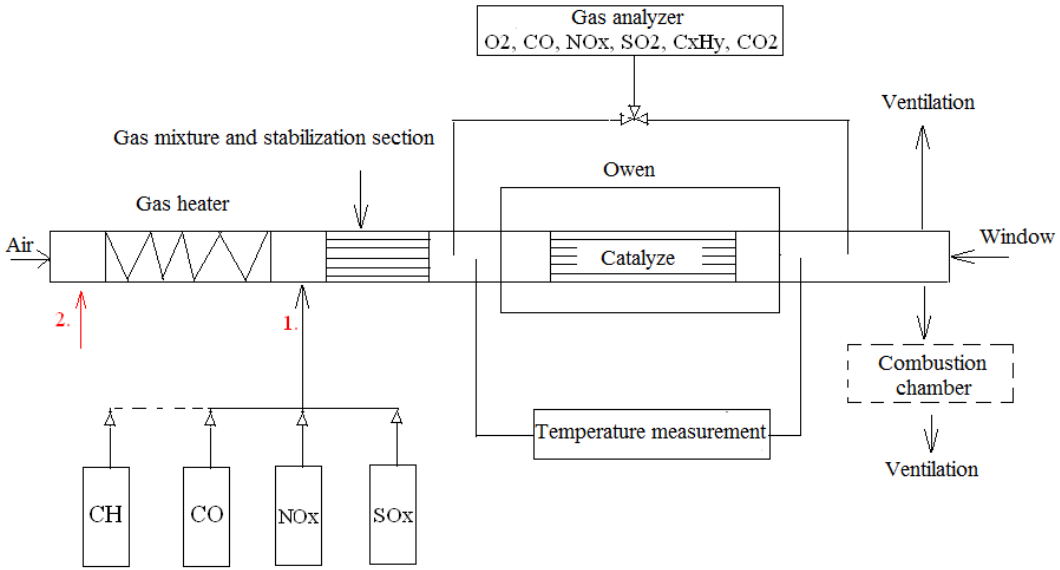


As sprayed

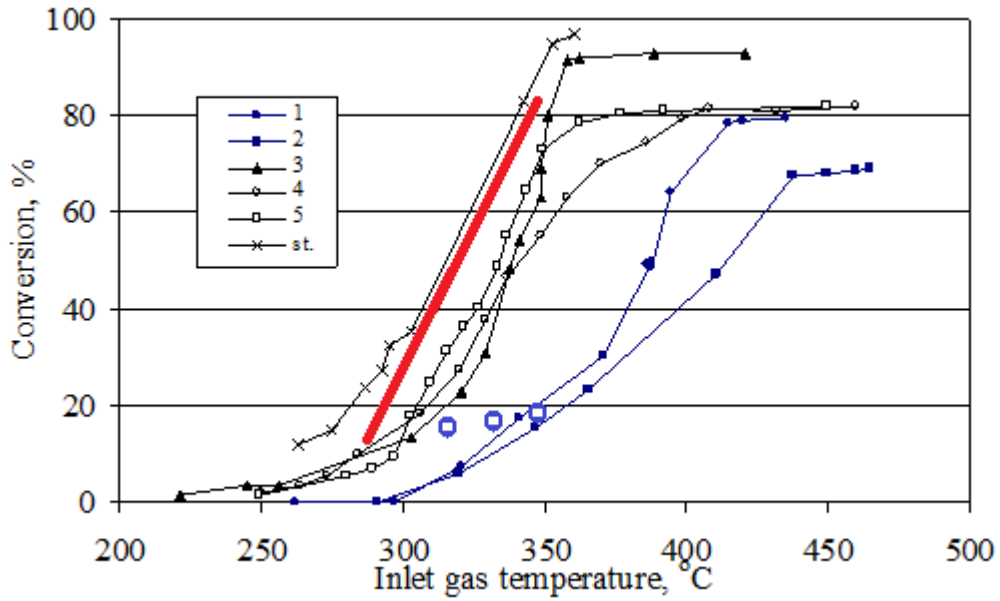


After10 hours annealing at 1000 oC

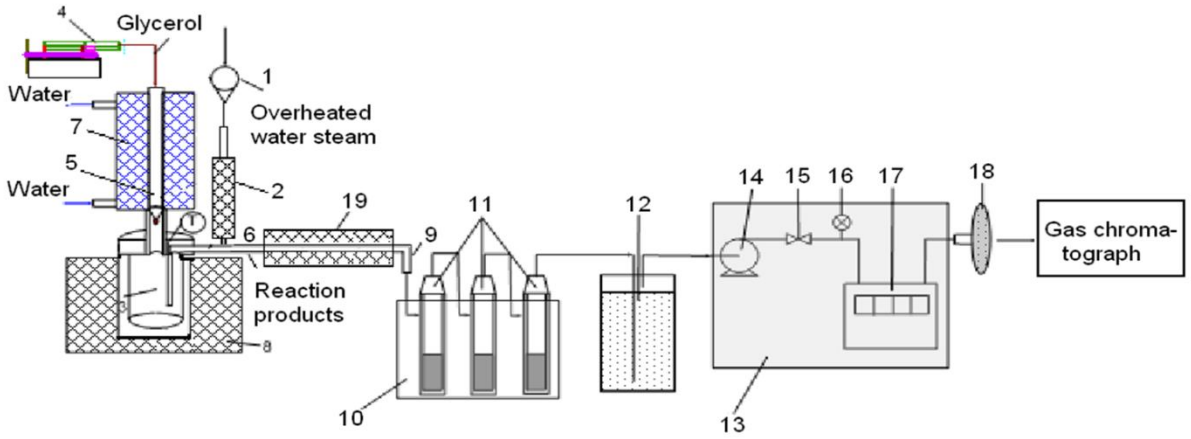
CO conversation in exaust gases



Test bench for catalyst testing

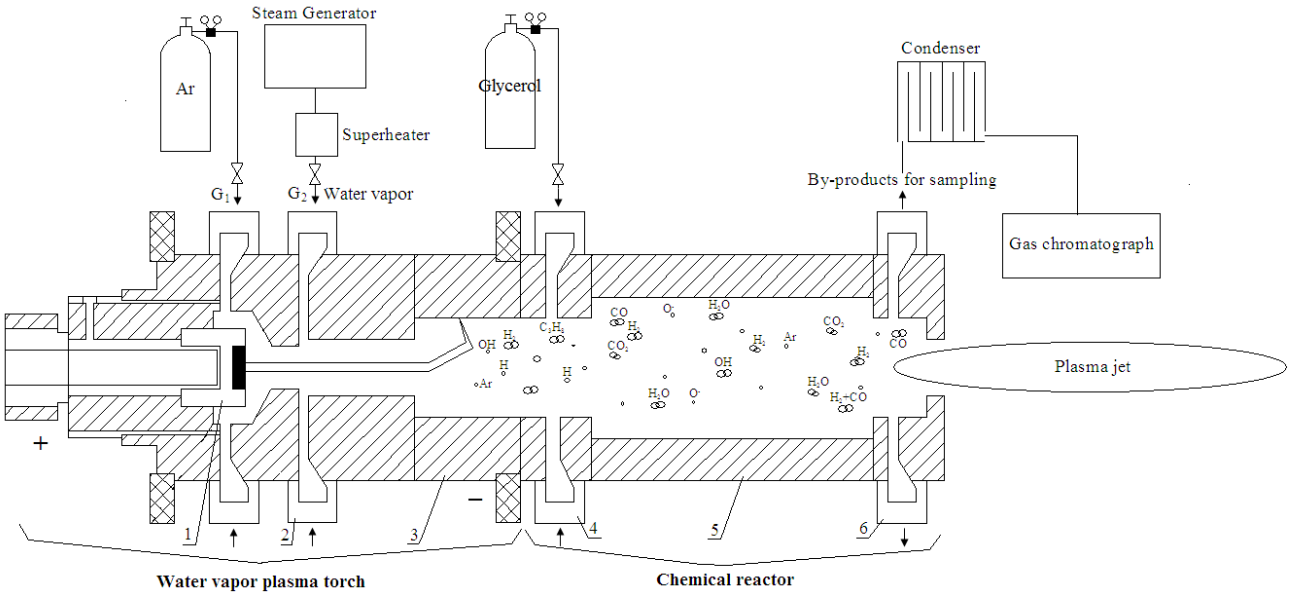

100
80
60
40
20
0
Conversion, %
200
250
300
350
400
450
500
Inlet gas temperature, °C
1
2
3
4
5
st.

Use of catalytic fibre for glycerol decomposition



Experimental set up for thermal glycerol decomposition: 1, 2 – overheated water vapor supply, 3 – 8 - glycerol decomposition system, 9 – 18 – gas products collecting system, 19 – heated channel for catalytic reactions

Use of catalytic fibre for glycerol decomposition by water vapor plasma torch



Concentration of produced synthetic gas after decomposition of glycerol

Process	Catalyst	H_2, %	CO, %	CO_2, %
Gasification		28.3	33.8	3.6
Gasification	Zeolite fibre + Cu, CuO	37.7	24.7	9.4
Steam reforming		31.5	30.6	11.4
Steam reforming	Zeolite fibre + Cu, CuO	42.1	14.9	13.7
Plasma torch		39	17,6	11,9

CONCLUSION

The use of the non-equilibrium plasma technology demonstrates the ability to process wide range of substances to obtain the product with specific structure and characteristics. Plasma technology allows the synthesis of catalytic, tribological and protective films, micro- and nanostructured particles, coatings and composites with controlled characteristics for specific applications.

Thank You for attention