DEPARTMENT OF SURFACE ENGINEERING AND OPTOELECTRONICS F-4

The research program is associated with vacuum science, technology and applications. The main activities are focused on plasma science, the modification of advanced biomedical materials and products for improved biocompatibility, the characterization of inorganic, polymer and composite materials with different thin films on the surface, the modification and characterization of fusion-relevant materials, the thermodynamics of trapped gases and methods for sustaining a ultra-high-vacuum environment, vacuum opto-electronics, and basic research in the field of surface and thin-film characterization by electron spectroscopy techniques.

Head:
Prof. Miran Mozetič

Non-equilibrium gaseous plasma is a suitable medium for tailoring the surface properties of hydrocarbons. These materials, especially when fibrous, may interact strongly with reactive gaseous particles, causing localized heating and thus a loss of treatment uniformity. A method for diminishing such effects is the application of a uniform gaseous plasma with a very low power density. Such a plasma is created at low pressure, which allows for the minimization of three-body collisions. The collision frequency depends slightly on the type of gas and the kinetic temperature, but with a major dependence is on the gas pressure. The frequency often increases as the square of the gas pressure and in a rough approximation the value of 1 s^{-1} is achieved at a pressure of several 10 Pa. Plasma of low power density cannot be sustained in small chambers due to the rapid diffusion of reactive particles towards the walls where they tend to be lost by neutralization, recombination and relaxation.

The characteristics of gaseous plasma were studied in an industrial scale reactor of volume 3 m^3. At a pressure of 13 Pa the plasma was sustained at a discharge power as low as 50 W. The discharge power density was therefore less than 20 W m^{-3}. Just for comparison, the minimal power density for sustaining plasma created by our surfatron discharge at the same vacuum level is over 10^7 W m^{-3}. Plasma in the large reactor was created by asymmetric capacitive coupled radio-frequency discharge. The powered electrode was immersed into the centre of the reactor, while the chamber walls made from stainless steel were grounded. Since the surface of the powered electrode was well over two orders of magnitude smaller than the surface of the grounded chamber, practically all the applied voltage appeared next to the powered electrode. The gas therefore remained at room temperature although the ionization and dissociation fractions of the gaseous molecules were reasonably high, of the order of 10^{-6} and 10^{-3}, respectively, corresponding to densities of 10^{16} and 10^{19} m^{-3}. Such a plasma is suitable for the treatment of fibrous polymer materials, such as textiles and allows for rapid functionalization with polar functional groups as well as the removal of surface impurities. A mild plasma created in oxygen or air, however, does not allow for a dramatic increase of surface morphology, so other reactive gaseous media should be used to obtain an extremely nanostructured surface of cellulose fibres.

Excellent functional properties for fibrous cellulose materials were achieved by the proper selection of plasma parameters.

The textile industry in developed countries is confronting the world's marketing conditions and competitive challenges that are driving it towards the development of advanced, highly functional textiles and textiles with higher added value. The conventional textile finishing techniques are wet chemical modifications where water and rather hazardous chemicals are used in large quantities and waste waters need to be processed before discharging the effluent, whereas the most problematic factors are ecological impacts to the environment and effects on human health. The increasing environmental concerns and demands for an environmentally friendly processing of textiles leads to the development of new technologies based on the modification of functional properties with nanoparticles. Such textiles exhibit improved radiation protection, bacteriostatic effects or improved flame-retardation. A major scientific concern about the application of nanoparticles is poor adsorption onto polymer fibres, which is due to a poor surface morphology. Although plasma created in air, oxygen, water vapour

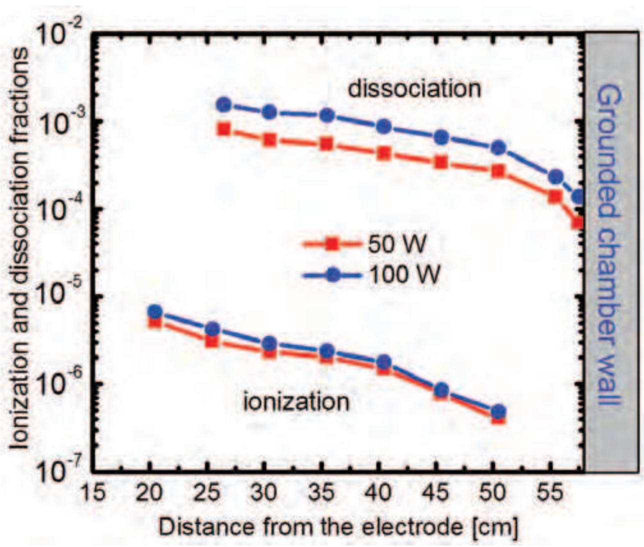

Figure 1: The ionization and dissociation fractions of oxygen molecules in plasma created in 3 m3 large reactor versus distance from the wall.

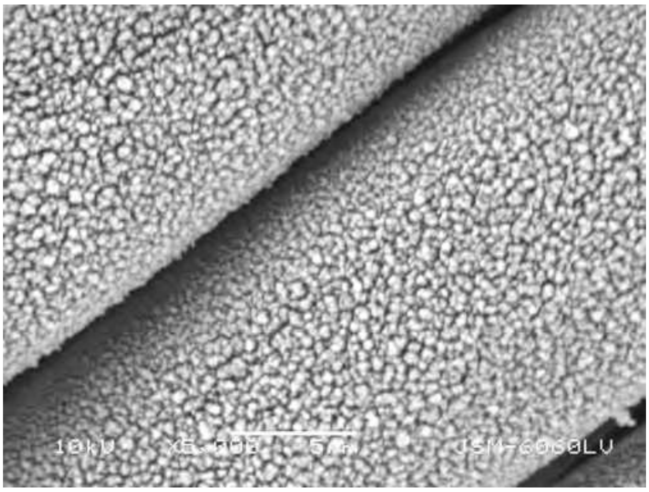

Figure 2: SEM image of cellulose fibres treated in moist CF_4 plasma.

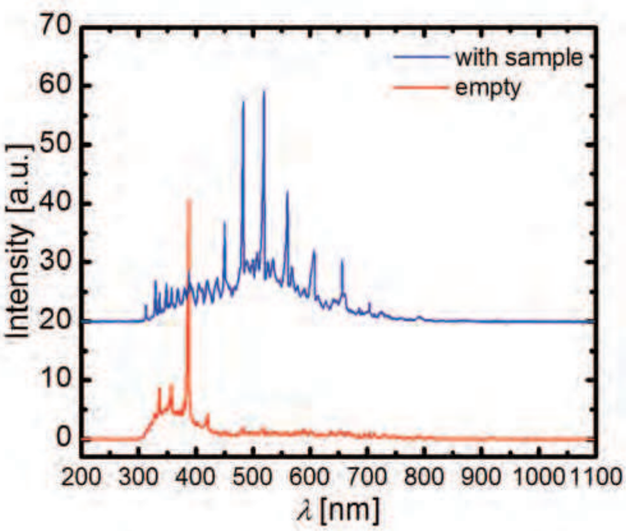

Figure 3: Optical spectra of plasma created in unloaded reactor in pure CF_4 (red curve) and reactor loaded with cellulose fabrics.

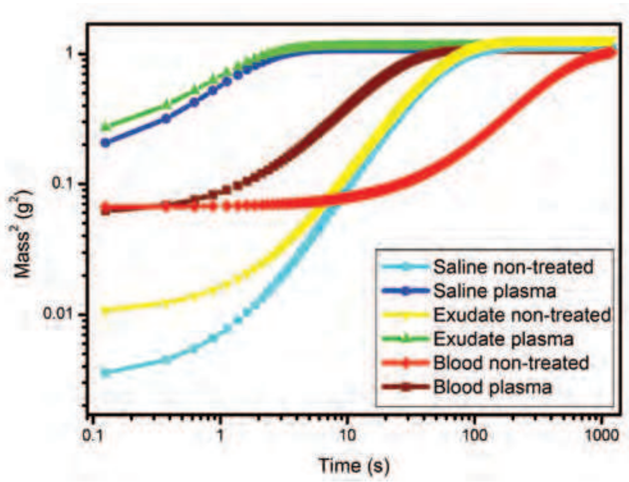

Figure 4: Average wetting rise curves for non-treated and plasma treated non-woven viscose for three different liquids.

or carbon dioxide allows for a stripped, cleaned and more distinct macro-fibril structure, it does not ensure the optimal adsorption of nanoparticles.

A method for the treatment of cellulose fibres that allows for almost optimal nano-structuring has been invented. The textiles were treated with a plasma created in tetraflourmethane (CF_4) with an admixture of water vapour (H_2O) in order to obtain an extremely rich surface morphology. The right treatment parameters allowed for etching resulting in a nanostructured surface with grain dimensions of roughly between 150 and 500 nm. The surface texture was uniform on a large area allowing for excellent absorption properties. The CF4 plasma is otherwise applied to obtain the opposite effect (hydrophobicity) but the right admixture of water vapour allowed for the creation of reactive particles that lead to extremely selective etching of cellulose fibres. Since the dissociation energy of a water molecule is several times lower than of CF_4 the O and OH radicals abound in plasma created in such a gas mixture and readily interact with fluorinated cellulose materials, causing etching of fluorine-rich segments. The etching was monitored using optical emission spectroscopy. The optical spectrum of plasma created in rather pure CF_4 is rich in CF_x bands as well as continua especially in the near-ultraviolet range of wavelengths. In the case the plasma reactor is loaded with wet cellulose fabrics the optical spectrum is completely different. Instead of the CF_x spectral features the spectrum revels an extremely strong emission that originates from the transitions of CO radicals. These radicals are formed upon the etching of cellulose material with gaseous plasma created in CF_4 gas with admixture of water vapour.

Wounds are considered as the major cause of morbidity and impaired quality of life, especially by patients suffering from diabetes. It has been estimated that over 1% of the world's population suffer from serious complications causing chronic ulcer wounds. The average cost of a treatment cycle is estimated to about €6600 for leg ulcers and €10,000 for foot ulcers. Wound dressings are regarded as the medical means of cleaning and protecting wounds in order to facilitate and accelerate the healing process. Although the healing process of wounds is a natural process, the speed of healing and fluid loss is still one of the major challenges. Significant improvements in developing wound-dressing products have been recorded since earliest times, but the properties of those materials currently used are still far from challenging the characteristics that chronic wounds exhibit. In order to improve the sorption kinetics of non-woven viscose materials, nowadays widely used as absorption material, we optimized the plasma parameters for the deep functionalization of such fibrous materials. Since charged particles are lost by neutralization on the fibres' surface we rather treated these materials with an extremely non-equilibrium plasma created in moist oxygen. The density of the charged particles was of the order of 10^{15} m^{-3}, while the neutral atom density was as high as 2×10^{21} m^{-3}. The neutral atoms do not interact aggressively with viscose materials, so they can diffuse deep into non-woven materials where they cause rather uniform functionalization with polar functional groups as well as the removal of any hydrophobic impurities that might be present on the fibre surfaces. The result of such a deep functionalization is a dramatic improvement of the sorption kinetics. Water and saline solution is soaked by plasma-treated materials about 100 × faster than by untreated materials, and the improvement for exudate and blood is up to an order of magnitude.

Plasma nano-science remains a priority of our research due to promising results and the broad range of future application from photovoltaics to biomedicine. We reported on the chemical synthesis of the arrays of silicon oxide nano-dots and their self-organization on the surface via physical processes triggered by surface charges. The method based on chemically active oxygen plasma leads to the rearrangement of nanostructures and eventually to the formation of groups of nano-dots. This behaviour is explained in terms of the effect of electric field on the kinetics of surface processes. The direct measurements of the electric charges on the surface demonstrate that the charge correlates with the density and arrangement of nano-dots within the array. Extensive numerical simulations support the proposed mechanism and prove the critical role of the electric charges in the self-organization. This simple and environment-friendly self-guided process could be used in the chemical synthesis of large arrays of nano-dots on semiconducting surfaces for a variety of applications in catalysis, energy conversion and storage, photochemistry, environmental, bio-sensing, and several others.

The characterization of surfaces and interfaces, layered structures and nanomaterials requires the application of advanced surface-sensitive analytical techniques. In our department X-ray photoelectron spectroscopy (XPS), secondary-ion mass spectroscopy (ToF-SIMS), Auger electron spectroscopy (AES) and atomic force microscopy (AFM) have been used successfully, both for basic research and the characterization of technological samples. Our research group is recognized worldwide as a leading group in the research field of the depth profiling of thin films and multilayers with a high depth resolution. In this field we continued studying the influences of different distortion effects on depth resolution upon measurements of the elements distribution in thin films and multi-layered structures. We succeeded to improve the existing mixing-roughness-information (MRI) model describing the influence of atomic mixing by ion bombardment, information depth of the analysed species, and the surface and interface roughness of the specimen. We introduced a new description for interface roughness with an asymmetrical function that differs from the Gaussian function used conventionally in analytical work. A comparison between the model and the experimental determination of the depth profiles shows that a realistic non-Gaussian function has to be taken into account if high accuracy in quantification of sputter depth profiles is required. This is of particular importance for analyses of ultra-thin multilayer structures (up to 10 nm), which are frequently involved in advanced applications.

Aminopropylsilanes bonded on silicon substrates promote adhesion between the inorganic material and organic compounds. Aminosilanes are self-assembled molecules since they form a multi-layer structure on a surface over a certain time span after deposition. Such a modified surface can be used in many applications from biological studies to attaching metal nanoparticles, and sensor applications. We performed a systematic characterization of a silicon surface modified by different self-assembled aminopropylsilanes (APS) with the purpose of using them in sensor applications. Single-crystal silicon wafers were modified with aminosilanes having different numbers of bonding sites: 3-aminopropyl-trimethoxysilane (APTMS), 3-aminopropyl-diethoxymethylsilane (APRDMS) and 3-aminopropyl-ethoxydimethylsilane (APREMS). We deposited the self-assembled layers from a solution of aminosilanes in toluene under various reaction conditions. The surface composition, the chemical bonding and the surface morphology were determined using XPS, ToF-SIMS, AFM and SEM. Our results show that the reactivity with the Si-oxide layer and the polymerization of aminosilanes depend on the number of possible bonding sites. The APTMS reacted most intensively with the Si-oxide layer; a less intensive reaction was observed for the APRDMS; and the least intensive reaction was observed for the APREMS. For aminosilane molecules with more bonding sites the effect of the polymerization is more intensive, resulting in island formation and a rougher surface. At 25 °C the polymerization is more intensive than at elevated temperatures, which we attribute to a faster deposition of the molecules at higher temperatures.

In collaboration with the company Melamin from Kočevje, Slovenia, we have studied novel materials for thermal insulation panels. Extensive work

The recently granted EU project "IP4Plasma" also involves a Slovenian industrial partner Tosama and the major goal is the development of functional textiles.

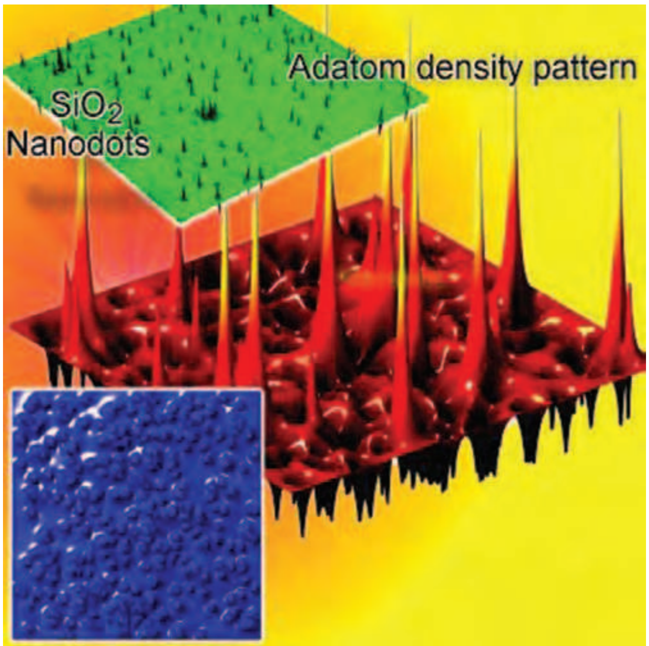

Figure 5: Simulated ad-atom density patterns defining QD movements upon the exposure of Si wafers to oxygen plasma and corresponding AFM images.

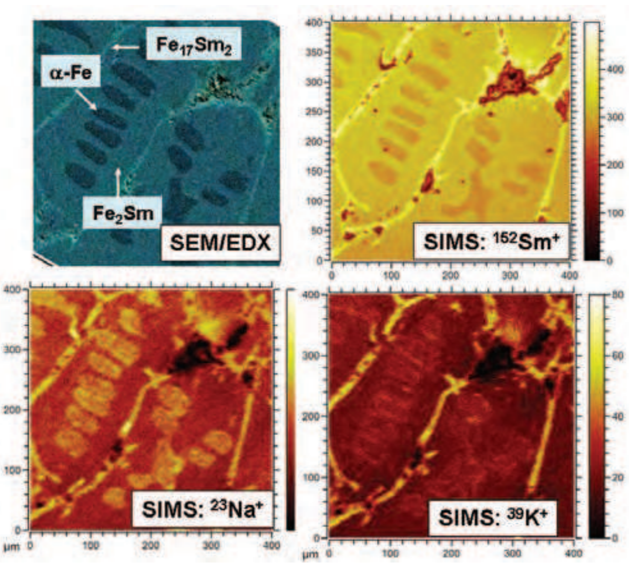

Figure 6: ToF-SIMS characterization of Fe-Sm alloy after annealing at 1250 °C allows for the identification of phases as well as the distribution of minor elements, thanks to a high sensitivity and lateral resolution.

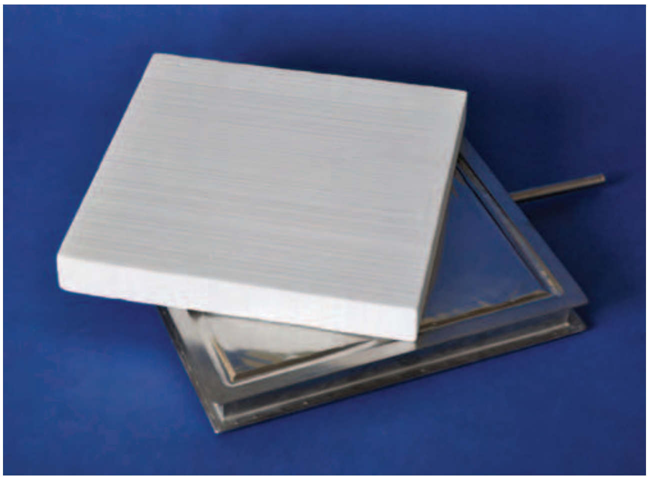

Figure 7: A melamine-formaldehyde foam sample that is to be encapsulated in vacuum insulation panels.

performed on rigid melamine-formaldehyde (MF) foams clearly showed it is a suitable material, which may substitute currently used organic foams.

All foams used in a standard way in industrial practise contain additives like bromine, which are added due to the required self-extinguishing properties of insulating materials. Such additives have to be abandoned by 2015. Besides the fact that the MF foams are already self-extinguishable since they contain appreciable amounts of nitrogen, they are also distinguished by a higher application temperature (180°C) comparing to the currently applied foams made on the basis of polystyrene or polypropylene. We tested the MF samples as potential candidates for core materials used in vacuum insulation panels. We developed a unique procedure for the evaluation of the thermal conductivity as a function of pressure in the foam, which also allows for long-term monitoring of the outgassing rate. The evacuated MF foams have a low thermal conductivity of about 6 W/K, which is equivalent to organic foams, but due to the extremely low outgassing rates they are even more suitable for vacuum panels.

Our fusion-related EURATOM project is focused on hydrogen-metal interaction, in particular with fusion relevant metals such as beryllium and tungsten. These two metals will represent the "first wall" (plasma-facing components) of international fusion reactor ITER. Thermal load and ion impact will induce tritium retention in mixed deposits of tungsten and beryllium. Since only little general data about such films exist, the knowledge should be improved so possible mechanisms involved at interaction between these materials and hydrogen were investigated. We studied properties of films containing various amounts of Be and W. Research on the outgassing rate was performed and subsequent hydrogen/deuterium gas permeation technique at temperatures up to 400 °C was elaborated. The same method has been applied for characterization of duplex membranes (a low-permeable film on a high-permeable substrate) and has been proved as a reliable technique, so a few papers have been published in last years on pure Be and W films. The most outstanding finding was an extremely high capability of nano-structured W film to retain hydrogen, reaching values as high as about 0.1H/W, which had not been expected since bulk tungsten is renowned for its very low hydrogen solubility. Films with various Be/W ratios were deposited at C. Lungu's laboratory at NILPRP, Bucharest, Romania, by the TVA method and thoroughly characterized by SEM and XPS in order to confirm the range of set values for Be/W ratio. A series of precise hydrogen-permeability measurements combined with long-term outgassing-rate measurements were realized. In addition, various experimental techniques were applied for the evaluation of film properties, like SEM, XRD, XPS and AFM.

Some outstanding publications in the past year

1. Lazović, S., Puač, N., Spasić, K., Malović, G., Cvelbar, U., Mozetič, M., Petrović, Z.: Plasma properties in a large-volume, cylindrical and asymmetric radio-frequency capacitively coupled industrial-prototype reactor. Journal of Physics D, Applied physics, 2013, vol. 46, no. 7, 075201-1–075201-8
2. Peršin, Z., Devetak, M., Drevenšek Olenik, I., Vesel, A., Mozetič, M., Stana-Kleinschek, K.: The study of plasma's modification effects in viscose used as an absorbent for wound-relevant fluids. Carbohydrate polymers, 2013, vol. 97, issue. 1, 143–151
3. Levichenko, I., Cvelbar, U., Modic, M., Filipič, G., Zhong, X., Mozetič, M., Ostrikov, K.: Nanoherding: plasma-chemical synthesis and electric-charge-driven self-organization of SiO_2 nanodots. The journal of physical chemistry letters, 2013, vol. 4, issue 4, 681–686
4. Liu, Y., Jian, W., Wang, J. Y., Hofmann, S., Kovač, J.: Influence of non-Gaussian roughness on sputter depth profiles, Applied Surface Science, 2013, vol. 276, 447–453
5. Zajec, B., Nemanič, V., Žumer, M., Porosnicu Corneliu Lungu, C.: Hydrogen permeability through beryllium films and the impact of surface oxides. Journal of Nuclear Materials, 2013, vol. 443, 185–194

Awards and appointments

1. Asst. Prof. Alenka Vesel; Award for the most cited article in the Journal *Dyes and Pigments* in years 2010 and 2011; title of the article: *"Colorimetric properties of reversible thermochromic printing inks"*

Organization of conferences, congresses and meetings

1. 20th International scientific meeting of Vacuum Science and Technology, Jeruzalem, Ljutomersko-Ormoške gorice, 9.–10. 5. 2013

INTERNATIONAL PROJECTS

1. Development of a Vacuum Measurement Method with Respect to Vacuum Glazing
   AGC Glass Europe
   Dr. Vincenc Nemanič
2. 7FP - EURATOM; Removal of Deposits by Neutral Oxygen and Nitrogen Atoms - 1.4.2.-FU; 3211-08-000102, FU07-CT-2007-00065
   Ministry of Higher Education, Science and Technology
   Prof. Miran Mozetič
3. 7FP - EURATOM-MHEST, 1.4.4-FU; Deuterium Interaction Kinetics with BE, W and Mixtures Relevant to ITER and DEMO
   Ministry of Education, Science and Sport
   Dr. Vincenc Nemanič
4. EFDA-JET 2013 Experimental Campaigns
   Ministry of Education, Science and Sport
   Dr. Aleksander Drenik
5. 7FP - EURATOM-MHEST, WP13-IPH-A01-P3-02/MESCS/PS, Permeation Measurements of Mixed Be/W Layers
   Ministry of Education, Science and Sport
   Dr. Vincenc Nemanič
6. EFDA-JET 2013 Analysis of Mixed Materials on ITER-like Wall Samples Using XPS/AES
   Ministry of Education, Science and Sport
   Dr. Vincenc Nemanič
7. COST MP1101; Biomedical Applications of Atmospheric Pressure Plasma Technology
   COST Office
   Prof. Uroš Cvelbar
8. NATO Planning Grant; SfP 984555; Atmospheric Pressure Plasma Jet for Neutralisation of CBW (Chemical Biological Weapons)
   NATO - North Atlantic Treaty Organisation
   Prof. Uroš Cvelbar
9. COST TD1208; Electrical Discharges with Liquids for Future Applications; COST Training School on Liquid Discharges
   COST Office
   Prof. Uroš Cvelbar
10. Plasma Synthesis and Application of Nanowalls
    Slovenian Research Agency
    Prof. Uroš Cvelbar
11. Plasma Synthesis and Deposition of Quantum Dots
    Slovenian Research Agency
    Prof. Uroš Cvelbar
12. Determination of Interdiffusion Coefficients in Nano-layered Structures by High Resolution Depth Profiling
    Slovenian Research Agency
    Asst. Prof. Janez Kovač
13. Plasma Treatment of Titanium Stents
    Slovenian Research Agency
    Prof. Uroš Cvelbar
14. Plasma-assisted Synthesis of Nano-objects
    Slovenian Research Agency
    Prof. Uroš Cvelbar
15. Formation of Nanocomposite Thin Films in Dusty Magnetized Plasma
    Slovenian Research Agency
    Asst. Prof. Alenka Vesel
16. Hydrogen Interaction With W/Be Films Relevant for Fusion Reactors
    Slovenian Research Agency
    Dr. Vincenc Nemanič
17. Characterization of Non-equilibrium Plasma for Modification of Nano and Biocompatible Materials
    Slovenian Research Agency
    Prof. Miran Mozetič
18. Ultra Nanoporous Nanowires of Metal Oxides
    Slovenian Research Agency
    Prof. Uroš Cvelbar
19. Development and Investigation of Optimal Regimes of RF Conditioning of Uragan-2M Vacuum Chamber Walls using Optical and Probe Methods of Plasma Diagnostics
    Slovenian Research Agency
    Prof. Miran Mozetič
20. Characterization of Processing Plasma with Catalytic and Cutoff Probes
    Slovenian Research Agency
    Prof. Miran Mozetič

RESEARCH PROGRAMS

1. Vacuum Technique and Materials for Electronics
   Dr. Vincenc Nemanič
2. Thin Film Structures and Plasma Surface Engineering
   Prof. Miran Mozetič

R&D GRANTS AND CONTRACTS

1. Near-Net Shape Nanoparticle-Reinforced Polymer-Composites for Highly-Loaded Advanced Mechanical Components with Superior Tribological Performance
   Asst. Prof. Janez Kovač
2. Organic-Inorganic Thin Film Structures for Electronics Components
   Asst. Prof. Janez Kovač
3. Research and Development of Integrated Overvoltage Protection Devices Based on Gaseous Discharger Toward a Reliable Miniature Technical Solution
   Dr. Vincenc Nemanič
4. Development of Advanced Processes for Attending High Efficient Nano Modified Textile Materials
   Prof. Miran Mozetič
5. Development of the Functional Textiles Used fot the Treatment of Diabetic Foot (Malum perforans)
   Prof. Miran Mozetič
6. New Materials for Printed Sensors and Indicators and their Integration in Smart Printed Matter
   Asst. Prof. Alenka Vesel
7. Multifunctional Nanostructured Films for Artificial Implants - Corrosion and Tribo-corrosion Processes
   Asst. Prof. Janez Kovač
8. Synthesis of Nanowires for Regenerative Energy Cells
   Prof. Uroš Cvelbar
9. Colour, Absorption and Protective Nanolayer Coatings for Aluminium Alloy
   Asst. Prof. Janez Kovač
10. Functionalization of Biomedical Samples by Thermodynamic Non-equilibrium Gaseous Plasma
    Prof. Miran Mozetič
11. Toward Ecologically Benign Alternative for Cleaning of Delicate Biomedical Instruments
    Asst. Prof. Alenka Vesel
12. Self-lubricating and Wear Resistant PVD Hard Coatings Based on (V,Cr,Al,Ti)N for Hot-working Processes
    Dr. Peter Panjan
13. Preparation of Hemocompatible Polymeric Surfaces for Biomedical Applications
    Dr. Ita Junkar

NEW CONTRACTS

1. Investigation of Melamine Foams as the Core Material in Vacuum Thermal Insulation
   Melamin Chemical Factory, d. d.
   Dr. Vincenc Nemanič
2. Investigation of Evaluation Methods for Vacuum Insulation Panel Performance Testing in Accordance with Draft of ISO Standard
   Stirolab, d. o. o.
   Dr. Vincenc Nemanič
3. Environmentally Friendly Cleaning of Components for Large Vacuum Systems
   Vacutech Vacuum Technologies and Systems, d. o. o.
   Prof. Miran Mozetič
4. Characteristics of Gaseous Plasma in Gaps
   Kolektor Sikom d. o. o.
   Prof. Uroš Cvelbar
5. Advanced Functional Implant
   Ekliptik, d. o. o.
   Dr. Ita Junkar
6. Nanowire Synthesis for Regenerative Energy Cells
   Kolektor Group, d. o. o.
   Prof. Uroš Cvelbar
7. Functionalization of biomedical samples with thermodynamically non-equilibrium gaseous plasma
   Bia Separations
   Prof. Miran Mozetič
8. Toward Ecologically Benign Alternative for Cleaning of Delicate Biomedical Instruments
   Eliptik, d.o.o.
   Asst. Prof. Alenka Vesel

VISITORS FROM ABROAD

1. Branislav Brindić, Marko Gocić, Ivan Tasić, Rade Nikolov, Harder Digital Sova, Niš, Republic of Serbia, 14.–15. 2. 2013
2. Dr. Davide Mariotti, Ulster University, Great Britain, 19.–24. 2. 2013
3. Dr. Nikša Krstulović, Institute for Physics, Zagreb, Croatia, 26. 4. 2013
4. Agelos Mourkas, Univerza v Ioannini, Ioannina, Greece, 12. 4. –12. 7. 2013
5. Yi Liu, Shantou University, Shantou, China, 21. 5.–3. 6. 2013
6. Prof. Jiang Wang, Shantou University, Shantou, China, 21. 5.–3. 6. 2013
7. Dr. Vladimir Sedlarik, Dr. Marian Lehockey, Dr. František Bilek, Tomas Bata University, Zlin, Czech Republic, 1.–3. 7. 2013
8. Dr. Petr Slobodian, Tomas Bata University, Zlin, Czech Republic, 17. 6. –14. 7. 2013
9. Dr. Xiao Xia Zhong, Shanghai University, Shanghai, China, 15.–18. 7. 2013
10. Dr. Aleš Mraček, Tomas Bata University, Zlin, Czech Republic, 19.–22. 8. 2013
11. Robert Olejnik, Tomas Bata University, Zlin, Czech Republic 27. 7.–5. 9. 2013
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14. Dr. Richard Clergereaux, Dr. Antoine Belinger, LAPLACE CNRS, Toulouse, France, 11.–14. 11. 2013
15. Dr. Nikša Krstulović, Institute for Physics, Zagreb, Croatia, 29. 11. 2013
16. Dr. Igor Levchenko, CSIRO Institute, Sydney, Australia, 10. 11.–2. 12. 2013
17. Dr. Nikša Krstulović, Institute for Physics, Zagreb, Croatia, 5. 12. 2013
18. Dr. Danijela Vujošević, Institute for public health of Montenegro, Podgorica, Montenegro, 15.–24. 12. 2013
19. Dr. Nikša Krstulović, Institute for Physics, Zagreb, Croatia, 23. 12. 2013
20. P. Eiselt, P. Zieger, F. Heinz, PlasmaIt GmbH, Lebring, Austria, 23. 12. 2013
21. Dr. Nikša Krstulović, Institute for Physics, Zagreb, Croatia, 30. 12. 2013

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4. Asst. Prof. Janez Kovač
5. **Prof. Miran Mozetič, Head**
6. Dr. Vincenc Nemanič
7. Asst. Prof. Alenka Vesel

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9. Dr. Martina Modic
10. Dr. Rok Zaplotnik

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11. Gregor Filipič, B. Sc.
12. Gregor Jakša, B. Sc.
13. *Borut Praček, B. Sc., retired 01.09.13*
14. Gregor Primc, B. Sc.
15. Nina Recek, B. Sc.
16. Marko Žumer, B. Sc.

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17. *Gregor Avbelj, B. Sc., left 01.10.13*
18. Tatjana Filipič, B. Sc.

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19. Urška Kisovec, B. Sc.
20. Janez Trtnik

BIBLIOGRAPHY

Original Article

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2. Milan Bizjak, Blaž Karpe, Gregor Jakša, Janez Kovač, "Surface precipitation of chromium in rapidly solidified CuCr alloys", *Appl. surf. sci.*, vol. 277, pp. 83-87, 2013.
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4. Aleksander Drenik, L. Salamon, Rok Zaplotnik, Alenka Vesel, Miran Mozetič, "Erosion of amorphous carbon layers in the afterglow of oxygen microwave plasma", In: Proceeding of the JVC-14, 14th Joint Vacuum Conference, EVC-12, 12th European Vacuum Conference, AMDVG-11, 11th Annual Meeting of the German Vacuum Society, CroSloVM-19, 19th Croatian-Slovenian Vacuum Meeting, [4-8 June 2012, Dubrovnik, Croatia], *Vacuum*, vol. 98, pp. 45-48, 2013.
5. Aleksander Drenik, Pavel Yuryev, Alenka Vesel, J. Margot, Richard Clergereaux, "Observation of plasma instabilities related to dust particle growth mechanisms in electron cyclotron resonance plasmas", *Phys. plasmas*, vol. 20, no. 10, pp. 100701-1-100701-4, 2013.
6. Lidija Fras Zemljič, Tina Tkavc, Alenka Vesel, Olivera Šauperl, "Chitosan coatings onto polyethylene terephthalate for the development of potential active packaging material", *Appl. surf. sci.*, vol. 265, pp. 697-703, 2013.
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