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 an ultra-high-vacuum environment, vacuum optoelectronics, and basic research in the field of surface and thin-film characterization by electron and ion spectroscopy techniques.

Head:

Prof. Miran Mozetič

The surface engineering of solid materials is often accomplished by the treatment of materials and products with non-equilibrium gaseous plasma. Such plasma is sustained by various electrical discharges in a range of powers up to about 10 kW. Suitable chambers of different dimensions have been developed and thoroughly verified by members of our research team. The plasma parameters depend on the applied power and coupling of the power supplies, pressure, gas flow through the discharge chamber and the properties of the materials facing plasma. Although plasma parameters can be roughly estimated using our expertize, the exact values cannot be predicted; therefore, they should be measured. Numerous techniques for plasma characterization have been introduced worldwide, but none is capable of providing all the parameters; therefore, a combination of different techniques is necessary for thorough plasma characterization. A comprehensive description of available techniques for plasma diagnostics has been published as a monograph chapter [1].

Gaseous plasma is a source of charged particles, neutral reactive species and radiation. The radiaton appears in a broad range of wavelengths. Particularly important is radiation in the ultraviolet (UV) range, from about 200 to 350 nm. This radiation is often absorbed in the surface film of solid materials, where it causes modifications of the material's structure. The penetration depth of UV photons depends on the wavelength and the type of material. For organic materials it is roughly of the order of a micrometre. Radiation is particularly suitable for crosslinking the surface film of polymers. UV radiation appears during the relaxation of highly excited states of both charged and neutral gaseous species, but in weakly ionized plasma suitable for surface engineering radiation from neutral species prevails. Radiation arising from the relaxation of atoms is usually discrete, so the integral intensity is not very large. More efficient sources are excited molecules, which radiate either in bands or continua. Although the integral UV radiation from molecules is often much stronger than from atoms, it is rarely used due to a natural obstacle: molecules tend to dissociate to parent atoms more extensively than they are excited because the excitation energy of UV-radiating states is usually larger than the dissociation energy. As a result, the majority of available discharge power is used for dissociation rather than UV radiation. This effect suppresses the efficiency of plasma UV sources. Our research team, however, managed to develop a powerful source of the UV radiation based on the excitation of molecular states of SO_x radicals. Energy efficacy of such UV sources is superior to other types of large-volume UV sources and is thus particularly suitable for the cross-linking of polymers that cannot withstand elevated temperatures. An appropriate patent application has been filed in 2016 and the patent was granted by the EU office in Munich in December 2018 [2]. The superior property of our innovative device is revealed by a comparison of plasma spectra with a commonly used commercial low-pressure mercury lamp. The spectra shown in Figure 1 were measured with the same spectrometer using the same integration time. Not only is our innovative plasma source much more efficient, but it also lacks radiation in the visible range, which causes extensive heating of the treated materials.

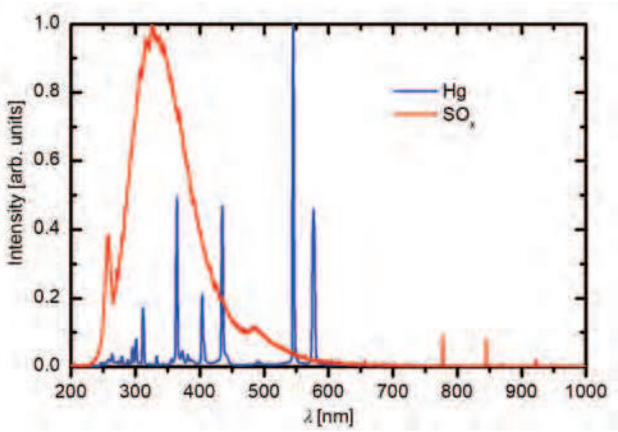

Figure 1: Spectra from a commercial Hg lamp (blue curve) and our patented source (red curve).

The research team also invented other plasma solutions of commercial interest and filled the appropriate patent applications. The application "Carbon nanostructured materials and methods for forming carbon nanostructured materials" discloses an original method for depositing carbon nanowalls using carbon dioxide as the precursor. The method is scalable to industrial-size substrates and enables a deposition rate of about 100 nm/s, which is one of the largest rates ever reported for the deposition of carbon nanostructures using non-equilibrium gaseous plasma. The patent application “Method for treatment medical devices made from nickel - titanium (NiTi) alloys” discloses a plasma technique that provides excellent biocompatibility. Not only is the activation of blood platelets supressed significantly, as compared to the known techniques for surface finishing of this alloy, but the methods of invention enable rapid edothellization as well. The technique is therefore suitable for the modification of commercial vascular stents made from this alloy. The third patent application filed in 2018 reveals a technique for the purification of biologically contaminated water. The application “Method for deactivation of a virus in water” protects our innovative technology, which takes advantage of the differences in the surface free-energy between water and organic materials, such as a virus. Viruses accumulate on the surface of bubbles containing water vapour, and the vapour is preferentially heated by gaseous plasma to high temperatures to produce a sterilization effect.

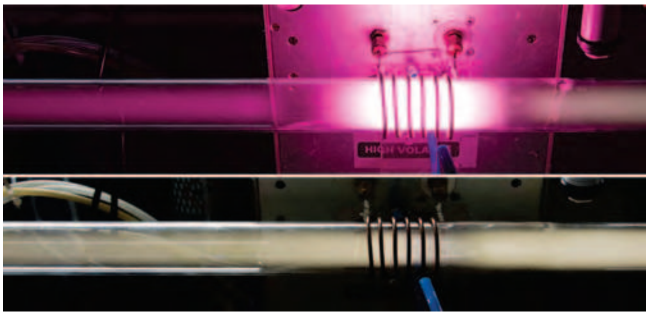

Figure 2: Ammonia plasma in E-mode (lower photo) and H-mode (upper photo).

Low-pressure ammonia plasma is used for the surface modification of various materials. Reactive gaseous species produced in ammonia plasma can be used for surface etching and thus removing undesired oxides or deposits, functionalization of surfaces with N-containing functional groups or for synthesizing various nitrides. Even though ammonia plasma is often used for the surface treatment and despite evident usefulness, the characteristics of ammonia plasma have not been studied thoroughly yet and no systematic measurements of the properties of low-pressure ammonia inductively coupled plasma (ICP) have been reported in the scientific literature. Low-pressure ammonia ICP plasma operates in two regimes: the so-called E and H modes. Images of both modes are shown in Figure 2. In the E-mode, plasma is partially dissociated and the main reactive species are NH and NH_2 radicals. Such plasma is particularly suitable for the treatment of delicate materials, for example, functionalization of polymer materials with nitrogen-containing groups including amino ($-NH_2$) groups. In H-mode, ammonia molecules are almost fully dissociated. In this case, the optical spectrum reveals only H and N atoms and some radiation arising from NH radicals, as well as N_2 molecular bands indicating partial association of N atoms to nitrogen molecules. Plasma in H-mode is therefore more suitable for etching or nitriding than functionalization with amino groups. Our detailed characterization of ammonia ICP plasma at different pressures and discharge powers showed hysteresis during transitions between E and H modes. Figure 3 shows the hysteresis in intensity arising from the excited NH radical. We systematically measured the behaviour of different nitrogen-containing reactive gaseous species in relation to discharge power and pressure. We have also found that the etching rate of the PET polymer in E-mode ammonia plasma is approximately a hundred times lower than in the H-mode under otherwise comparable discharge parameters. A detailed description of this phenomenon was published in an extensive article [3].

Neutral gaseous radicals are not stable, but are lost by different gas-phase and surface reactions. The loss rates influence plasma properties significantly. Therefore, the knowledge of how extensively atoms are lost on the surfaces of materials facing plasma is equally important as the knowledge of how they are produced in gaseous discharge. In order to estimate the atom density, one should know the atom-loss coefficient for different atoms and for various materials. Surface-loss rate is often expressed in terms of the recombination coefficient. Coefficients for some materials, such as metals, metal oxides, ceramics and glasses, have been measured by different authors using different techniques for decades and are easily found in the literature. The coefficients for polymers, however, have been measured rarely and results obtained by different authors vary significantly. Using our original technique, we systematically measured loss rates of hydrogen and oxygen atoms on the surface of three technologically important polymers: polyethylene terephthalate (PET), polystyrene (PS) and polytretrafluoroethylene (PTFE, often known as Teflon) at different fluxes of either type of atoms onto the polymer samples. We confirmed the hypothesis that the coefficient does not depend much on the atom flux since the surface quickly saturates with adsorbed atoms. The largest coefficient for hydrogen atoms was determined for PET and was approximately 0.0023 and the lowest was 0.0008 for PTFE (Teflon). The PTFE also exhibited the lowest coefficient for the heterogeneous surface recombination of oxygen atoms, which

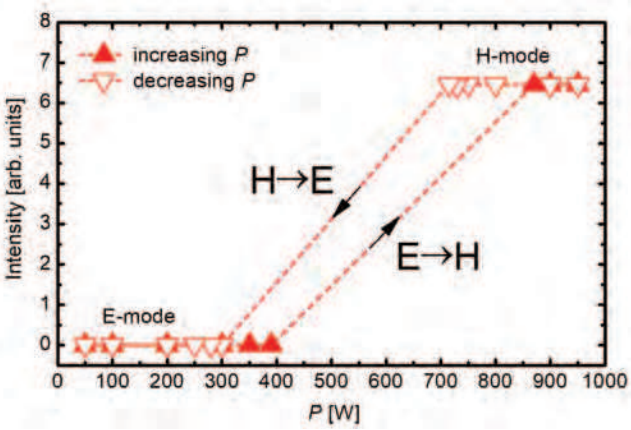

Figure 3: Hysteresis of the NH optical emission peak intensity at transitions between the E and H modes.

was approximately 0.001. The results are useful for numerous users of plasma technologies for tailoring surface properties of polymer materials. The corresponding paper was published as [4].

Although gaseous plasma has been used for surface functionalization of polymers on an industrial scale for decades, the scientific background on the initial stages of polymer functionalisation upon interaction with neutral oxygen atoms remained unknown, due to the lack of appropriate experimental setups. We managed to reveal the interaction kinetics by dosing O atoms in a highly precise manner. The preparation chamber of our XPS instrument was equipped with a source of O atoms that enabled an adjustable density of atoms in the ground state in a broad range from 3×10^{16} to 3×10^{20} m^{-3}. Such a huge range enabled the exposure of a polystyrene sample to O atoms of almost arbitrary fluences. Vacuum conditions were not broken between the exposure in the XPS pre-chamber and the characterization in the XPS main chamber; therefore, measurements were very reliable. We found that the initial reaction was breakage of the phenyl ring, because the intensity of the characteristic XPS shakeup peak dropped by more than a factor of two, even for a fluence as low as 2×10^{21} m^{-2}. Simultaneously, the hydroxyl functional group appeared on the sample surface. Other functional groups appeared at larger fluences. For example, the highly polar O-C=O functional group became measurable at fluences above 10^{22} m^{-2}. While the surface concentration of the hydroxyl group saturated at a fluence of about 10^{23} m^{-2}, other groups kept increasing with the increasing fluence of oxygen atoms. The characteristic shake-up peak was not influenced much after the sample received a fluence of approximately 2×10^{21} m^{-2} indicating that functionalization was limited to a very thin surface film, definitely thinner than the mean free path of the photoelectrons [5]. The behaviour of all the functional groups versus the O-atom fluence is shown in Figure 4.

The formation of different functional groups on a polymer surface upon treatment with O atoms has been revealed.

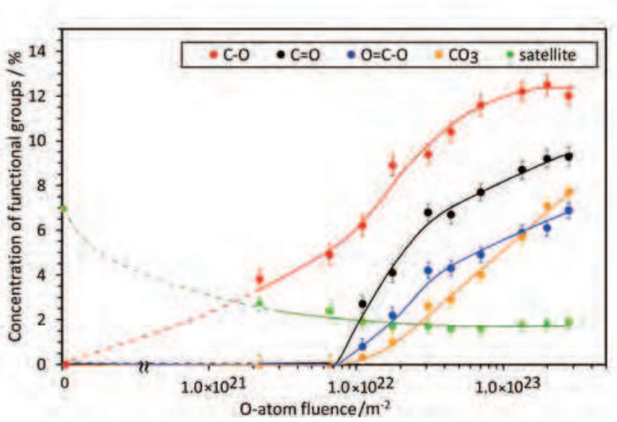

Figure 4: Formation of various functional groups on a polystyrene surface versus fluence of O atoms in the ground state.

Weakly ionized plasma, rich in neutral radicals, is suitable for surface functionalization, but almost useless when charged particles are the key reactants. This is the case when plasma is used for sputtering solid materials and thus the transfer of material from a target to a substrate. In collaboration with the Institute of Solid State Physics from Vienna University of Technology, Austria, we employed a moderately ionized gaseous plasma for the deposition of thin metal films. The films were then oxidized in our labs by treating them with a rather mild oxygen plasma. The original hypothesis was that the oxygen plasma treatment of zirconia alloys leads to the preferential formation of tetragonal zirconium dioxide (ZrO_2), which exhibits very good photocatalytic activity. We investigated the range of parameters where the stabilization of tetragonal zirconium dioxide was possible with alternative dopants, like aluminum or copper. Thin metallic films were produced with a dual-cathode magnetron-sputtering device using energetic argon ions. The deposited films resembled ZrAl and ZrCu alloys. After synthesizing they were further treated with oxygen plasma and then thoroughly characterized. Depth profiles were recorded by Auger electron spectroscopy (AES) to follow the film's composition and the progress of the oxidation. For the crystallographic analysis, X-ray diffraction (XRD) was employed, while the evolution of the surface morphology was determined by atomic force microscopy (AFM). Within a limited range of deposition and oxidation parameters, we managed to obtain tetragonal zirconia when copper was used for the stabilization. In the case of aluminum, no formation of the tetragonal ZrO_2 phase was observed over a broad range of parameters. The doping of Zr with Cu and subsequent treatment with oxygen plasma was therefore found to be a promising method for the stabilization of tetragonal zirconia. We managed to obtain the desired properties with a brief oxygen-plasma treatment of the order of seconds, and the method could also be scaled up using larger samples and treatment chambers [6]. This work can be considered as a proof of concept, and further work will be done with respect to the optimization of the dopant content and plasma treatment parameters.

Using surface-sensitive techniques such as time-of-flight secondary-ion mass spectroscopy (ToF-SIMS), X-ray photoelectron spectroscopy (XPS) and AFM we studied the adsorption of two corrosion inhibitors, propargyl alcohol (PA) and cinnamaldehyde (CIN) on a steel surface. These compounds are known to be effective corrosion inhibitors for lower-grade steel materials in acidising oilfield applications. We managed to confirm the adsorption of cinnamaldehyde and propargyl alcohol molecules on a steel surface due to the low detection limit and selectivity of the ToF-SIMS method, even for very thin layers of thickness in the nm range. In the ToF-SIMS analysis of the CIN corrosion inhibitor, a signal related to the CIN molecule was identified at 131.04 Da, corresponding to $C_9H_7O^+$ ions. The adsorption of PA molecules was also confirmed by a signal at 55.02 Da

The desorption kinetics of selected corrosion inhibitors has been revealed for the first time anywhere in the world.

($C_3H_3O^+$) related to the PA molecule in the positive part of the ion spectrum. The possibility of spatially resolved ToF-SIMS analyses with a high mass resolution allowed us to follow the lateral distribution of the adsorbed corrosion inhibitors. We managed to identify the non-homogenous distribution of CIN molecules on a steel surface, as revealed by Figure 5. A more homogenous distribution was observed for PA molecules on the steel surface, but some PA agglomerates were detected. For the first time anywhere in the world we showed that by using the SIMS method it was possible to study the temperature stability of corrosion inhibitors by annealing the samples and performing an *in-situ* ToF-SIMS analysis [7]. We estimated the desorption temperature for the CIN corrosion inhibitor to be 150 ± 10 °C, from which the desorption energy for the CIN layer on the C15 steel was calculated to be 122 ± 5 kJ/mol. For the PA corrosion inhibitor, desorption from C15 steel occurs over a wider temperature range between 100 °C and 300 °C, which allowed us to estimate the desorption energy for the PA corrosion inhibitor to be in the range of 107–167 kJ/mol.

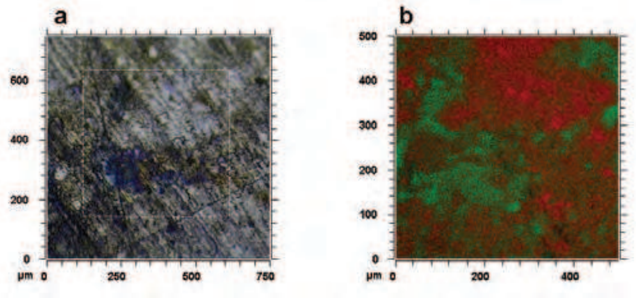

Figure 5: Optical (a) and ToF-SIMS molecular specific image (b) of the spatial distribution of the corrosion inhibitor cinnamaldehyde adsorbed on the C15 steel over an area of 500 × 500 µm².

In collaboration with the Department of Nanostructured Materials we invented a novel approach to synthesize electrically conductive ceramics reinforced by cellulose nanofibers. This material exhibits a rather high electrical conductivity and dielectric permittivity. Some rather hydrophobic nano-cellulose was introduced into alumina and yttria-stabilized zirconia at concentrations between 0.5 and 3 wt.%. A sintering procedure was performed using the spark-plasma technique. XPS characterization revealed the transformation of the cellulose fibrils into two-dimensional graphitic sheets upon heating during sintering. The sheets represented the key to remarkable electronic and dielectric properties. Thermal conductivity was actually decoupled from electron conductivity. We envisage that our results can pave the way to better composite materials for telecommunication and energy applications. The results of our research on these composite ceramics were published as [8].

Our research team has been involved in fusion-oriented research since 2005. A major contribution of our team is studying details about the interaction of hot hydrogen plasma with solid materials. The results of our research are useful for a better understanding of the plasma behaviour in current large and medium-sized fusion plasma reactors, as well as for giving directions about the construction details of future fusion reactors, including the largest international experimental thermofusion reactor (ITER), which is built in France. The vacuum chamber of the ITER plasma reactor weights 8000 tonnes and is made of special grade stainless steel. Tritium retention may represent a serious safety threat. Among the activities which could contribute to a more accurate prediction of the tritium retention was also our study of hydrogen permeation through the austenitic steel membranes AISI 316 LN ITER grade. Our measurements were carried out at different temperatures between 100 and 400 °C and in the pressure range between 50 and 1000 mbar. All membranes were only covered by native oxides, which were evidently modified by baking in vacuum conditions at 160 °C. This fact may be assumed relevant for the ITER operation, as similar conditions regarding the residual atmosphere could be readily met during every vacuum bake-out cycle [9].

Another important technological challenge is the long-term maintenance of low pressure in thermal insulating vacuum devices. Even in completely tight metal envelopes, gas accumulation, due to the outgassing of applied materials, represents the main problem. Among the gases that are not desorbed completely during pre-processing and which are dissolved in constructional metals, hydrogen is the most harmful. Fortunately, it is also the only gas that might permeate through the metallic envelopes. If we could effectively pump hydrogen the problem would be solved. So far, the selective pumping of hydrogen has not been realized. A heated metal membrane made of martensitic steel Eurofer was fixed to an extended part of a tight ultra-high vacuum (UHV) chamber. The initial hydrogen pressure was set in a broad range from 1.5 bar to 1×10^{-3} mbar at temperatures from 100 to 400 °C. The observed hydrogen permeation flow was expressed in the terms of the specific pumping speed, which is defined as the volume flow of hydrogen per unit surface area. At a pressure of 1 mbar and a temperature of 400 °C the permeation was about 1.6×10^{-6} L $s^{-1}cm^{-2}$. This is about the value needed in numerous applications so the membrane may be used as an innovative pump in specific applications. At lower pressures, this attractive pump performance was overwhelmed by the background outgassing of carbon dioxide and monoxide. At temperatures lower than 200 °C, the outgassing rate of carbon oxides was not detectable and the pumping continued into the 10^{-4} mbar pressure range.

Figure 6: Prof Janez Kovač opened the meeting organized by Strategic Partnership "Factories of Future".

Researchers have been active in the preparation of the Slovenian Smart Specialisation Strategy (S4), which is the key strategic document for the modernization of the Slovenian economy and the development of specific sectors that have been indicated as comparative advantages of our country. Smart specialisation is a platform for concentrating development investments in areas where Slovenia has the critical mass of knowledge, capacities and competences and where there is innovation potential for placing Slovenia within global markets and thus enhancing its recognisability. Plasma technologies have been recognized as one of six key emerging technologies and a member of our research team has been assigned the leader of this horizontal activity. Furthermore, the head of our research team has been assigned as Board Member of the Strategic Research and Innovation Partnership "Factories of Future". The action plan has been prepared and it includes R&D projects that will enable the introduction of plasma technologies into various sectors from the electronics industry to agriculture. Several meetings have been organized, with the aim of networking between the academic sector and industry. Numerous scientists and business people, renowned worldwide in the niche of plasma technologies, attended the meetings. Among the meetings, we organized a conference on vacuum science and technology, which was chaired by a group member, Prof. Janez Kovač (Figure 6).

Some outstanding publications in the past three years

[1] Mozetič, Miran, Vesel, Alenka, Primc, Gregor, Zaplotnik, Rok. Introduction to plasma and plasma diagnostics in Non-thermal plasma technology for polymeric materials: applications in composites, nanostructured materials, and biomedical fields. Amsterdam: Elsevier, 2019, 23-65.

[2] Lehocký, Marián, Stloukal, Petr, Sedlarik, Vladimír, Humpolíček, Petr, Vesel, Alenka, Mozetič, Miran, Zaplotnik, Rok, Primc, Gregor. Device and method for producing UV radiation: patent EP3168860 (B1). München: European Patent Office, granted on 19th Dec. 2018.

[3] Draškovič-Bračun, Aljaž, Mozetič, Miran, Zaplotnik, Rok. E- and H-mode transition in a low pressure inductively coupled ammonia plasma. Plasma processes and polymers, 2018, 15, 1-10.

[4] Zaplotnik, Rok, Vesel, Alenka, Mozetič, Miran. Atomic oxygen and hydrogen loss coefficient on functionalized polyethylene terephthalate, polystyrene, and polytetrafluoroethylene polymers. Plasma processes and polymers, 2018, 15, e1800021-1-e1800021-8.

[5] Vesel, Alenka, Zaplotnik, Rok, Kovač, Janez, Mozetič, Miran. Initial stages in functionalization of polystyrene upon treatment with oxygen plasma late flowing afterglow. Plasma sources science & technology, 2018, 27, 094005-1-094005-9.

[6] Eisenmenger-Sittner, Christoph, Nöbauer, C., Mozetič, Miran, Kovač, Janez, Zaplotnik, Rok. Stabilization of tetragonal ZrO_2 by oxygen plasma treatment of sputtered ZrCu and ZrAl thin films. Surface & coatings technology, 2018, 347, 270-277.

[7] Kovač, Janez, Finšgar, Matjaž. Analysis of the thermal stability of very thin surface layers of corrosion inhibitors by time-of-flight secondary ion mass spectrometry. Journal of the American Society for Mass Spectrometry, 2018, 29, 2305-2316.

[8] Kocjan, Andraž, Schmidt, Rainer, Lazar, Ana, Prado-Gonjal, Jesus, Kovač, Janez, Logar, Manca, Mompean, Francisco J., García-Hernández, Mar, Ruiz-Hitzky, Eduardo, Wicklein, Bernd. In situ generation of 3D graphene-like networks from cellulose nanofibres in sintered ceramics. Nanoscale, 2018, 10, 10488-1049728.

[9] Nemanič, Vincenc, Žumer, Marko. Hydrogen pumping with a hot martensitic steel membrane. Vacuum, 2018, 151, 1-17.

Patents granted

1. Matej Holc, Ita Junkar, Gregor Primc, Miran Mozetič, Jernej Iskra, Primož Titan, Method of treating garlic cloves, SI25440 (A), Urad RS za intelektualno lastnino, 31. 12. 2018.
2. Marián Lehocký, Petr Stloukal, Vladimír Sedlarik, Petr Humpolíček, Alenka Vesel, Miran Mozetič, Rok Zaplotnik, Gregor Primc, Device and method for producing UV radiation, EP3168860 (B1), European Patent Office, 19. 12. 2018.

INTERNATIONAL PROJECTS

1. COST CA15114; Anti-Microbal Coating Innovations to prevent Infectious Diseases (AMICI)
   Prof. Uroš Cvelbar
   Cost Office
2. COST TD1305; Improved Protection of Medical Devices Against Infection (IPROMEDAI)
   Dr. Martina Modic
   Cost Office
3. H2020 - PEGASUS; Plasma Enabled and Graphene Allowed Synthesis of Unique nano Structures
   Prof. Uroš Cvelbar
   European Commission
4. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Asst. Prof. Rok Zaplotnik
   European Commission
5. H2020 EUROfusion - Education-ED-FU
   Prof. Miran Mozetič
   European Commission
6. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
   Asst. Prof. Rok Zaplotnik
   European Commission
7. Making Luminescent C-dots and GQDs Based on Atmospheric Pressure Microplasma-Liquid Interaction
   Prof. Uroš Cvelbar
   Slovenian Research Agency

8. Quantitative Depth Profiling of Ultra-Thin Films
   Prof. Janez Kovač
   Slovenian Research Agency
9. Catalytic Activity of Nanomaterials for Elimination of Sulfur
   Prof. Uroš Cvelbar
   Slovenian Research Agency
10. Determination of Neutral-Atom Densities in Large Plasma Reactors
    Prof. Miran Mozetič
    Slovenian Research Agency
11. Plasma Assisted-Deposition of Antibacterial Coatings and their Testing
    Dr. Martina Modic
    Slovenian Research Agency
12. Plasma-Assisted Design of Multifunctional Carbon Nanowalls Bio-Sensor
    Prof. Uroš Cvelbar
    Slovenian Research Agency
13. Innovative Coatings for Bare Metallic Vascular Stents for Reduction of Restenosis and Acceleration of Natural Endothelization
    Prof. Miran Mozetič
    Slovenian Research Agency
14. Transport and Field Emission Properties of Low-Dimensional Molybdenum and Tungsten Based Nanomaterials
    Dr. Vincenc Nemanič
    Slovenian Research Agency
15. DST Treasurer of ECS - Division Dielectric Science and Technology DST, eElection ECS
    Prof. Uroš Cvelbar
    Slovenian Research Agency
16. Catalytic Probes for Characterization of Hydrogen Plasma
    Asst. Prof. Gregor Primc
    Slovenian Research Agency
17. Control of Chemical Composition of Thin Films by High Resolution Mass Spectrometry of Secondary Ions
    Prof. Janez Kovač
    Slovenian Research Agency
18. Advanced Catalysts based on Multilayered Vertically Oriented Graphene Nanostructures
    Prof. Alenka Vesel
    Slovenian Research Agency
19. Consequences of electron emission from hot plasma-facing components in nuclear fusion reactors
    Prof. Miran Mozetič
    Slovenian Research Agency

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. Nanoscale engineering of the contract interfaces for green lubrication technology
   Prof. Janez Kovač
2. Multifunctional electrospunned nanofibers development and dynamic interaction studies with pathogen bacteria
   Prof. Miran Mozetič
3. Understanding plasma processes and thin film growth in High Power Impulse Magnetron Sputtering
   Prof. Uroš Cvelbar
4. Plasma-assisted wound treatment and topical introduction of molecules
   Prof. Uroš Cvelbar
5. Novel higly sensitive and fast water qulity monitoring sensors
   Prof. Uroš Cvelbar
6. Advanced surface finishing technologies for antibacterial properties of patient specific 3D printed implantable materials
   Asst. Prof. Ita Junkar
7. New generation of superior creep resistant steels with nanoparticles modified microstructure
   Prof. Uroš Cvelbar
8. Development of new, environment-friendly approaches for plant and human virus inactivation in waters
   Asst. Prof. Gregor Primc
9. Advanced hydrodesulphurisation with catalyst nanomaterials
   Prof. Uroš Cvelbar
10. Advanced hemocompatible surfaces of vascular stents
    Asst. Prof. Ita Junkar
11. Evaluation of the range of plasma parameters suitable for nanostructuring of polymers on industrial scale
    Prof. Miran Mozetič
12. Selective plasma oxidation of FeCrAl alloys for extended-lifetime of glow plugs for diesel engines
    Prof. Janez Kovač
13. Innovative configuration of inductively coupled gaseous plasma sources for up-scaling to industrial-size reactors
    Prof. Miran Mozetič
14. Food for future - F4F
    Prof. Alenka Vesel
    Ministry of Education, Science and Sport
15. Potential of biomass for development of advanced materials and bio-based products
    Asst. Prof. Ita Junkar
    Ministry of Education, Science and Sport
16. Building blocks, tools and systems for the Factories of the Future – GOSTOP
    Prof. Miran Mozetič
    Ministry of Education, Science and Sport
17. Development of nanostructured biosensors for diagnosis/treatment of cancer and surfaces with antibacterial
    Dr. Metka Benčina
    Ministry of Education, Science and Sport
18. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
    Prof. Miran Mozetič
    Ministry of Economic Development and Technology
19. Novel type of antibacterial coatings on textile materials and plastics with controllable release of antibacterial agent
    Prof. Uroš Cvelbar
    Ministry of Education, Science and Sport
20. Preparation and Analysis of Samples for Customer
    Prof. Uroš Cvelbar
    Tomas Bata University in Zlin
21. Income from Coowners of Invention for Reimbursement of Costs for IP Protection in the Case of EVT140_Mozetič_Carbon Nanowall
    Prof. Miran Mozetič
    Nagoya University

NEW CONTRACTS

1. Ecologically benign technology for joining polymeric products
   Asst. Prof. Gregor Primc
   Simtrona d. o. o.
2. Innovative configuration of inductively coupled gaseous plasma sources for up-scaling to industrial-size reactors
   Prof. Miran Mozetič
   Vacutech Vakuumske Tehnologije in Sistemi d. o. o.
3. Regulation of mutual relations between the Company and JSI in joint research and development ("KET4CleanProduction")
   Asst. Prof. Ita Junkar
   Brinox Inženiring d. o. o.

VISITORS FROM ABROAD

1. Dr. Marian Lehocky, Tomas Bata University, Zlin, Czech Republic, 16–17 January 2018
2. Dr. Danijela Vujošević, Institute for Public Health of Montenegro, Podgorica, Montenegro, 18–21 January 2018
3. Prof. Hiroki Kondo, Nagoya University, Nagoya, Japan, 16–20 January 2018
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9. Dr. Suzana Petrović, Vinča Institute of Nuclear Science, Belgrade, Serbia, 13–19 May 2018
10. Dr. Robert Olejnik, Tomas Bata University, Zlin, Czech Republic 13–19 May 2018
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12. Prof. Dr. Nandakumar Kalarikkal, Mahatma Gandhi University, Kottayam, India, 3–7 June 201
13. Prof. Paul Paulsen, University of Vienna, Vienna, Austria, 5 July 2018
14. Dr. James Walsh, University of Liverpool, Liverpool, United Kingdom, 5 July 2018
15. Prof. Hiroki Kondo, Nagoya University, Nagoya, Japan, 4–7 July 2018
16. Prof. Zdenko Machala, Comenius University, Bratislava, Slovakia, 5–6 July 2018
17. Dr. Petr Slobodian, Tomas Bata University, Zlin, Czech Republic, 4–6 July 2018
18. Prof. Masaru Hori, Nagoya University, Nagoya, Japan, 4–7 July 2018

19. Prof. Kursat Kazmanli, Prof. Dr. Mustafa Kamil Ürgen, Dr. Cagatay Yelkarasi, Istanbul Technical University, Istanbul, Turkey, 3–7 July 2018
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Review Article

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Klimov, J. Ricker, J. Scherschligt, J. Stone, Gregory F. Strouse, Ivana Capan, M. Buljan, Slobodan Milošević, Christian Teichert, S.R. Cohen, A.G. Silva, Marián Lehocký, Petr Humpolíček, C. Rodriguez, J. Hernandez-Montelongo, D. Mercier, M. Manso-Silván, G. Ceccone, A. Galtayries, Karin Stana-Kleinschek, Ivan Petrov, Joseph E. Greene, José Avila, C.Y. Chen, B. Caja-Munoz, H. Yi, A. Boury, S. Lorcy, Maria C Asensio, J. Bredin, T. Gans, D. O'Connell, J. Brendin, F. Reniers, Andrej Vincze, M. Anderle, L. Montelius, "Recent developments in surface science and engineering, thin films, nanoscience, biomaterials, plasma science, and vacuum technology", *Thin solid films*, 2018, **660**, 120-160.

PUBLISHED CONFERENCE CONTRIBUTION (INVITED LECTURE)

1. Ita Junkar, Metka Benčina, Mukta Vishwanath Kulkarni, Barbara Drašler, Neža Repar, Damjana Drobne, Darij Kreuh, Janez Mohar, Rene Mihalič, Aleš Iglič, Miran Mozetič, "Surface finishing procedures for custom made medical implants", In: Joško Valentinčič (ed.), *WCMNM 2018: The Congress incorporates: International Conference on Mult-Materials Micro Manufacturing, (4M), International Conference on Micro Manufacturing, (ICOMM) and Intrenational Forum on Micro Manufaturing, (IFMM)*, 2018, 9-15.

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3. Andrea Jurov, Uroš Cvelbar, Martina Modic, Zoran Lj. Petrović, Nikola Škoro, Kosta Spasić, Nataša Hojnik, Danijela Vujošević, Vesna Vuksanović, Marina Đurović, "Optimal atmospheric pressure plasma Jet parameters for bactria sterilization", In: *IX. International Conference Plasma Physics and Plasma Technology, Minsk, Belarus, September 17-21, 2018: contrubuted papers*, 2018, 312-315.
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INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Tina Mavrič, Metka Benčina, Roghayeh Imani, Ita Junkar, Matjaž Valant, Veronika Kralj-Iglič, Aleš Iglič, "Electrochemical biosensor based on TiO_2 nanomaterials for cancer diagnostics", In: Aleš Iglič (ed.), Michael Rappolt (ed.), Ana J. García-Sáez (ed.), (Advances in biomembranes and lipid self-assembly **27**) 2018,, 63-105.
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MENTORING

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