

CENAB - Centrum nanomateriálů a biotechnologií, PŘF UJEP;

Příprava a charakterizace nanomateriálů;

CENAB - Centre of nanomaterials and biotechnology, Faculty of Science, UJEP;

Nanomaterials preparation and characterization

UNIVERZITA J. E. PURKYNĚ V ÚSTÍ NAD LABEM



UNIVERZITA J. E. PURKYNĚ V ÚSTÍ NAD LABEM

Přírodovědecká fakulta



VYSOKÁ ŠKOLA
CHEMICKO-TECHNOLOGICKÁ
V PRAZE

Z. Kolská and my girl team, CENAB, Faculty of Science, UJEP
Ústí nad Labem;

V. Švorčík, O. Lyutakov, et al.; ÚIPL, FCHT, UCT Prague

Contents

Surface modification

Methods of characterization

Zeta potential

Other activities at CENAB

Sjezd chemiků 2026

Materials

Many of excellent properties

Usage: in many fields of common life, industry, medicine

For some application unsuitable

Surface modification

mechanical

physical

e.g. plasma, laser, UV, ...

chemical

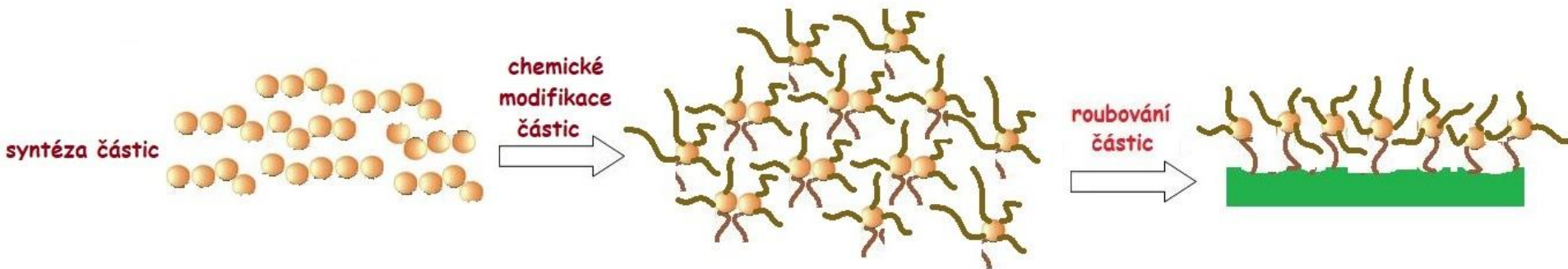
(A) e.g. surface activation (Piranha solutions)

(B) and/or subsequent grafting of ...

(i) compounds of functional groups (PEG, aminoacids, -SH)

(ii) metal (Au, Ag) or C nanoparticles

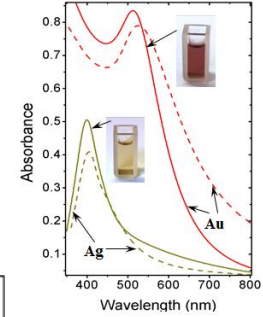
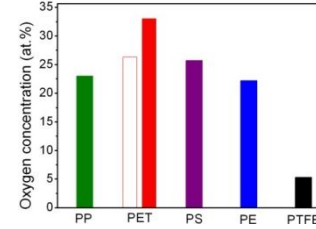
Our surface modification



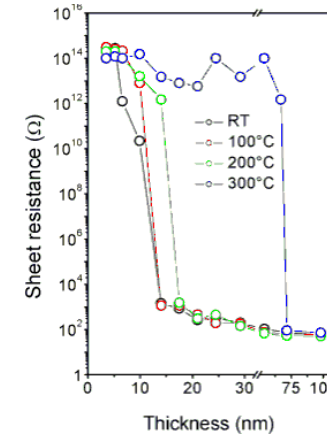
depending on the requirements, usage

Characterization methods

Chemical composition (spectroscopy methods - FTIR, UV-Vis, XPS, AAS, RBS, Raman, ...)



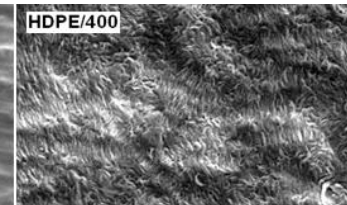
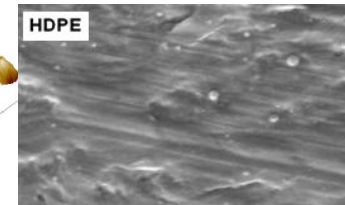
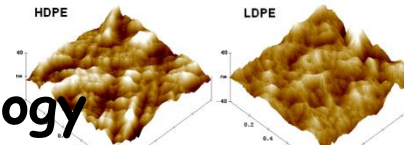
Electrical properties (surface resistance, ...)



Optical properties (elipsometry, Eg, ..)

Surface ablation (gravimetry)

Surface roughness and morphology (microscopy methods - AFM, FIB-SEM, TEM)



Characterization methods

Wettability (goniometry)

Nanostructures size, lattice parameters (XRD)

Hardness and adhesion of deposited layers (nanoindentance)

Antimicrobial test (antibacterial test, inhibition of algae growth)

Cytocompatibility (cell adhesion and proliferation, cytotoxicity)

Magnetic properties

Surface area, porosity (adsorption/desorption isotherms)

Electrokinetic analysis (zeta potential - 2x, Ps x flat)

Electrokinetic potential (ζ -potential)

1) What is it and for what is it?

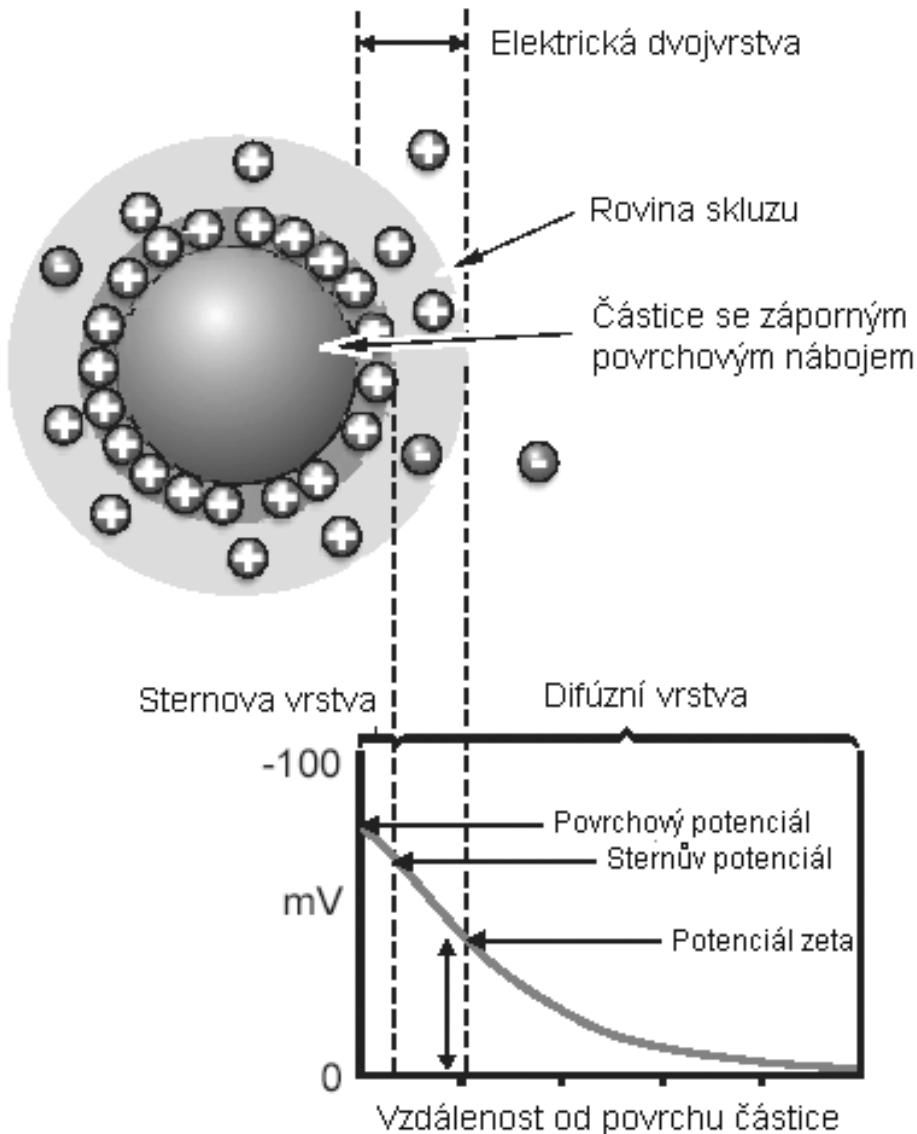
Important parameter for:
description of solid materials surfaces

Usage: food industry; automotive
industry; construction, engineering;
medicine

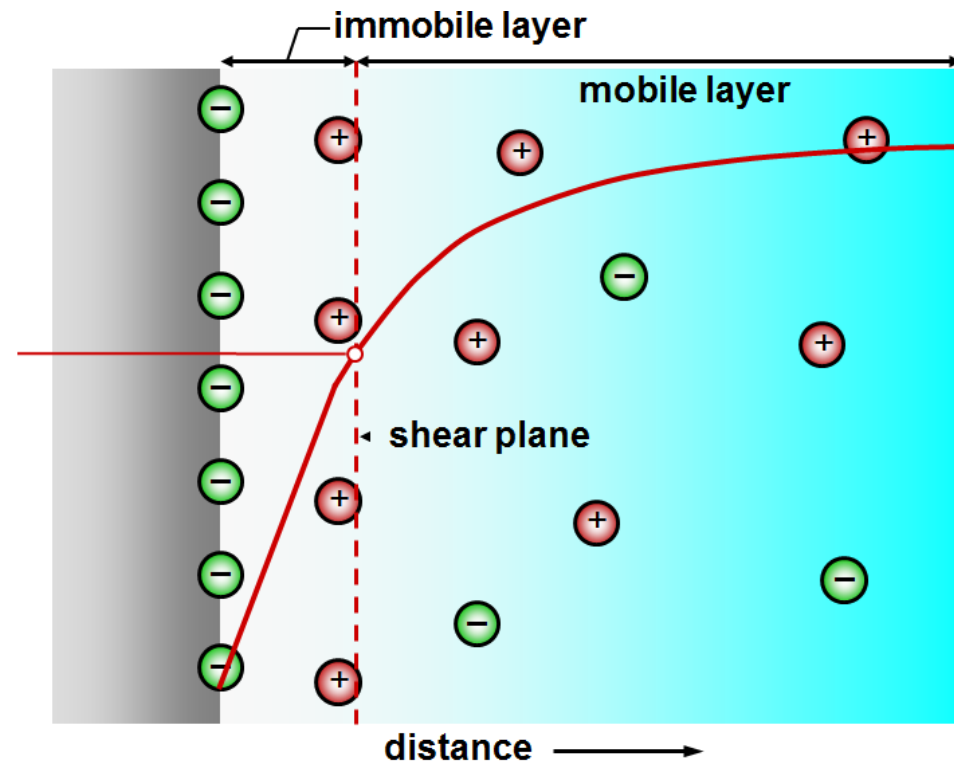
- Planar samples (cellulose, glass, metals, textiles, ceramics, fibers, powders, hair, tooth enamel, membranes, filters,...);
- Characterization of un/modified solid substrates;
- For stability of colloidal systems;
- For study of ability/success of surface adhesions (cells, preparation of nanomaterials, nanostructured materials, coatings, ...);
- For wastewater treatment.

Electrokinetic potential (ζ -potential)

1) What is it and for what is it?

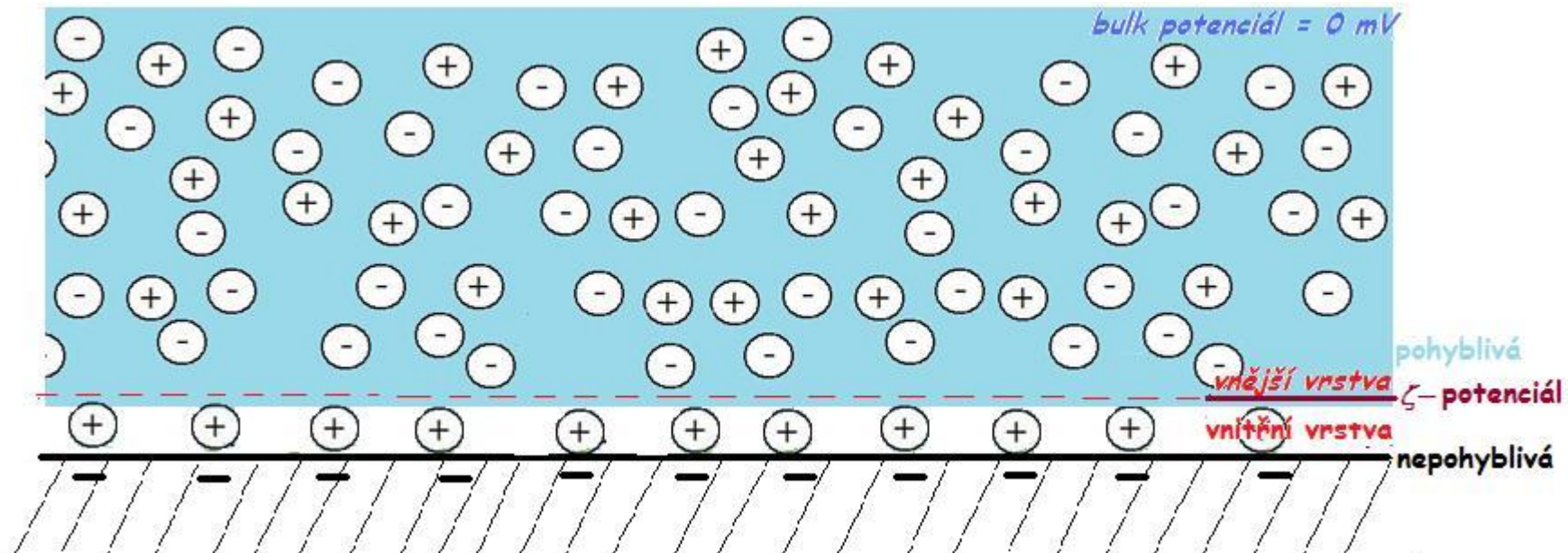
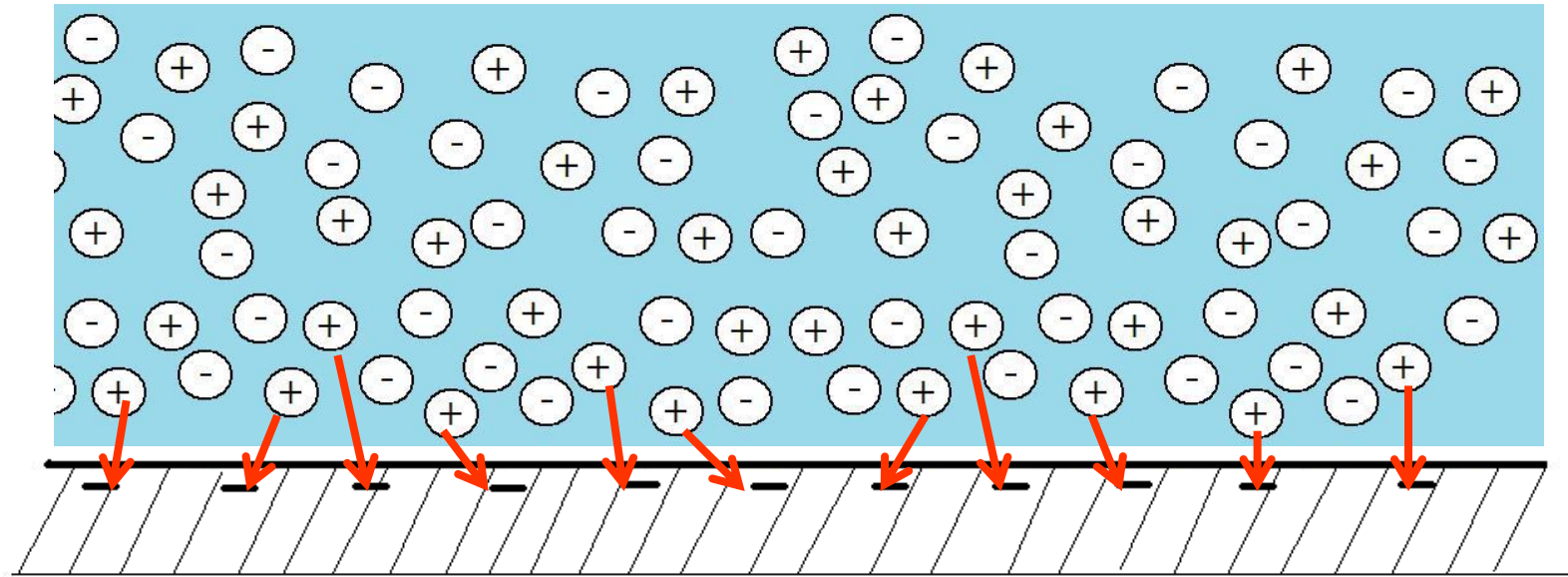


For colloids: studied for a long time
For planar samples: more recent



Electrokinetic potential (ζ -potential)

2) How it is created?



Electrokinetic potential (ζ -potential)

2) How it is created? mechanisms of the surface charge formation

- (i) **ionization of surface layers**; detachment of $(OH)^- \times H^+$ group, acceptance of H^+ , ... (is possible where there are some active functional groups on the surface)
- (ii) **preferential dissolution of a lattice ion in crystals** of sparingly soluble salts in contact with water;
- (iii) **preferential adsorption of one type of ion from an aqueous solution on the initially uncharged surface of a solid**, e.g. adsorption of either $(OH)^-$ or H_3O^+ ions formed by the dissociation of water at the surface; (inert surfaces, polymers, ..)
- (iv) **in the case of clay materials, isomorphic substitution** of surface ions of higher valence with ions of lower valence (e.g. Si^{4+} za Al^{3+});
- (v) **by "accumulation" of electrons** at the metal-solution interface

1 P. Hiemenz and R. Rajagopalan, *The Electrical Double Layer and Double-Layer Interactions*. In: *Principles of colloid and surface chemistry*, Marcel Dekker, Inc., New York, 1997, p. 499.

2 J. K. Beattie, *Lab. Chip*, 2006, **6**, 1409.

3 M. Kosmulski, *Chemical Properties of Material Surfaces*. Vol. 102, Marcel Dekker, Inc., New York, 2001.

Electrokinetic potential (ζ -potential)

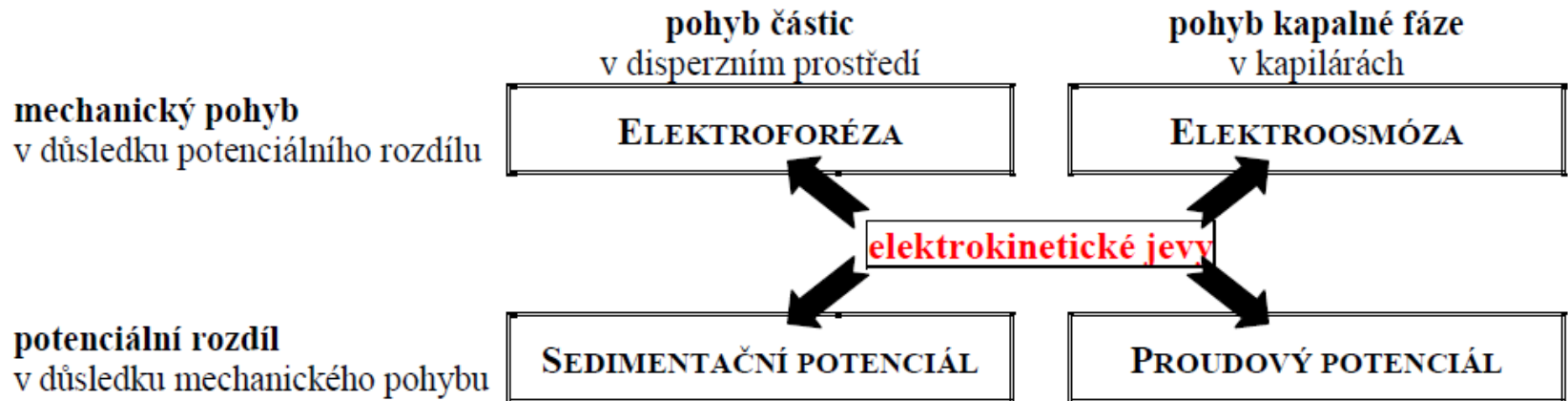
3) How is it measured/determined?

Using electrokinetic methods:

- Electrophoresis
- Sedimentation potential
- Electroosmosis
- Streaming potential
- Streaming current

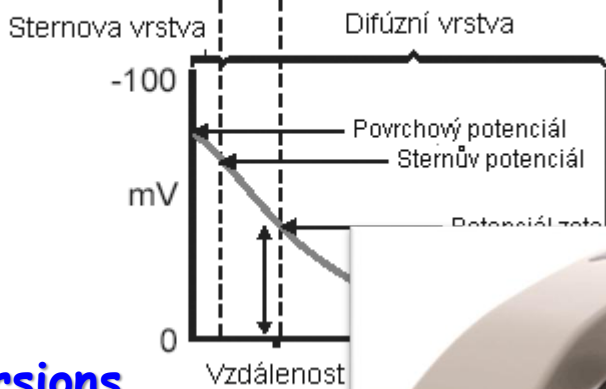
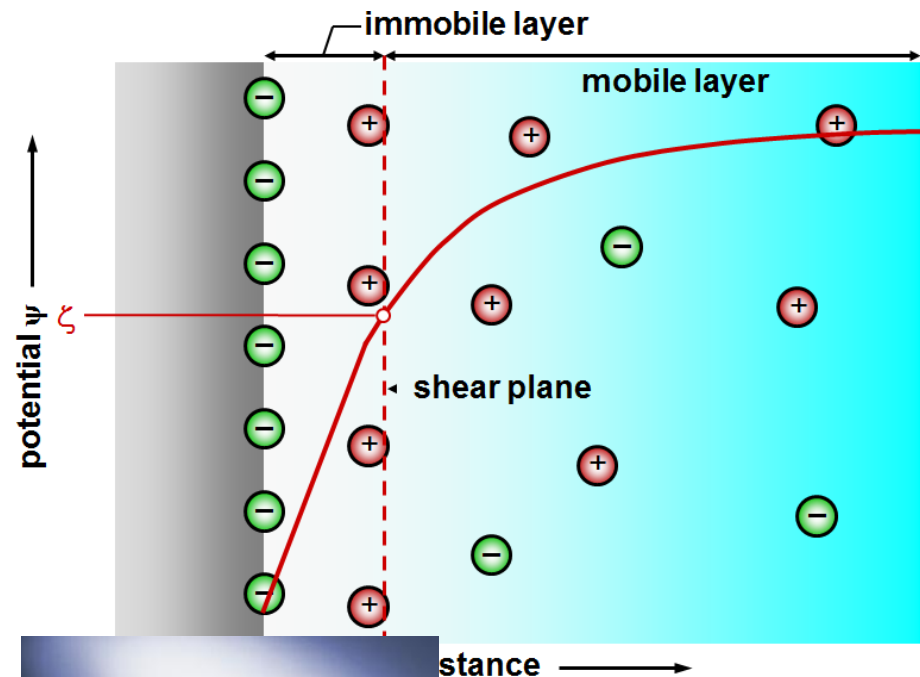
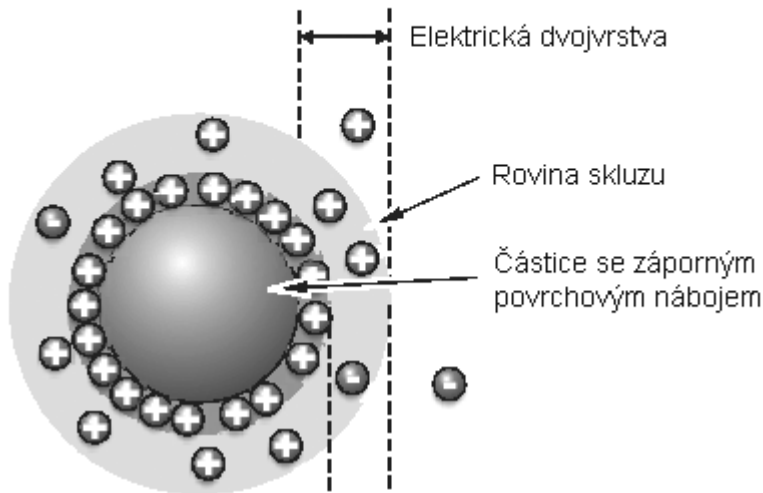
For planar samples
Fibers, powders

For dispersions



Electrokinetic potential (ζ -potential)

4) Instruments for determination



Dispersions

(almost everywhere)

Zetasizer (Malvern);

Litesizer (Anton Paar), ...

Solids
planar samples,
fibres, powders, ...
(Only Ústí, Zlín! 😊)

SurPASS (Anton Paar)

Electrokinetic potential (ζ -potential)

4) Instruments for determination

Electrokinetic analyzer SurPASS (Anton Paar, Graz, Rakousko)

suitable for ζ -potential determination of solids:

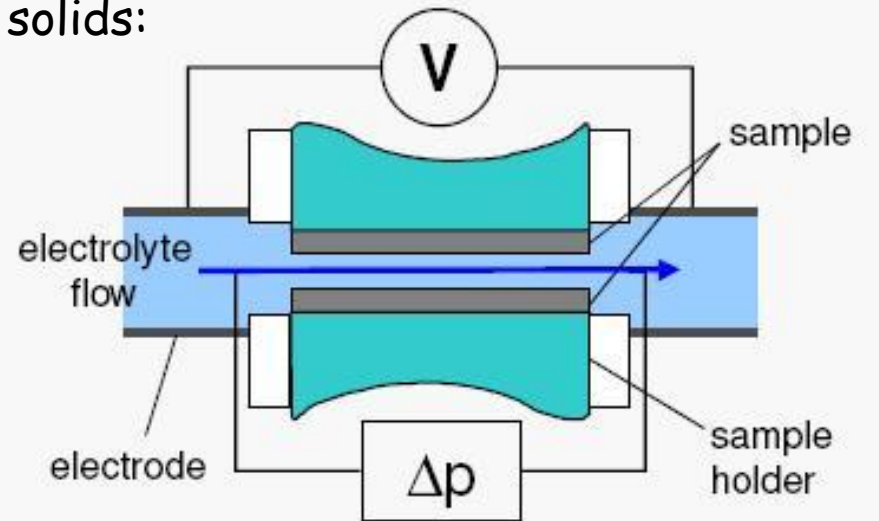
powders, fibers, planar samples

T , pH, conductivity

measurement of changing voltage or current with increasing electrolyte pressure

$$\zeta = \frac{dI}{dp} \cdot \frac{\eta}{\varepsilon \cdot \varepsilon_0} \cdot \frac{L}{A}$$

Streaming current
Helmholtz-Smoluchowski eq. (HS)



$$\zeta_{\text{apparent}} = \frac{dU}{dp} \cdot \frac{\eta}{\varepsilon \cdot \varepsilon_0} \cdot K_B$$

Streaming potential
Fairbrother-Mastins eq. (FM)

Colloids stability

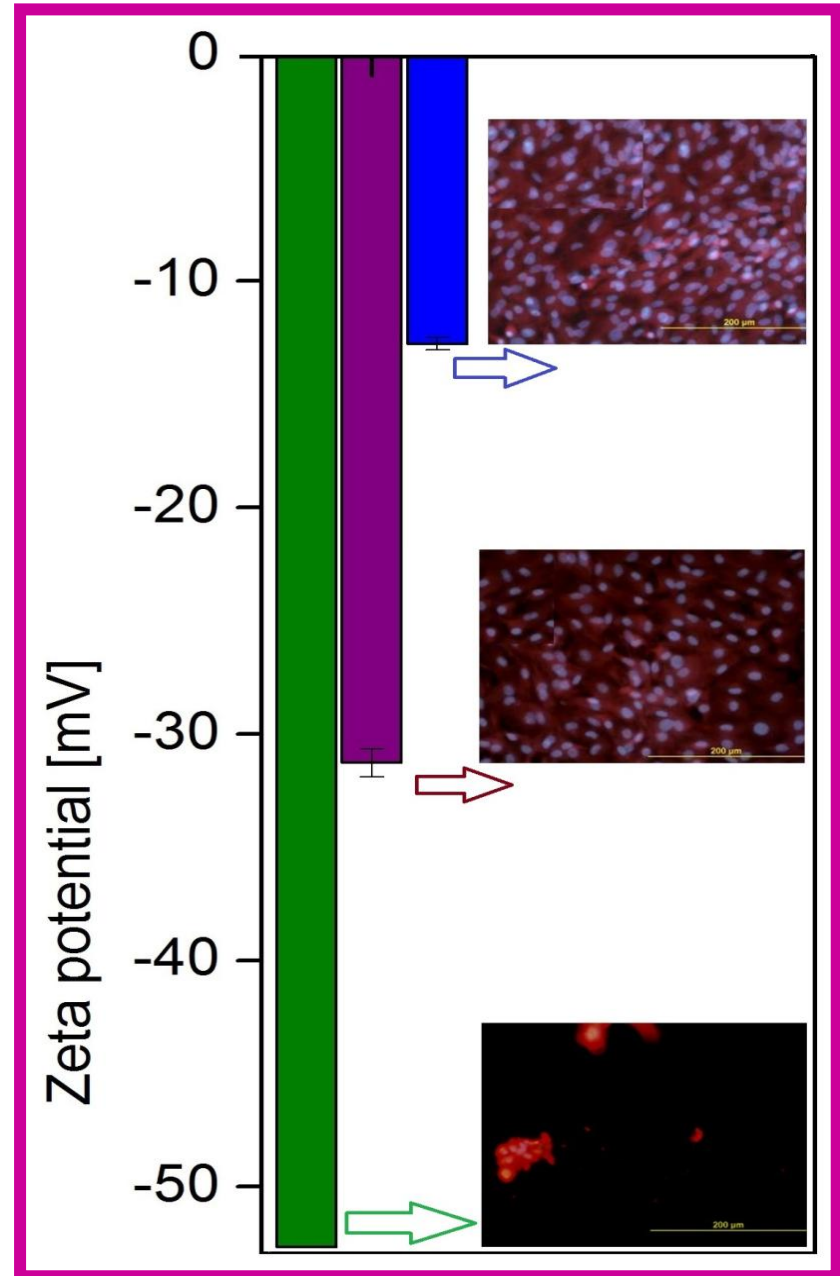


$\zeta = -49,7 \text{ mV}$



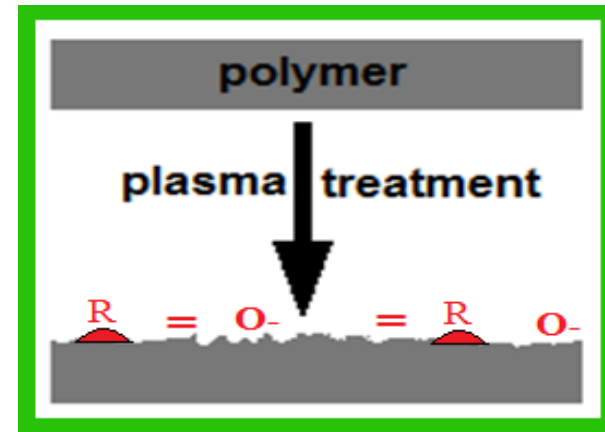
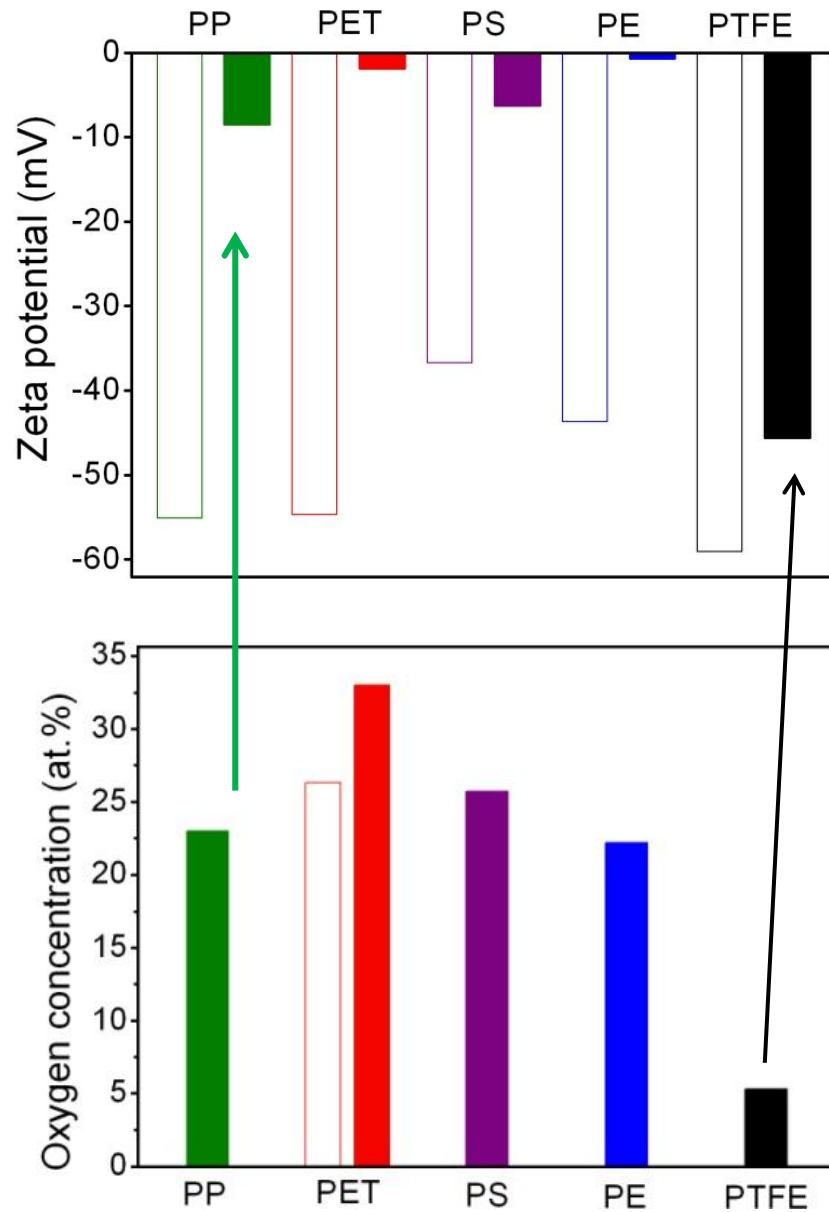
$\zeta = -26,6 \text{ mV}$

Cell adhesion



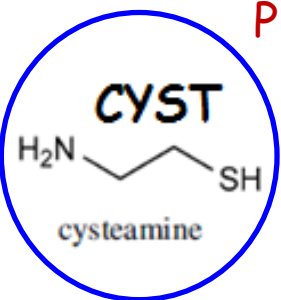
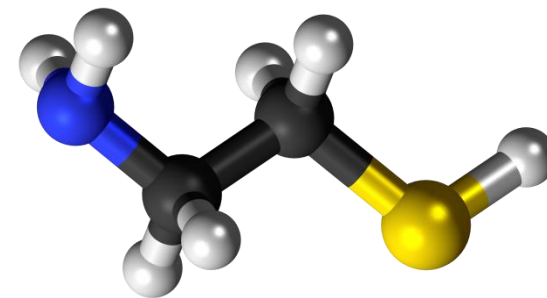
Results

Plasma modification (zeta x XPS)

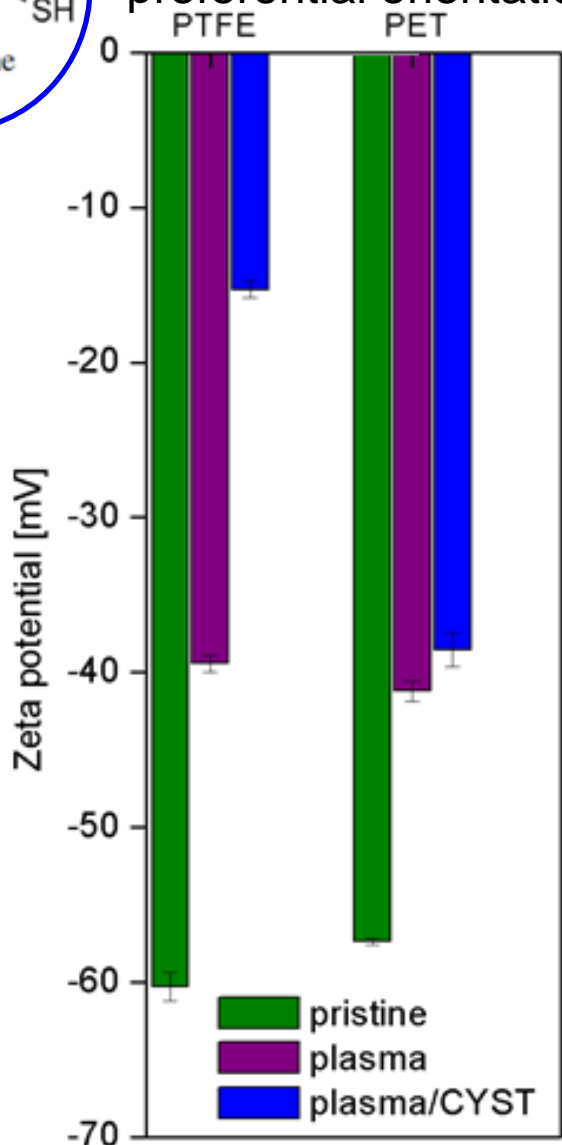


Results

PET, PTFE, PVF, PVDF, PS, HDPE, LDPE, PLLA



Characterization: zeta, XPS, preferential orientation



Sample	Elements concentration [at %]									
	Angle 0 [°]					Angle 81 [°]				
	C	O	S	F	N	C	O	S	F	N
PET pristine	72.5	27.5	-	-	-	NA				
PET/plasma	67.0	33.0	-	-	-	NA				
PET/CYST	71.3	21.2	3.2	-	4.3	75.3	18.5	2.9	-	3.3
PLLA pristine	66.9	33.1	-	-	-	NA				
PLLA/plasma	61.7	38.3	-	-	-	NA				
PLLA/CYST	73.4	21.9	1.8	-	2.9	75.7	18.8	2.5	-	3.1
PS pristine	100.0	-	-	-	-	NA				
PS/plasma	88.3	11.7	-	-	-	NA				
PS/CYST	81.7	12.3	3.1	-	2.9	74.3	14.1	3.6	-	7.3
PTFE pristine	33.2	-	-	66.8	-	NA				
PTFE/plasma	44.3	9.4	-	46.4	-	NA				
PTFE/CYST	51.6	10.1	6.0	26.0	6.3	53.8	11.1	4.3	22.0	8.2
PVF pristine	68.3	0.4	-	31.3	-	NA				
PVF/plasma	63.8	17.3	-	19.0	-	NA				
PVF/CYST	72.3	14.0	4.0	4.6	5.1	72.5	14.1	4.2	2.2	7.0
PVDF pristine	50.6	0.3	-	49.1	-	NA				
PVDF/plasma	55.5	16.1	-	28.4	-	NA				
PVDF/CYST	63.5	14.0	5.8	9.5	7.2	69.8	13.1	4.8	5.5	6.8
LDPE pristine	99.6	0.4	-	-	-	NA				
LDPE/plasma	84.9	15.1	-	-	-	NA				
LDPE/CYST	80.2	14.0	2.1	-	3.7	79.2	11.3	4.4	-	5.1
HDPE pristine	100.0	-	-	-	-	NA				
HDPE/plasma	79.6	20.4	-	-	-	NA				
HDPE/CYST	77.9	15.1	3.0	-	4.0	76.8	13.8	4.5	-	5.0

Results

	C	C-NH ₂	C-CONH(CH ₂) ₆ NH ₂
Velikost povrchu	1050.45 m ² /g	520.92 m ² /g	33.140 m ² /g
Celkový objem porů	2.3593 ml/g	1.0253 ml/g	0.1678 ml/g

Pristine C **ED** **DET** **TET** **TAE** **TMAE**

Surface area (m² g⁻¹)

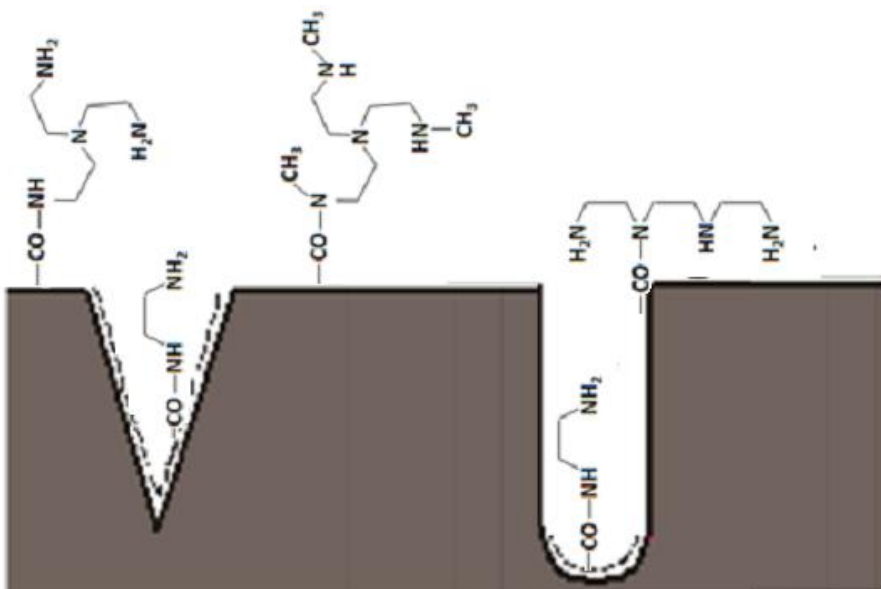
1058.9 74.2 156.5 386.1 150.4 81.4

Pore volume (cm³ g⁻¹)

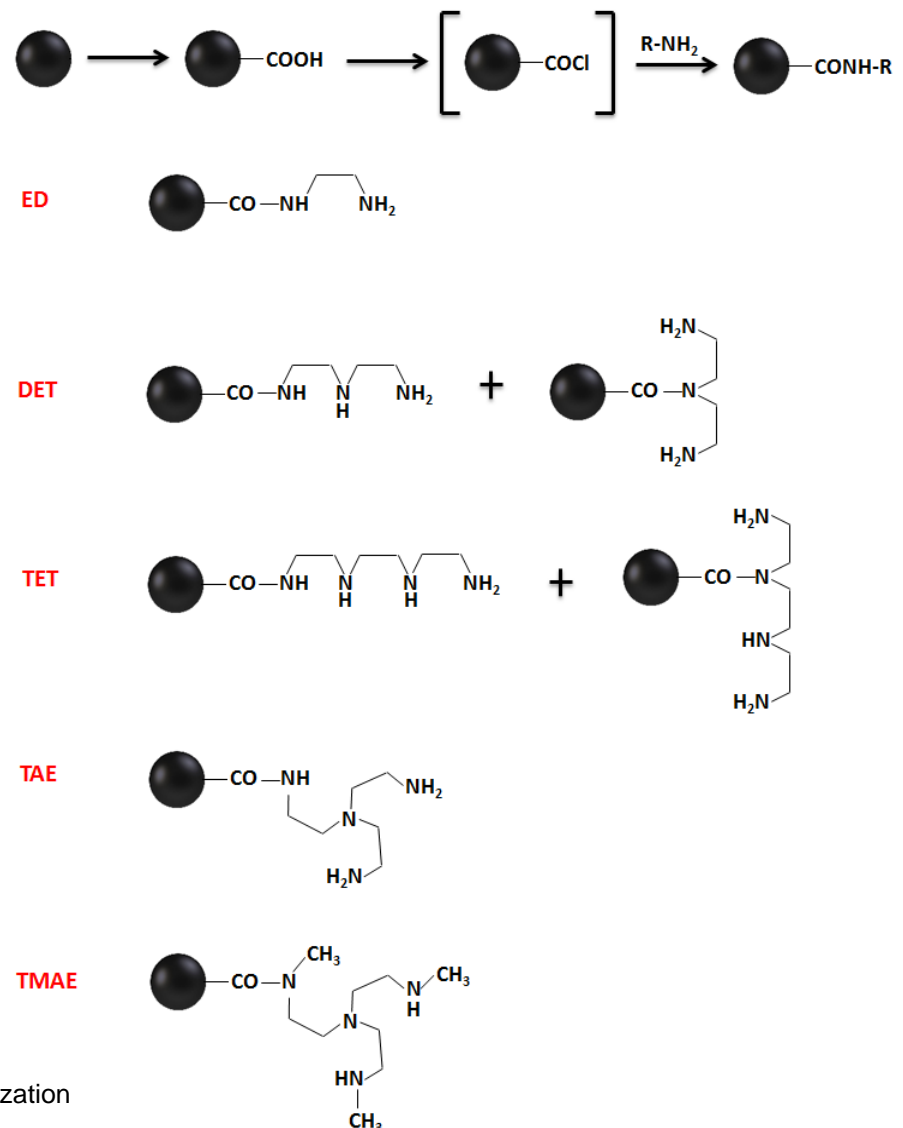
0.602 0.154 0.264 0.420 0.349 0.169

Zeta potential (mV)

-10.5 15.9 19.4 21.3 27.5 21.0



Trostová, S.; Stibor, I.; Karpíšková, J.; Kolská, Z.; Švorčík, V. Characterization of surface chemical modified carbon nano-particles. *Mater. Lett.* 102: 83-86, 2013.



P. Žáková, Z. Kolská, J. Leitner, J. Karpíšková, I. Stibor, V. Švorčík. Characterization of functionalized carbon nanoparticles. *Mater. Sci. Eng. C.* 60: 394-401, 2016.

Acknowledgement

This work has been funded by a grant from the Programme Johannes Amos Comenius under the Ministry of Education, Youth and Sports of the Czech Republic CZ.02.01.01/00/22_008/0004558 Advanced MULTIScale materials for key Enabling Technologies;

GAČR projet no. 23-05197S;

TACR project no. TK01030128 (VŠCHT, ZČU, UJEP, LISS, a.s.).

Thanks to all colleagues for a nice and successful cooperation

Thanks to colleagues from UCT Prague

Other research at CENAB PŘF UJEP



Přírodovědecká fakulta UJEP
Centrum Nanomateriálů a biotechnologií

Skupina nanovláčkových materiálů

Členové týmu a vybavení

Vedoucí skupiny: Petr Ryšánek, Ph.D. (petr.rysanek@ujep.cz)

profesor: prof. RNDr. Pavla Čapková, Ph.D.

Doktorandi: Mgr. Jakub Hoskovec, Mgr. Michal Syrový

Studenti NMgr. Bc. Eliška Šlanhofová, Bc. Jakub Doubek

Laboratorní přístroj pro přípravu nanovláknenných materiálů



Testery vzdušné a kapalinové propustnosti



DBD plazmovací jednotka pro aktivaci povrchů



Přístroj pro testování mechanických vlastností



Sdílené přístroje: XRD, XRF, XPS, hybridní zvlákňování

Co umíme

Zvlákňované polymery:

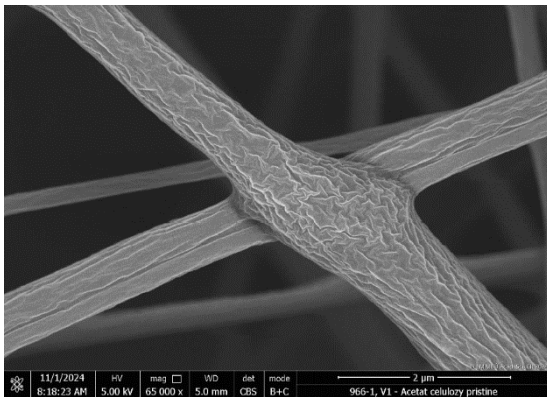
PA6; PA6,6; PS; PVA; PVDF; PCL; AC; Chitosan;
PUR; PAN; možno i jiné

Možnosti zvlákňování: jehla, více jehel, koaxiální jehla, pojízdná jehla, bezjehlové zvlákňování z hrany

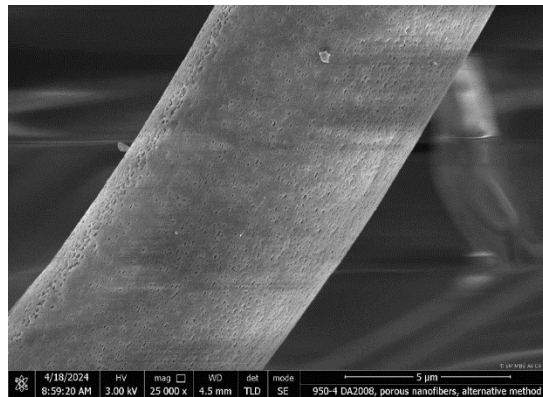
Kolektory: planární, rotační válec, rotační cévní, převíjecí kolektor



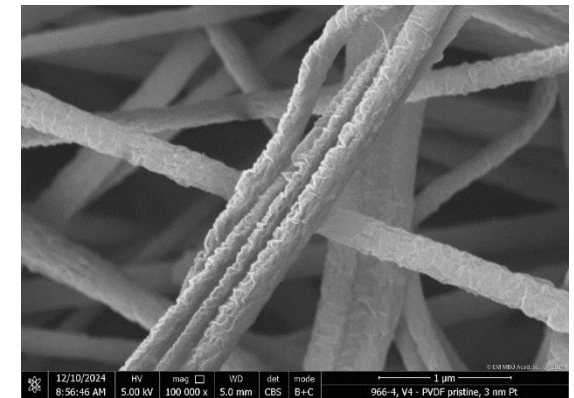
Možnost úpravy teploty a vlhkosti ve zvlákňovací komoře - tvorba porézních vláken



Acetát celulózy

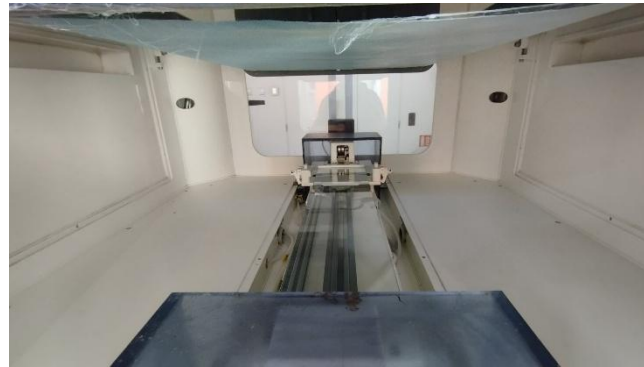


PS



PVDF

Nové zařízení od roku 2026



Elmarco NS1WS500U Nanospider

poloprovozní zařízení
zvlákňování ze struny, šíře pásu
nanovláken 50 cm
vhodné pro produkci velké množství
nanovláčenného materiálu

Zaměření výzkumu

Optimalizace procesu eletrospinningu pro různé druhy polymerů a studium vlivu parametrů zvláknění na strukturu a vlastnosti připravených nanovláken

Příprava antibakteriálních nanovláčenných membrán pro filtrace vzduchu

Úprava povrchových vlastností nanovláčenných membrán

Příprava smart textilií pro likvidaci polutantů

Příprava nanovláčenných membrán pro záchyt a separaci plynů (H_2 , CO_2)

Vývoj nových separátorů pro Li baterie

Publikace: 20 odborných článků zaměřených na výzkum nanovláčenných materiálů

2 patenty, 2 užitné vzory

Další výzkumné plány

- Využití nasorbovaného vodíku - vodíková mobilita, uložení energie
- Nanovlákná pro likvidaci polutantů (voda, vzduch)
- Nanovlákná pro boj s antibiotickou rezistencí
- Nanovlákná pro využití v katalýze a fotokatalýze

Možnosti spolupráce

- Příprava nanovláknenných materiálů pro vaše aplikace
- Modifikace nanovláknenných materiálů pro různé funkce
- Analýza pevných látek (XRD, XRF, digitální mikroskopie)



CENAB – Centre for Nanomaterials and Biotechnology

Jan Malý

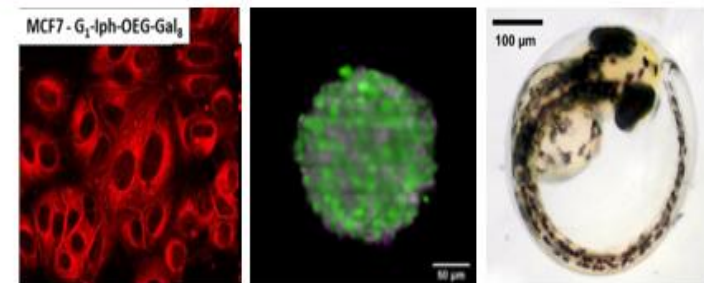
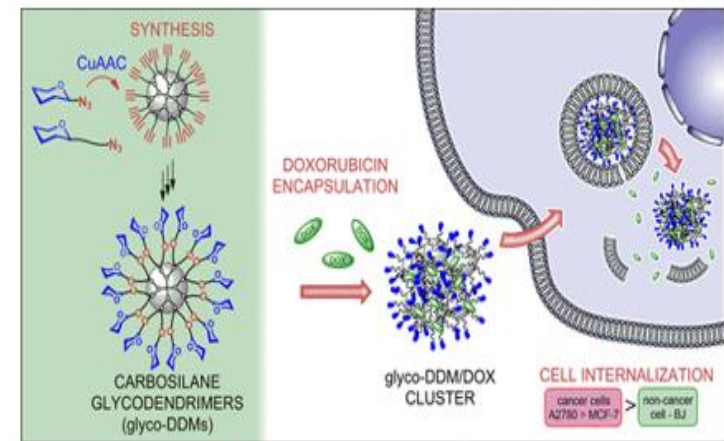
Faculty of Science UJEP

<https://cenab.ujep.cz/cs/>

Research topics - biotechnology

(1) Study of the interaction of nanomaterials with cells or biological models and their use for targeted drug delivery

- ▶ Nanomaterials can be used as effective **therapeutics**, as **vectors in targeting therapy** and for improving the biodistribution of drugs
- ▶ Study of wide range of nanomaterials (**polymers, nanocrystals, nanogels, dendrimers**) intended for medical applications and their interaction with cells or cell models *in vitro*
- ▶ The aim of the study is to describe the **behavior of cells and cell models** in terms of morphology, viability, changes in gene and protein expression, proliferation and differentiation **after interaction with nanomaterial**

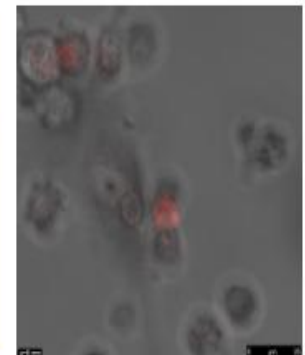
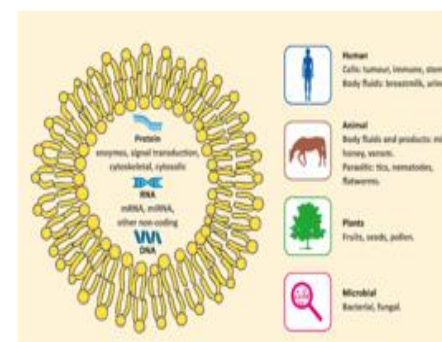
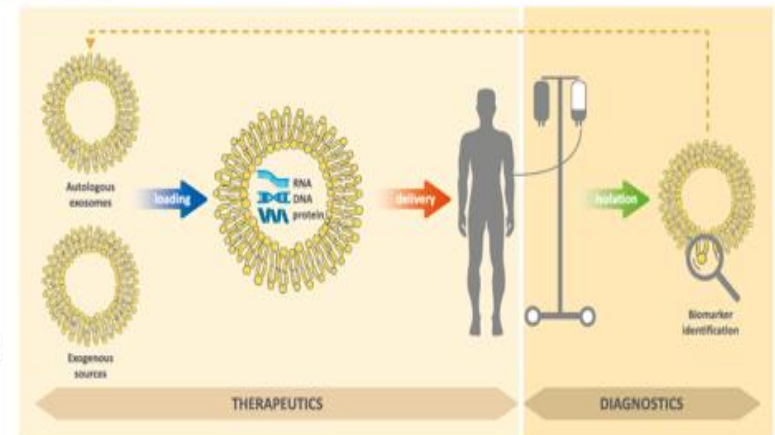


Complexity of biological model →

Research topics - biotechnology

(2) Exosomes as natural nanovesicles in intercellular communication and their biotechnological and biomedical applications

- ▶ **Exosomes are lipid nanovesicles arising from the plasma membrane of cells** - they are important indicators of physiological and pathological processes of the organism and individual cells.
- ▶ Exosomes have a significant effect as **diagnostic markers** and at the same time can affect, for example, **the development of metastases in cancer or the progression of degenerative changes**
- ▶ **Exosomes have an enormous biotechnological and biomedical potential** (diagnostics, drug delivery, immunomodulation, vaccines, regeneration medicine, cosmetics etc.)



Types of extracellular vesicles/exosomes we work with at CENAB

Mammalian cells

2D cell cultures
3D cell cultures

Cancer cells
(MFC-7,
GAMG,
HEK293 etc.)

Stem cells
(hMSCs)

Cancer
spheroids

Exosomes

100 000 g

Microvesicules
size 200-1000nm

Cancer cells
(MFC-7)

20 000g

Plants

Tabacco plant (or other type of plants)

callus

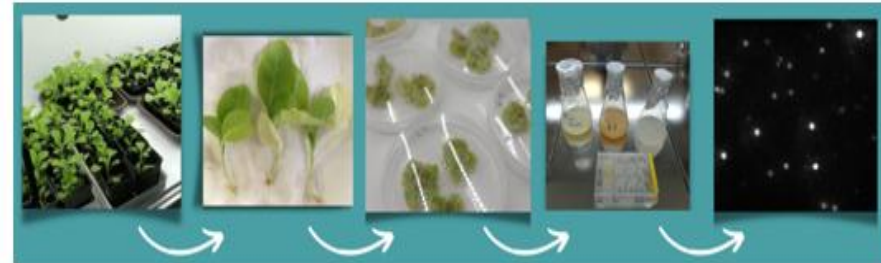
suspension
culture

100 000 g

Exosomes

Microvesicules
size 200-1000nm

15 000g



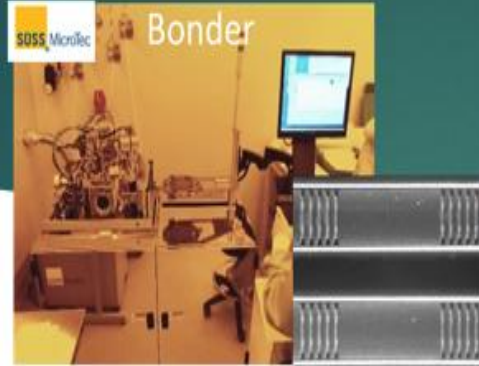
Running projects – exosomes

- ▶ **Galectin-positive glioblastoma exosomes - novel biomarkers and targets for glyconanotherapeutics** (collaboration - UEM AVČR, LF UK, MBU AVČR)
- ▶ **Plant exosomes in regenerative medicine – topical formulations based on hydrogels and nanofibrous materials** (collaboration UEM AVČR, Masaryk university Brno, Technical university Liberec)
- ▶ **Plant exosomes as a natural carriers of enzymes with antimicrobial activity in veterinary medicine applications** (collaboration with Dyntec spol s.r.o., BTU AVČR)
- ▶ **Plant exosomes with immunomodulatory properties for medical applications** (collaboration with BTU AVČR, LF Palacky University, VSCHT)
- ▶ **Plant exosomes as a DNA vaccine delivery system for fish vaccination** (collaboration with Dyntec spol s.r.o.)

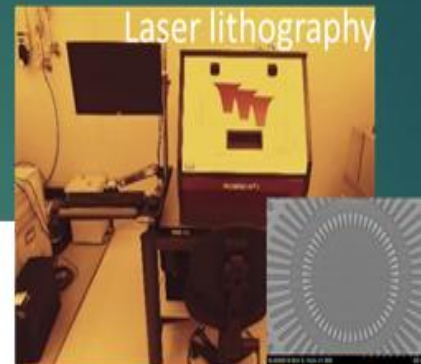
Infrastructure for microfluidics development



Basic preparation of substrates for subsequent lithographic processes



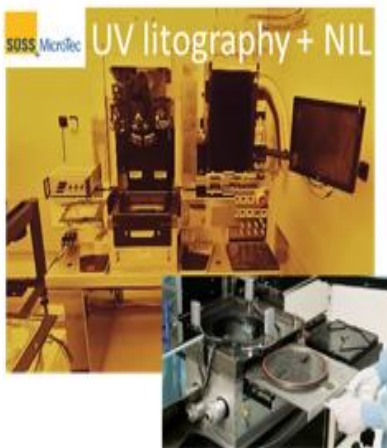
Joining flat substrates
Closure of microfluidic channels
Stacking of substrates
Hot embossing of polymeric materials



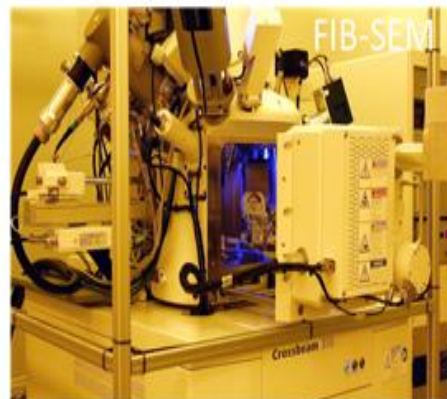
Production of chrome masks for UV photolithography
Preparation of microfluidics or so-called hard masters from SU-8 photoresist
Preparation of masks for DRIE



Production of chrome masks
Au/Pt deposition during electrode construction
Sample preparation for SEM



Replicating patterns on substrates through a chrome mask
Stacking of substrates and preparation for bonding processes
Soft-lithographic processes (UV-NIL)



SEM/FIB-SEM imaging
EBL and FIB lithography processes
3D tomography
Preparation of TEM slides



Creation of so-called hard masters for soft-lithographic processes
Etching of final structures mainly into silicon (MEMS, BioMEMS)

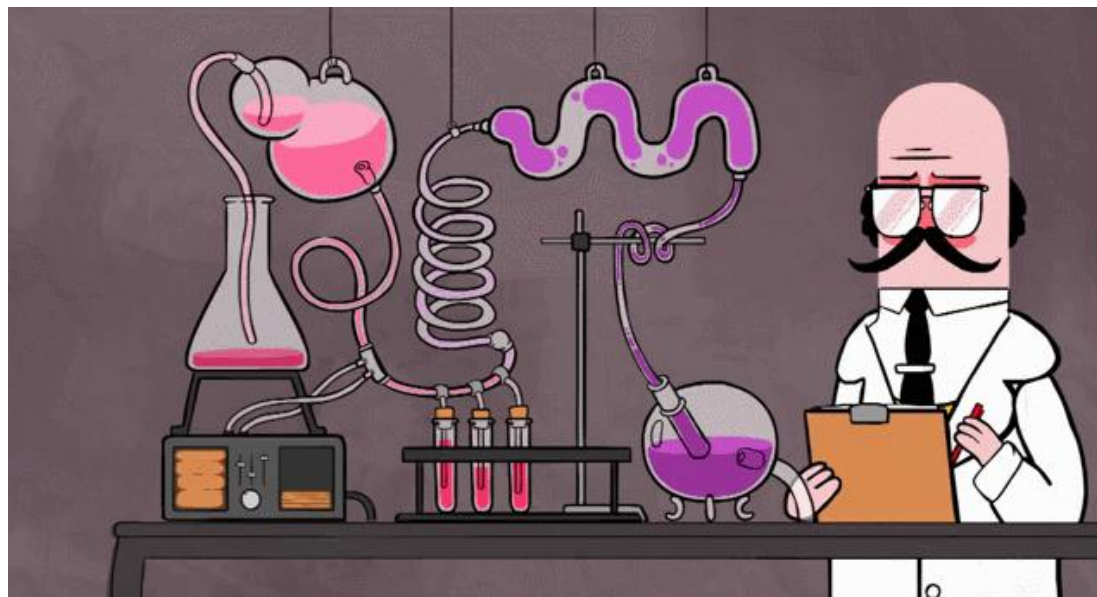
Nanovlákná – dr. Petr Ryšánek
(CENAB PŘF UJEP)

Bio(nano)technologie – dr. Jan Malý
(CENAB PŘF UJEP)

Další charakterizace –
doc. M. Kormunda, dr. A. Jagerová
(XPS, AFM, elipsometrie, vznosový plasma
reaktor, magnetronové naprašování)
(KFY PŘF UJEP)

Další výzkum a analytické vybavení –
FŽP UJEP, dr. Sylvie Kříženecká, doc. J. Orava

78. Sjezd chemiků, 2026, Ústí nad Labem
Sjezd chemických společností
po 7.9.2026 - čt 10.9.2026



Organizátor: Česká (a Slovenská) společnost chemická: (<https://csch.cz/>; <https://schems.sk/>)