DEPARTMENT OF SURFACE ENGINEERING AND OPTOELECTRONICS F-4

The research program of the department 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 spectroscopy techniques.

Head:
Prof. Miran Mozetič

The construction of a large plasma reactor for the modification of large samples as well as for the development of plasma-based technologies for our industrial partners has been accomplished. The length of the new plasma reactor is over 2 m. The plasma is excited at moderately low pressure by a high-frequency electrical discharge. The coupling between the high-frequency generator and the plasma in large volumes is far from being trivial. Both theoretical simulations and experimental work have been performed in order to optimize the coupling. Extensive theoretical investigation gave valuable results in terms of coupling efficiency and stability. The most promising configurations were realized in our workshop and experiments with suitable components of the matching network allowed for optimization in the real environment. The impedance of the secondary oscillating circuit at such large dimensions is prohibitively large, so it does not allow for application of a common induction coil due to a very high voltage amplitude. This problem was solved using a multilayered coil which turned out to be very useful for the achievement of good plasma uniformity along the discharge vessel as well as in terms of the coupling efficiency. The original idea was protected by a patent application filed in 2011 and submitted to the Slovenian Intellectual Property Office. Such a multilayered coil allows for a rather low peak voltage and thus a substantial decrease in the stray effects caused by the capacitive component of the coupling. In comparison with standard induction coils in use worldwide the innovative approach resulted not only in a very good homogeneity of the plasma along the 2-m-long discharge vessel made from a dielectric material but also for an at least 60% better coupling efficiency at powers exceeding 5 kW.

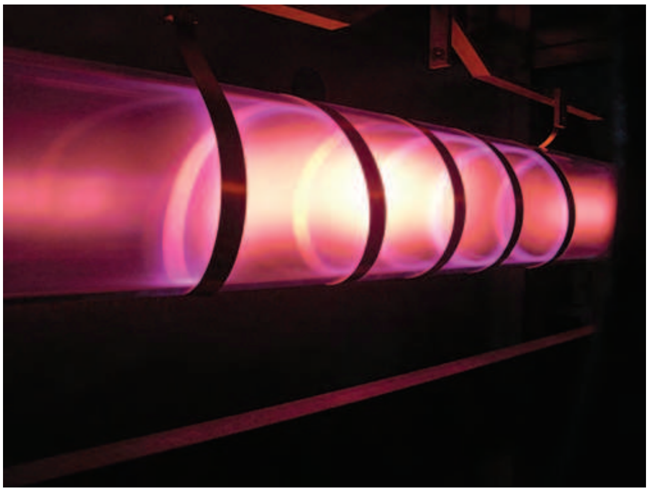

Figure 1: Gaseous plasma in the reactor with a 2-m-long discharge vessel.

The high-frequency discharge used for the excitation of the gaseous plasma at moderately low pressures is found either in E or H mode. The major characteristic of the E mode is the prevalence of the capacitive-coupling component between the powered electrode and the grounded one. A consequence of such a coupling is the formation of rather narrow sheaths next to the powered electrode. Free electrons gain energy from the electric field only in a sheath and are able to transfer a part of the energy to electrons far from the sheath only by diffusing from the sheath into the central part of the discharge vessel. In cases of particular interest, i.e., when samples are treated by plasma in order to functionalize their surfaces or remove surface impurities or etch selectively a particular component of composite materials, such a coupling is not useful since the plasma is not homogeneous in the entire volume. Reactive particles are lost by surface reactions and could be replaced only if the electron energy close to the samples is favorably large. In such cases it is better to keep a discharge in the H mode. The transition from E to H mode occurs at a sufficiently large density of oscillating magnetic field in the discharge chamber. The high-frequency magnetic field induces an appropriate oscillating electric field in the absence of any electrode. Free electrons oscillate in the electric field and may change their direction during collisions with molecules or atoms. If the mean free path is similar to the oscillation amplitude a resonance accumulation of electron energy will occur so the electrons will be able to gain enough energy for non-elastic collisions that can result in ionization or dissociation of a molecule. The H mode has therefore a unique advantage over the E mode since electrons are heated throughout a discharge vessel. Plasma in the H mode is thus rather homogeneous in the entire volume,

Two of our senior researchers, Prof. Miran Mozetič and Asst. Prof. Uroš Cvelbar, received the highest National Order for Innovations, Development Achievements and Application of Scientific Discoveries in Industrial Practice – the Puh award to the innovator.

practically independent of the nature of the samples placed inside the vessel. The appearance of each mode depends on numerous parameters, including the gas pressure and the useful power transferred from the high-frequency generator to the charged particles in plasma. In general, a low pressure and high magnetic field density will favor the H mode of an electrical discharge.

The transitions between the E and H modes were studied in detail for a smaller plasma reactor. Both discharge and plasma parameters were measured. The transition is far from being gradual. A sudden change in the discharge voltage, current and phase shift occurs at the transition. The plasma luminosity may increase by three orders of magnitude and so does the density of the free electrons at the transition from E to H mode. A subject of particular interest is the behavior of the neutral atom density at the transition in cases when the plasma is generated in gases containing two- or multi-atom molecules. Systematic research of the neutral oxygen atom density at the transition has been performed and a well-pronounced hysteresis was observed. The hysteresis was largest at moderately high pressures and the results of our research were published in a respected European physical journal.

A large plasma reactor, as a powerful source of neutral oxygen atoms in the ground state, has been developed in close collaboration with EURATOM partners.

Plasma created by high-frequency discharge in a dielectric vessel is thus a rich source of neutral atoms in the ground state. The atoms are suitable for modification of the surface properties of different materials. The modified surface characteristics depend on the flux of atoms onto the surface of a sample and a good control of the surface reactions needs precise adjustment of the neutral atom density in a processing chamber. The density could be adjusted by tuning discharge parameters, such as gas pressure, discharge voltage, current and the phase shift, but in applications such tuning is not always practical, especially in cases where the consumption of atoms by surface reactions changes during processing. It is much better to control and adjust the atom density in a processing chamber without changing the discharge parameters. To achieve such a configuration an innovative approach was applied. In a preferred embodiment the atom density is adjusted by mounting a movable active component into the processing chamber. The feed-back loop allows for active adjustment of the atoms' density and thus keeping the flux of atoms onto the surface of a sample independent of the surface properties or discharge parameters. This innovative approach has been also protected by a patent application.

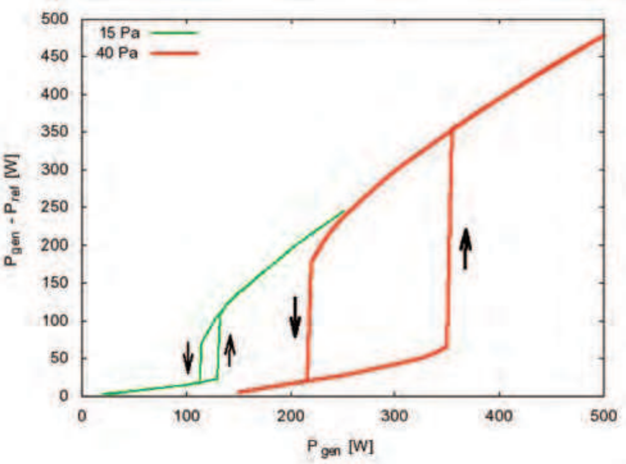

Figure 2: A hysteresis is observed at the transition of an electrode-less radiofrequency discharge between E and H modes. The hysteresis depends largely on the pressure in the discharge vessel.

We are partners in the European project "PlasmaNice": Atmospheric plasmas for nanoscale industrial surface processing, funded as part of the EU's 7th FP. Fifteen European partners from research and industry are involved in the project. It aims at the improvement of the recyclability of conventional fossil-fuel-based plastics for packaging and their replacement by renewable bio-based and biodegradable materials. The main objective of the PlasmaNice project is the development of technology and equipment for industrial in-line atmospheric plasma deposition of functional nanocoatings on various fibre- and polymer-based substrates for packaging. Our group carried out a precise surface characterization of plasma-deposited sol-gel coatings using XPS, AFM and SEM methods. We determined the correlation between the plasma process parameters, the degree of surface fuctionalization and the thickness of the deposited coatings. In the frame of the project we have developed a new method for the fast and in-line monitoring of the efficiency of air plasma surface activation at very high velocity, which has great potential for industrial applications.

Advanced surface analytical methods are indispensable for the characterization of the surfaces and interfaces of bulk materials, layered structures and nanomaterials. In our department X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), and atomic force microscopy (AFM) have been used successfully, both for basic research and the characterization of technological samples. A new method, secondary ion mass spectroscopy (TOF-SIMS), has been introduced in our laboratories. Our research group is world recognized for the depth profiling of thin films and multilayers at a high depth resolution.

Using surface analytical methods we investigated the formation of laser-induced periodic surface structures (LIPSS) and structural changes in Ni/Ti multilayers after laser irradiation. These periodic structures have potential applications in the field of nanolitography for the patterning of gratings with periodicity in the nm range. In collaboration with the Institute for Nuclear Sciences from Vinča, Serbia, magnetron sputtering was used to deposit (Ni/Ti) × 5 multilayers on a Si substrate with the thickness of the individual layer being 18 nm. Laser irradiation was performed with a Nd:YAG laser, operating at 1064 nm wavelength and with a pulse duration of 150 ps. The samples were treated with 100 and 200 pulses, the laser pulse energy was of 55 mJ and the total fluence was about 1 J/cm^2. The composition and surface morphology were monitored by Auger electron spectroscopy (AES) and by atomic force microscopy (AFM). Unexpectedly, we found the formation of a regularly rippled surface topography with a periodicity of 780 nm and a height of the ripples of 5–15 nm. This periodicity depends on the laser wavelength, the polarization and the angle of incidence. Depth profile AES analyses revealed that laser annealing also induced intermixing between the individual Ni and Ti layers with indications of the possible formation of Ni–Ti intermetallic compounds. An interesting outcome is the surface segregation of Ti, although the original topmost layer prior to laser irradiation was Ni.

Optimized coupling between the RF generator and the gaseous plasma allows for a dissociation fraction of the oxygen molecules exceeding 99% at room gas kinetic temperature.

An innovative permeation technique enabling the resolution of extremely low hydrogen fluxes with subsequent quantitative analysis has been invented. The technique has been applied for studying the interaction of hydrogen with fusion-relevant materials. Special attention was devoted to the suppression of a hydrogen background from the heated sample holder. Permeation measurements through various duplex membranes were realized. The fusion-relevant materials were deposited as thin films on Eurofer (a special stainless-steel material suitable as a construction material for future fusion reactors) substrates. The activities were performed within Euratom and EFDA projects. In cooperation with dr. W. Waldhauser at Joanneum Research Centre in Leoben (Austria) we found that silicon oxy-nitride and silicon nitride films could be prepared in a form with a very high permeation reduction factor (PRF). It was shown that 0.5-micrometer-thick SiN films have the highest PRF ever reported for such thin materials.

Pure beryllium, tungsten and mixed beryllium/tungsten films deposited onto Eurofer were investigated in this context, too. Both pure metals are intended to be applied as first-wall materials in future large fusion reactors, and thin films of mixed deposits are supposed to accumulate on the cooled walls of reactors during operation with a hot hydrogen plasma. Several beryllium and Be/W films were deposited in dr. Cristian Lungu's lab at "National Institute for Laser, Plasma and Radiation Physics" (NILPRP), Bucharest, Romania, using their thermionic vacuum arc method. Relatively reproducible results have been obtained. So far, no data on the permeation of such films have been reported. The unexpected kinetics could be well explained by our improved model and respecting the fact that data on bulk Be are rather old and inaccurate.

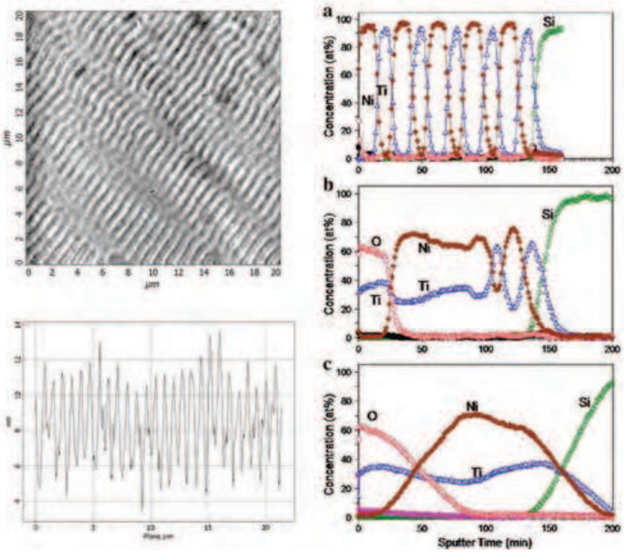

Figure 3: Surface topography and depth distribution of elements in the multilayered (Ni/Ti)x5/Si nanocomposites upon laser irradiation with 100 and 200 pulses. Unexpectedly, the laser induced periodical surface structures (LIPSS) were formed with a periodicity of 780 nm.

An investigation of the permeability of tungsten films deposited onto the Eurofer alloy by pulsed laser deposition (PLD) was realized for the first time. Tungsten films (1 and 10 μm thick) were provided by dr. Matteo Passoni at Politecnico di Milano, Italy. Their main feature was a nanocrystalline structure, which resulted in an over two orders of magnitude lower permeability compared to the values obtained for W films deposited by the combined magnetron sputtering and ion implantation (CMSII). Moreover, the hydrogen content in W films deposited by the PLD method was as high as ~0.1 H/W. Such high ratios have been reported only for hydrogen storage materials. These unexpected results are in agreement with theoretical models reported recently.

Our studies on thermionic energy conversion within a bilateral project with our partner at Arizona State University revealed that besides the structure of a nanostructured diamond film hydrogen plays the key role in achieving an extremely low work function. Hydrogen could be incorporated in the topmost layer just after the synthesis and also at any later time to recover the loss caused by its slow evaporation at elevated temperatures.

Our report on hysteresis in neutral oxygen atom density at the discharge transition from E to H mode was published in a respected European physical journal: Europhysics letters.

Our improved set-up for quantitative gas analysis was successfully applied also in an investigation of the breakdown-voltage drift with time in gas surge arresters. Consequently, with the proper gas mixture and thermal treatment, an extremely stable breakdown voltage was achieved. Our industrial partner Iskra Zaščite has already launched a new generation of reduced-size and stable breakdown voltage gas surge arresters on the global market.

The new open-pore rigid organic foams, which are stable at temperatures up to 200°C, were synthesized at the Melamin Company from Kočevje, Slovenia. Using our extremely sensitive techniques it was revealed that they also have an extremely low outgassing rate. Their low thermal conductivity, equal to 6 mW/(mK), and low cost in continuous production, make them extremely attractive as the core material in vacuum insulating panels (VIP). Novel VIP solutions are the most promising approaches towards energy-efficient devices and buildings.

Some outstanding publications in the past year

1. Zaplotnik, Rok, Vesel, Alenka, Mozetič, Miran. Transition from E to H mode in inductively coupled oxygen plasma : hysteresis and the behaviour of oxygen atom density. *Europhys. lett.*, 2011, vol. 95, no. 5, str. 55001-1-55001-5, doi: 10.1209/0295-5075/95/55001.
2. Jyotishkumar, P., Pionteck, Jürgen, Özdilek, Ceren, Moldenaers, P., Cvelbar, Uroš, Mozetič, Miran, Thomas, Sabu. Rheology and pressure-volume-temperature behavior of the thermoplastic poly(acrylonitrile-butadiene-styrene)-modified epoxy-DDS system during reaction induced phase separation. *Soft matter*, 2011, vol. 7, issue 16, str. 7248-7256, doi: 10.1039/C1SM05718A.
3. Jerman, Ivan, Mihelčič, Mohor, Verhovšek, Dejan, Kovač, Janez, Orel, Boris. Polyhedral oligomeric silsesquioxane trisilanols as pigment surface modifiers for fluoropolymer based Thickness Sensitive Spectrally Selective (TSSS) paint coatings. *Sol. energy mater. sol. cells*., 2011, vol. 95, iss. 2, str. 423-431, doi: 10.1016/j.solmat.2010.08.005.
4. Zajec, Bojan, Nemanič, Vincenc, Žumer, Marko, Bryan, Eugene N., Nemanich, Robert J. Ring-shaped field emission patterns from carbon nanotube films. Carbon (N. Y.). [Print ed.], 2011, vol. 49, issue 10, str. 3332-3339, doi: 10.1016/j.carbon.2011.04.020.

Patent granted

1. Method for synthesis of magnetic liposomes in electric field
   Kristina Eleršič, Miran Mozetič, Alenka Vesel, Janez Pavlič, Aleš Iglič, Andrej Žnidaršič, Aljoša Košak
   SI23095 (A), Urad RS za intelektualno lastnino, 31.1.2011.

Awards and Appointments

1. Two senior researchers received the highest Slovenian prize for innovations and knowledge transfer to industrial production – the Puh award.

Organization of Conferences, Congresses and Meetings

1. 2nd International Workshop on Plasma Nano-Interfaces and Plasma Diagnostics, Cerklje, Slovenia, 1st – 3rd April 2011
2. 18th International Scientific Meeting on Vacuum Science and Techniques, Bohinj, Slovenia, 2nd – 3rd June 2011
3. 112 IUVSTA executive council meeting, Strunjan, Slovenia, 9th – 11th September 2011
4. 4rd International Conference on Advanced Plasma Technologies (ICAPT-IV), Strunjan, Slovenia, 11th –13th September 2011

INTERNATIONAL PROJECTS

1. Atmospheric Plasmas for Nanoscale Industrial Surface Processing
   PlasmaNice
   7. FP
   EC; Dr. Johanna Lahti, Tampere University of Technology, Paper Converting and Packaging Technology, Tampere, Finland
   Asst. Prof. Janez Kovač
2. Removal of Deposits by Neutral Oxygen and Nitrogen Atoms - 1.4.2. – FU
   WP10-PWI-02-02/MHEST/PS; Detailed Characterization of Reaction Products from Removal of A-C:H with Mixed H2/N2 Plasmas
   WP11-PWI-02-04-01; Application of Neutral Atoms for Fuel Removal in Gaps
   EURATOM – MHEST
   7. FP - EURATOM, Slovenian Fusion Association – SFA
   Annex 3, 3211-08-000102, FU07-CT-2007-00065
   EC; RS, Ministry of Higher Education, Science and Technology, Ljubljana, Slovenia
   Prof. Miran Mozetič
3. Deuterium Interation Kinetics Metals Relevant to Iter or Demo - 1.4.4. – FU
   WP11-PWI-01-02-01/PS; Hydrogen Permeability of W/BE Films
   EURATOM – MHEST
   7. FP - EURATOM, Slovenian Fusion Association – SFA
   Annex 3, 3211-08-000102, FU07-CT-2007-00065
   EC; RS, Ministry of Higher Education, Science and Technology, Ljubljana, Slovenia
   Dr. Vincenc Nemanič
4. Plasma Sterilization and Decontamination of Water
   NATO CLG. REF.983580
   Dr. Fausto Pedrazziini, NATO - North Atlantic Treaty Organisation, Brussels, Belgium
   Asst. Prof. Uroš Cvelbar
5. Development of Bioactive Packaging
   BIOPACKAGING
   EUREKA
   Univerza v Mariboru, Inštitut za inženirske materiale in oblikovanje, Maribor, Slovenia
   Prof. Miran Mozetič
6. Hydrogen Impermeable Nano-material Coatings for Steels
   Hy - Nano – IM
   MNT ERA NET
   Dr. Vincenc Nemanič, Asst. Prof. Paul McGuiness, Asst. Prof. Miha Čekada
7. Biomedical Applications of Atmospheric Pressure Plasma Technology
   COST MP1101
   EC; COST Office, Brussels, Belgium
   Asst. Prof. Uroš Cvelbar
8. Thermal Cycle (1h at 150°C) with Outgassing Data recorded by QMS with Final SRG Measurements at R.T.
   PO 450274913, 2.12.11
   Dr. Vincenc Nemanič
9. Outgassing Measurements of Glass Plates at Elevated Temperatures
   PO 450233251, 3.8.2011
   Dr. Vincenc Nemanič
10. Characterization of Microorganism Structures by Advanced Analytical Techniques
    BI-ME/10-11-1

Dr. Zoran Vratnica, Institute of Public Health, Podgorica, Montenegro
Prof. Miran Mozetič
11. Sterilization of Medicine Materials with Gaseous Plasma
BI-ME/10-11-3
Dr. Danijela Vujošević, Institute of Public Health, Podgorica, Montenegro
Asst. Prof. Uroš Cvelbar
12. Interaction of Highly Dissociated CO2 Plasma with Materials Suitable as Outer Protective Layers of Future Space Vehichles
PROTEUS 2010 – 2011
BI-FR/10-11-PROTEUS-005
Dr. Marianne Balat-Pichelin, Processes, Materials and Solar Energy Laboratory (PROMES-CNRS), Font-Romeu Odeillo, France
Asst. Prof. Alenka Vesel
13. Improvement of Adhesive Properties of Biomedical Materials by Plasma Treatment
BI-HR/10-11-020
Dr. Morana Jaganjac, Ruđer Bošković Institute, Zagreb, Croatia
Asst. Prof. Alenka Vesel
14. Plasma Synthesis and Application of Nanowalls
BI-JP/11-13-001
Prof. Makoto Sakine, Plasma Nanotechnology Research Centre, Graduate School of Engineering, Nagoya University, Nagoya, Japan
Asst. Prof. Uroš Cvelbar
15. Determination of Interdiffusion Coefficients in Nano-layered Structures by High Resolution Depth Profiling
BI-CN/11-13-006
Prof. Jiang Yong Wang, Shantou University, Department of Physics, Shantou Guangdong, China
Asst. Prof. Janez Kovač
16. Plasma Synthesis and Deposition of Quantum Dots
BI-CN/11-13-005
Asst. Prof. Xiaoxia Zhong, Shanghai Jiao Tong University, Shanghai, China
Asst. Prof. Uroš Cvelbar
17. Quantum Dots for Solar Cells
BI-CN/09-11-003
Dr. Xiaoxia Zhong, Shanghai Jiao Tong University, Shanghai, China
Asst. Prof. Uroš Cvelbar
18. Plasma Diagnostics for Applied Research of Dusty Plasmas with Nanoparticles
BI-KR11-12-001
Prof. Choe Wonho, Korea Advance Institute of Science and Technology, Dept. of Physics / Dept. of Nuclear & Quantum Eng., Daejeon, Korea
Asst. Prof. Uroš Cvelbar
19. Investigation of Microwave Discharges Applicable in Biomedicine and Nanotechnology
BI-HU/11-12-001
Dr. Kinga Kutasi, Research Institute for Solid State Physics Optics, Budapest, Hungary
Prof. Miran Mozetič
20. Dissociation Kinetics in Technological Plasmas
BI-SR/10-11-001
Prof. Zoran Petrovič, Institute of Physics, Belgrade - Zemun, Serbia
Prof. Miran Mozetič
21. Nanowires for Photoelectrochemical Energy Conversion and Water Splitting
BI-US/11-12-007
Prof. K. Mahendra Sukara, Oddelek za kemijsko inženirstvo, University of Louisville, Conn Center for Renewable Energy Research, Louisville, KY, USA
Asst. Prof. Uroš Cvelbar
22. Thermoionic Energy Conversion
BI-US/09-12-021
Prof. Robert Nemanich, Arizona State University, (ASU), Tempe, Arizona, USA
Dr. Vincenc Nemanič

R &D GRANTS AND CONTRACTS

1. Use of Nanoparticles as Additives in Lubricants and in Tribology
Prof. Maja Remškar
2. Organic-inorganic thin film structures for electronic components
Asst. Prof. Janez Kovač
3. Development of treatments and procedures for improvement of hemocompatibility of polyethyleneterftalate surfaces
Prof. Miran Mozetič
4. A study of plasma parameters for conditioning of the inner surfaces of a fusion reactor
Prof. Miran Mozetič
5. Printed passive electronic components for smart packaging
Asst. Prof. Alenka Vesel
6. Investigation of gaseous diascharges for introduction of new enviromental friendly technology for functionalization of semiproduct in capacitor production
Prof. Miran Mozetič
7. Synthesis and functionalization of composite nanobeads for early diagnosis of neurodegenerative diseases
Asst. Prof. Alenka Vesel
8. Superhydrophilicity of surfaces and its application in technological processes for industrial application
Asst. Prof. Uroš Cvelbar
9. Ignition and self-extinguishing of arc in a gas surge arrester at high overvoltages
Dr. Vincenc Nemanič
10. Multifunctional nanocomposite coatings and paints
Prof. Miran Mozetič
11. Research and development of integrated overvoltage protection devices based on gaseous discharger toward a reliable miniature technical solution
Dr. Vincenc Nemanič
12. Development of advanced processes for attending high efficient nano modified textile materials
Dr. Igor Mozetič
13. Multifunctional Nanostructured Films for Artificial Implants - Corrosion and Tribo-corrosion Processes
Dr. Darinka Kek Merl
14. Synthesis of nanowires for regenerative energy cells
Asst. Prof. Uroš Cvelbar
15. Colour, absorption and protective nanolayer coatings for aluminium alloy
Dr. Peter Panjan
16. Plasma treatment of vascular grafts
Prof. Miran Mozetič
17. Functionalization of biomedical samples by thermodynamic non-equilibrium gaseous plasma
Prof. Miran Mozetič
18. Toward ecologically benign alternative for cleaning of delicate biomedical instruments
Asst. Prof. Alenka Vesel
19. Studa of gaseous deuterium retention and release from metals relevant to ITER
Dr. Bojan Zajec
20. Preparation of hemocompatible polymeric surfaces for biomedical applications
Dr. Ita Junkar

RESEARCH PROGRAMS

1. Vacuum technique and materials for electronics
Dr. Vincenc Nemanič
2. Thin film structures and plasma surface engineering
Prof. Miran Mozetič

MENTORING

Ph. D. Theses

1. Gorazd Golob, Elastomer surface energy modification applying oxygen and nitrogen plasma treatment with laser deactivation of the surface (mentors Mladen Lovreček, Miran Mozetič).
2. Tjaša Vrlinič, Development of new anti-bioadhesive surfaces for specific neurodegenerative agents (mentor Miran Mozetič; co-mentor Fabienne Poncin-Epaillard).

VISITORS FROM ABROAD

1. Dr. Slobodan Miloševič, Marijan Biščan, dr. Nikša Krstulovič, Zlatko Kregar, Krešimir Salamon, Institute of Physics, Zagreb, Croatia, several times
2. Dr. Primož Eiselt, dr. Peter Ziegler, dr. Heinz Schmidt, Plasmabull, Lebring, Austria, several times
3. Dr. Zoran Vratnica, dr. Danijela Vujoševič, dr. Ljubica Terić, dr. Sanja Medenica, prof. dr. Boban Mugoša, Institute of public health, Podgorica, Montenegro, several times
4. Ludvik Kumar, Kolektor Group, Idrija, Slovenia, several times
5. Prof. dr. Karin Stana Kleinschek, prof. dr. Simona Strnad, Institute of textiles University of v Maribor, Slovenia, several times
6. Dr. Nevena Puač, dr. Željka Nikitović, Institute of Physics, Belgrade, Serbia, several times
7. Prof. dr. Zoran Petrović, Institute of Physics, Belgrade, Serbia , 9-12 Jan. 2011
8. Dr. Lidija Mrakovčič-Milkovič, dr. Ana Cipak Gašparović, dr. Morana Jaganjac, Rudjer Bošković Institute, Zagreb, Croatia, several times

9. Dr. Visakh P.M. Puthanpurachkanchira, Univerza Mahatma Gandhi, Indija, 1 May – 1 Jun. 2011
10. Prof. Francesco Tabares, dr. Jose Fereira, Institut CIEMAT, Madrid, Spain, 11-24 Aug. 2011
11. Prof. Robert J. Nemanich, North Carolina State University, Raleigh, USA, 8-13 Sept. 2011
12. Prof. dr. Xiaoxia Zhong, Yi Lu, prof. Yiada Wu , prof. Ning Xu, Univerza Jiao Tong, Shanghai, Shanghai,10–16 Sept. 2011
13. Prof. dr. Masaru Hori, prof. dr. Hiroki Kondo, prof. dr. Mineo Hiramatsu, prof. dr. Makoto Sekira, University in Nagoya, Nagoya, Japan, 9–13 Sept. 2011
14. Prof. Zoran Petrovič, prof. Gordana Malovič, Nikola Skoro, Maria Savič, Institute of Physics, Belgrade, Serbia 11–15 Sept. 2011
15. Dr. Vladimir Savić, Institute of Physics, Belgrade, Serbia, 4-8 Oct. 2011
16. Dr. Kil Byoung Chai, dr. Heesoo Jung, prof. dr. Wonho Choe, Korea Advanced Institute of Science and Technology, Daegeon, Korea, 23–28 Oct. 2011
17. Prof. dr. Marian Lehocky, prof. dr. Vladimir Sedlarik, prof. dr. Aleš Mraček, Pavel Kucharczy, Univerza Thomas Bata, Zlin, Czech Republic, 15–18 Nov. 2011
18. Prof. dr. Fabienne Poncin, Universite du Maine, Le Mans, France, 5–11 Dec. 2011

STAFF

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21. Tatjana Filipič, B. Sc.

Technical and administrative staff
22. Ružica Bolte
23. Janez Trtnik

Note:
** postgraduate financed by industry

BIBLIOGRAPHY

Original Articles

1. Andrew Das Arulsamy, Zlatko Kregar, Kristina Eleršič, Martina Modic, Uma Shankar Subramani, "Polarization induced water molecule dissociation below the first-order electronic-phase transition temperature", *PCCP. Phys. chem. chem. phys. (Print)*, vol. 13, no. 33, pp. 15175-15181, 2011.
2. Marianne Balat-Pichelin, Alenka Vesel, Miran Mozetič, "Microwave discharge as an effective tool for surface treatment of small samples", *IEEE trans. plasma sci.*, vol. 39, no. 11, part 1, pp. 2064-2065, 2011.
3. Maria Calafat, Pavel Yuryev, Aleksander Drenik, Aref Slim, Richard Clergereaux, "Carbon nanoparticle/hydrogenated amorphous carbon composite thin films formed in ECR plasma", *Plasma processes polym. (Print)*, vol. 8, no. 5, pp. 401-408, 2011.
4. Uroš Cvelbar, "Removal of a thin hydrogenated carbon film by oxygen plasma treatment", *Mater. tehnol.*, vol. 45, no. 3, pp. 179-183, 2011.
5. Uroš Cvelbar, "Towards large-scale plasma-assisted synthesis of nanowires", *J. phys., D, Appl. phys.*, vol. 44, pp. 174014-1-174014-9, 2011.
6. Uroš Cvelbar, Ita Junkar, Martina Modic, "Hemocompatible poly(ethylene terephthalate) polymer modified via reactive plasma treatment", In: Proceedings of the 7th International Conference on Reactive Plasmas, 28th Symposium on Plasma Processing, 63rd Gaseous Electronics Conference, Paris, *Jpn. J. Appl. Phys.,* vol. 50, no. 8, pp. 08JF02-1-08JF02-5, 2011.
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PATENT APPLICATIONS

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