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 and ion spectroscopy techniques.

Head:
Prof. Miran Mozetič

The surfaces of solid materials are engineered using non-equilibrium gaseous plasma created at low pressures by the appropriate gaseous discharges. Gaseous molecules are partially dissociated and ionized upon inelastic collisions with free electrons. The distribution of neutral as well as charged particles over their kinetic energies is essentially Maxwell–Boltzmann, but electrons have a kinetic temperature between 10,000 and 100,000 K, while other gaseous particles remain close to room temperature. The distribution of molecules over excited states, however, does not follow the Boltzmann law, but can be tailored using appropriate discharge parameters over a broad range over many decades. Such a paradox is explained by the lack of channels for the thermallization of molecules excited to different states. While thermallization is easily achieved at atmospheric pressure, the deviations from this distribution increase with a decreasing pressure. The major reason is the conservation of the total energy and momentum during collisions, which often require three-body events that are unlikely to occur at low pressure. The probability of such collisions increases with the square of the pressure and small deviations from the Boltzmann distribution are already observed at a sub-atmospheric pressure, while at the pressure of 100 Pa the three-body collision frequency becomes as low as 10 s^{-1}. Five major paradoxes concerning deviations from thermal equilibrium have been explained in a simplified manner in a monograph published in 2014 by Lampert Academic Publishing. The book, containing about 150 pages, is aimed primarily at users of plasma technologies for the modification of polymers rather than plasma physicists or chemists.

The Scientific Council of the Slovenian Research Agency selected the paper N. Recek at al., Protein Adsorption on Various Plasma-Treated Polyethylene Terephthalate Substrates, Molecules 18 (2013) 12441-12463 as an outstanding achievement and the corresponding author, A. Vesel, presented the achievement at the 9th Slovenian Innovation Forum in November 2014.

A non-equilibrium plasma created in oxygen is particularly suitable for the oxidation of various solid materials. The chemical reactivity of such a plasma, as compared to oxygen at thermal equilibrium, is just enormous, so the oxidation of any material occurs in a fraction of a second. Polymers are treated essentially at room temperature in order to prevent any modification of their bulk properties. The oxidation of polymer surfaces causes the formation of oxygen-containing functional groups, which is reflected in an improved wettability and thus properties suitable for the rapid adhesion of both inorganic particles and biological cells. The surface modification is monitored by advanced surface-sensitive techniques available in our laboratories, in particular X-ray Photoelectron Spectroscopy (XPS) and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS). A high-resolution carbon 1s XPS spectrum of plasma-treated polystyrene reveals the formation of highly hydrophilic functional groups on the surface of the originally oxygen-free polymer. Such a surface finish of polymer materials makes possible the rapid adhesion and proliferation of biological cells. Not only the substrates, but the cells themselves have been treated with gaseous plasma in order to achieve the desired effects. In such a case a low-pressure environment is unsuitable, so the plasma was created at atmospheric pressure. The biological cells were exposed to a medium that was rich in gold nanoparticles and then treated with gaseous plasma. A high selectivity of the cell destruction was observed, since the benign cells caused apoptosis at a much lower rate than cancer ones.

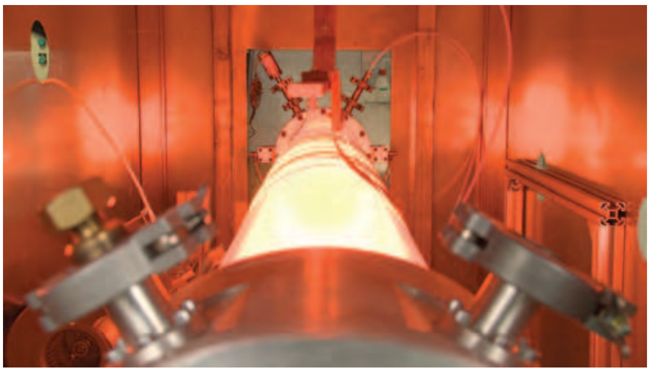

Figure 1: Glowing nitrogen plasma emits radiation at different wavelengths, peaking in the orange part of the optical spectrum

The textile industry is seeking fabrics of improved functionalities. These products should allow for protection against ultra-violet radiation and should be bacteriostatic. Both effects are achieved by the deposition of nanoparticles onto the textile materials. The adhesion of such nanoparticles, however, is insufficient, so the functionalities vanish

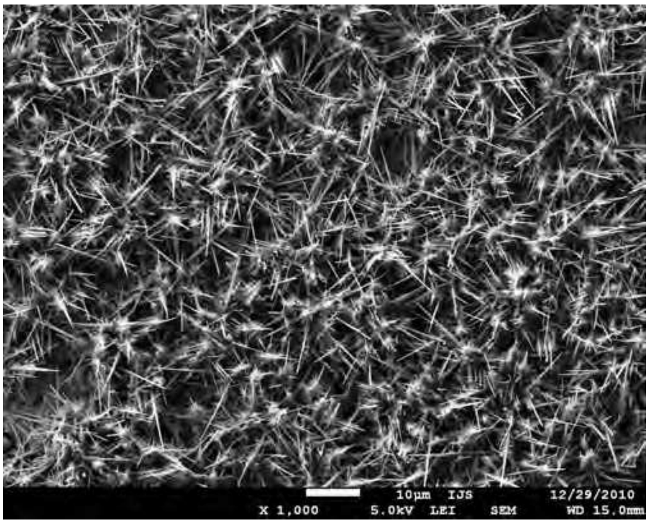

Figure 10: Dense spikes are observed on the SiC surface after treatment with oxygen plasma at 1850 K

after several washing cycles. The reason for poor adhesion is an inadequate surface finish of the fabrics. Systematic research on tailoring the surface properties of cotton fabrics by plasma treatment has been performed. The plasma was generated in different gases. The best results in terms of the adhesion of zinc oxide nanoparticles were achieved using plasma created in moist tetrafluoromethane. The dissociation energy for CF_4 molecules is much higher than for water vapour, so the plasma electrons are likely to form OH and O radicals in such an environment, although the water partial pressure is much lower than the CF_4. The concentration of F radicals is therefore much lower than OH radicals. Although F radicals bond chemically to the surface of the polymer, the OH and O radicals cause extensive oxidation and the formation of unstable molecular fragments rich in C, H, F and O, which are rapidly desorbed from the surfaces. As a result of such synergistic effects of F- and O-rich radicals substantial etching of the materials, without leaving hydrophobic functional groups on the cellulose fibres, occurs, leading to an optimal surface finish for adhesion of ZnO nanoparticles. Unlike for untreated materials, the ZnO nanoparticles are rather uniformly distributed in the fabrics, which allows for excellent protection against both UV A and B radiation. The amount of ZnO nanoparticles on materials treated under optimal conditions is double, when compared to the untreated fabrics and the functional properties remain almost unchanged even after several washing cycles.

Textiles are also used as materials for wound dressings. Instead of cotton, which is prohibitively expensive, synthetic cellulose fibres called viscose are used for the dressings. A drawback of the current technologies used for the processing of viscose materials is the suitability for bacteria, which are likely to appear on the wounds. The material could be made bactericidal by silver chloride nanoparticles, but such a surface finish would also reduce the proliferation of cells and thus slow down the curing process. The viscose fabrics were treated using plasma created in nitrogen and ammonia in order to functionalize them with nitrogen-containing functional groups that are renowned for their bacteriostatic and weakly bactericidal effects. The treatment effect on the antimicrobial activity was determined by the AATCC 100-1999 standard test adopted in medicine. The antimicrobial activity of such a surface finish was proven against a couple of Gram-negative bacteria, i.e., *S. aureus* and *E. faecalis*. A 100% reduction of the bacteria was found for *S. aureus,* demonstrating that the nitrogen or ammonia plasma was as efficient as the silver chloride nanoparticles. The efficiency for *E. faecalis* was somehow lower (80% reduction for ammonia-plasma-treated samples versus 100% for silver chloride deposited onto oxygen-plasma-treated samples), but still good compared to current practise. An important advantage of the functionalization using nitrogen or ammonia plasma is the preservation of the excellent wettability of the materials. The contact angle of a water drop on materials functionalized with nitrogen functional groups remained at 30°, while the deposition of the silver chloride nanoparticles caused a substantial loss of hydrophilicity, since the contact angle increased to about 65°. This value is still much better than for untreated viscose materials that exhibit a rather hydrophobic character with a water contact angle of about 90°.

Dr. Gregor Primc received the first award for the development of an innovative sensor at the 7th International Conference on Technology Transfer.

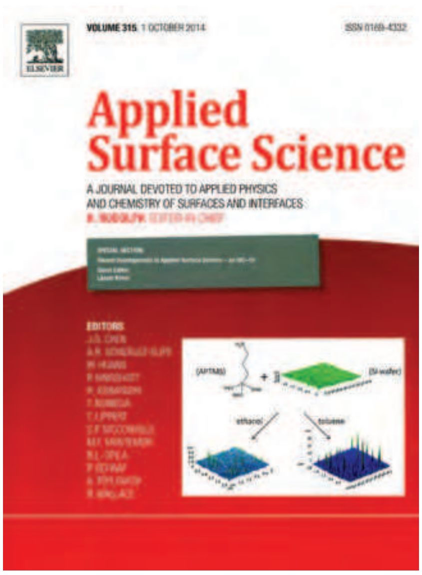

Figure 11: Image on the cover page of Applied Surface Science journal (Vol. 315, 2014) presenting our research on the aminosilane APTMS used for surface modification and adhesion promotion (publication #7)

For the textile industry, novel and cost-efficient processes were also developed based on the deposition of polymers with embedded nanoparticles with atmospheric pressure plasma jets. An innovative antibacterial thin film with embedded silver nanoparticles was synthesized through atmospheric pressure plasma discharge and characterized thoroughly. This process was based on the single-step fabrication of nanocomposite films, where silver nanoparticles were fed directly into the discharge zone along with tetramethyldisiloxane (TMDSO) and nitrogen as the primary carrier gas. Depending on the discharge parameters, the morphology and stoichiometry of the thin films was tailored. An exceptional 32% of silver nanoparticles were uploaded into the deposited polymer film. The bacterial assays using *E. coli* and *S. aureus* strains showed the effective antibacterial activity of the films and indicate that the fabrication of the nanocomposite films using atmospheric pressure plasma represents a feasible way to overcome the issues related to material surface infections.

Melamine-formaldehyde fibres were synthesized from a meltable pre-polymer of etherified melamine-formaldehyde in the form of a low density fleece, subsequently thermally cured in a conveyor belt oven at temperatures of up to 200 °C and post-heated at 260 °C. A high thermal stability and a small fibre diameter, below 5 μm, made it a serious candidate to be a novel core material for vacuum thermal insulation panels. The two most crucial core properties, thermal conductivity and outgassing rate, were investigated in thin-walled stainless-steel envelopes, enabling thermal processing combined with a pump-out procedure. A base thermal conductivity of ~ 2.3 mW m^{-1} K^{-1} was achieved with randomly oriented fibres at a density of ~250 kg m^{-3}. The long-term pressure-rise measurements revealed extremely low outgassing rates, $q \sim 10^{-15}$ mbar L s^{-1} cm^{-2}. Additional measurements of the thermal conductivity in a wide pressure range from 10^{-3} mbar to atmospheric pressure indicate that these melamine-formaldehyde fibres could be the first organic candidates applied as the core material in vacuum insulating panels with an adequate service lifetime. Their performance is comparable to selected inorganic core materials like glass fibres.

Our group is also involved in the European project IP4Plasma: Industrial innovations based on EU intellectual property assets in the field of atmospheric pressure plasma technology, funded by European Union under the 7th Framework Programme for Research and Innovation. In the IP4Plasma project, plasma-equipment manufacturers and end-users work with leading experts in research to demonstrate the suitability of the atmospheric pressure plasma technology for existing and new industrial applications in the advanced medical diagnostics sector and health-care products. In this project, nine European partners from research and industry areas are involved: Spinverse Ltd (Finland), Fraunhofer Institute for Surface Engineering and Thin Films IST (Germany), IMA (Belgium), Jožef Stefan Institute (Slovenia), LIONEX GmbH (Germany), SOFTAL Corona & Plasma GmbH (Germany), Tosama (Slovenia), VITO - Flemish Institute for Technological Research (Belgium). The IP4Plasma project is scheduled to run for three years between 2014 and 2016. In the frame of the IP4Plasma project a new type of plasma equipment is being developed, capable of the cost- and resource-efficient deposition of coatings, even those containing more complex molecules such as enzymes, on substrates uniformly over full treatment widths of substrates up to 120 cm. The IP4Plasma project also aims to produce new. advanced medical diagnostic products with increased performance and lower cost, including sensitive, quick and cheap tuberculosis and HIV tests and advanced wound-care products with substantially lower production costs and a smaller carbon footprint. Our group is responsible for the precise surface characterization of the plasma-deposited coatings using a new, on-line method to follow the plasma efficiency as well as conventional methods like XPS, ToF-SIMS and AFM.

An alternative method that is suitable for the treatment of delicate materials is the application of a plasma flowing afterglow instead of glowing plasma. Oxygen gas is allowed to pass a discharge region where the plasma is sustained and continues its way to an afterglow chamber. The charged particles neutralize on the way from the discharge region to the afterglow chamber and highly excited metastable atoms quench so the gaseous medium in the afterglow chamber contains only long-living reactive particles, such as neutral atoms in the ground state and molecules in the first electronically excited state. Such particles are reactive enough to interact chemically with materials of high oxidation affinity, but are unlikely to cause substantial etching of other materials such as many types of polymers. The oxygen plasma flowing afterglow was successfully applied for the cleaning of delicate components used in medical practise, such as polymer catheters. The polymer used as the material catheters are made from was deposited onto quartz crystals, contaminated with blood proteins and exposed to both early and late afterglows. The etching rate of the proteins was measured under various conditions rather precisely using a quartz-crystal microbalance. Substantial etching rates of the order of nm/s were determined. A rather independent adjustment of the fluxes of neutral atoms and excited molecules allowed for a hypothesis on etching mechanisms. The density of the neutral atoms along the afterglow chamber was determined both theoretically and experimentally and the agreement was almost perfect, showing the reliability of the simulation code. The density of the excited molecules was determined only theoretically due to a lack of reliable experimental methods. The synergistic effects of atoms and excited molecules were found to be crucial for an explanation of the etching rate versus the treatment parameters. The

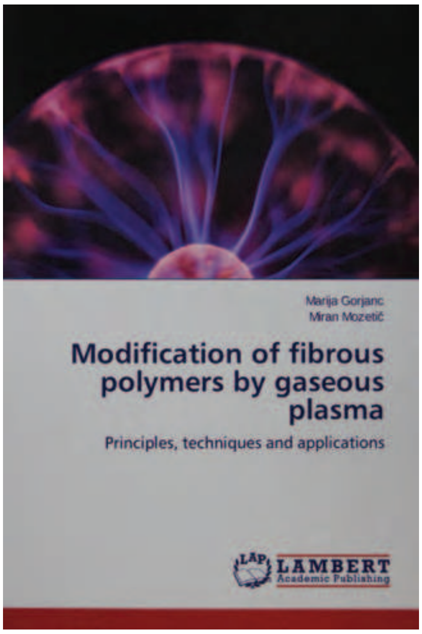

Figure 2: Cover page of the monograph

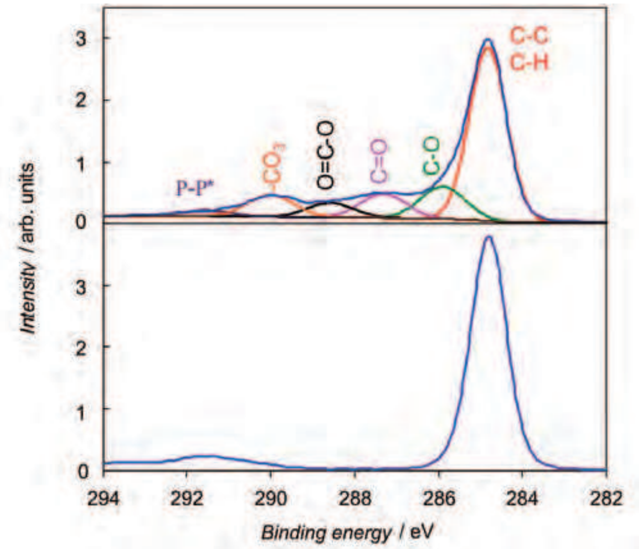

Figure 3: XPS carbon 1s spectra of untreated and oxygen-plasma treated polystyrene

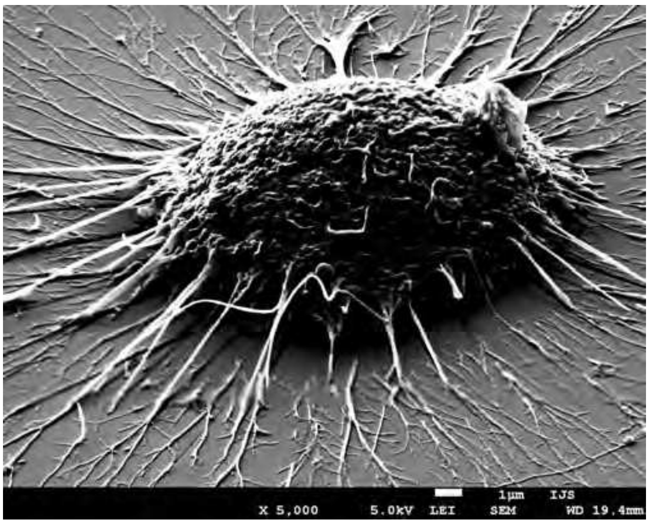

Figure 4: Biological cells feel comfortable on plasma-treated polystyrene

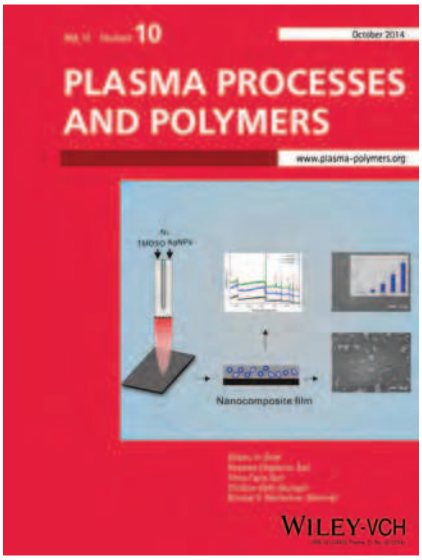

Figure 5: Image from publication #6 appeared on the journal cover page

corresponding scientific paper represents the first report worldwide on such synergistic effects. After removing the blood proteins from the surface of polymer catheters using an oxygen plasma afterglow the substrate surface remains functionalized with polar functional groups. The adsorption kinetics upon the incubation of such materials with blood proteins was studied in details and huge differences between the untreated and cleaned materials were observed. The adsorption kinetics was found to be abnormal for polymers functionalized with polar functional groups, since blood proteins bind to such surfaces both reversibly and irreversibly. Such a kinetic makes the innovative technique useless. The difficulty was successfully overcome by a brief treatment of the cleaned materials for catheters with a fluorine-rich medium that allowed for re-establishing the original surface properties of the treated materials.

Inorganic materials form oxides upon exposure to an oxygen atmosphere at elevated temperature. The oxide is usually in the form of a rather uniform film whose thickness depends on the material properties and the processing temperature. The transformation of oxygen into the plasma state causes substantial differences in the oxidation mechanism. Since the plasma is rich in highly reactive oxygen atoms there is no need for surface dissociation of molecules, so oxidation is achieved at a lower temperature, compared to oxygen at thermal equilibrium. Furthermore, oxygen plasma is rich in fast electrons and slow positive ions so the surface of any material exposed to non-equilibrium gaseous plasma is charged negatively. The charge concentrates at bulges on the surfaces. The electric field between the surface and the substrate is therefore distributed non-uniformly on the surface, so the electro-migration of metallic ions diffusing through the oxide film onto the surface is favoured towards the peak of a bulge. As a result, the oxide does not grow in the form of a rather uniform thin film, but rather as quasi-one-dimensional structures. The growing mechanism has been elaborated for several types of metal substrates and both the morphological shapes as well as the physiochemical properties of the structures depend on the plasma parameters as well as on the temperatures involved. Since metal oxides are rather poor thermal conductors, strong temperature gradients occur between the peaks of the nanostructures and the bulk material. Such temperature gradients further favour the migration of metallic ions through the oxide nanoparticles, so the nanoparticles form nanowires with a large aspect ratio.

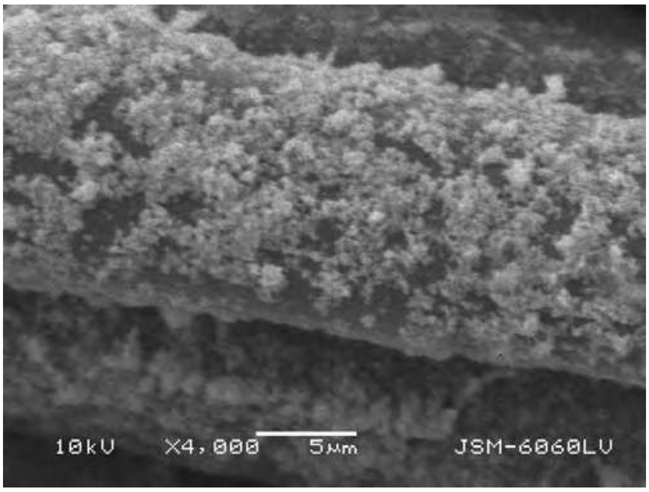

Figure 6: ZnO nanoparticles are dense on plasma-treated cotton

The metal oxides in the form of nanostructures are especially interesting for various applications and the efficient conversion of solar energy in 3rd and 4th generation of solar cells, photo-catalytic coatings, dye solar cells or water-splitting energy cells. For these applications one needs single crystalline nanowires with the appropriate energy band gap and catalytic activity. There are a number of methods and routes to produce these metal oxide nanowires, but one of the fastest and most efficient is a synthesis by a plasma-assisted process. A promising material for various applications and especially for water-splitting cells consists of copper oxide nanowires. To achieve efficient performance of water-splitting cells, one needs not only single-crystalline copper oxide nanowire in high densities, but also a homogeneous distribution over large areas on electrodes. This uniform growth of copper oxide nanowires on the top of a copper plate was systematically investigated during exposure to a radio-frequency oxygen-argon plasma discharge in respect to plasma properties and its localization. An almost uniform growth of nanowires was achieved over a large surface. However, some significant distortions in the nanowire length and shape were found near the edges. Based on experimental results, a theoretical model of nanowire growth was developed, which could predict the maximum lengths of nanowires and the dependence on the plasma parameters. It was demonstrated that the limiting factors for nanowire growth were distortions in the distributions of ions and their local fluxes. In contrast, the heating of materials by the potential interactions of plasma species was found to have little influence on the length of nanowires, and smaller deviations in particle fluxes are allowed for the uniformity of nanowire growth.

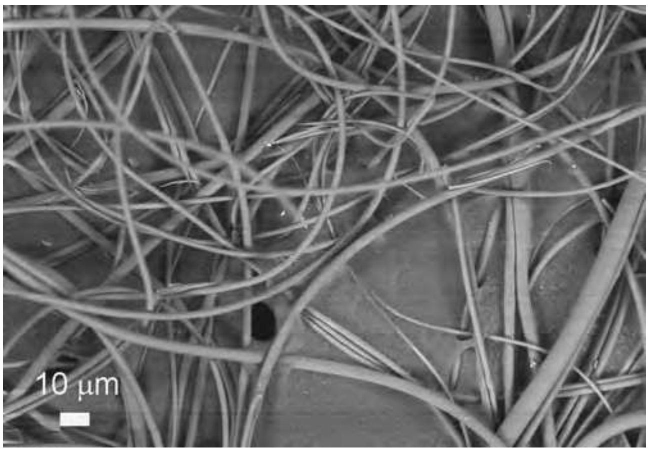

Figure 7: Low-density fleece made from melamine-formaldehyde fibres is suitable for vacuum insulation panels.

The formation of one-dimensional oxide nanoparticles on the surface of silicon carbide samples upon treatment with oxygen-rich gaseous plasma was elaborated. Samples were exposed simultaneously to an oxygen plasma created with a microwave discharge in a resonant cavity and concentrated solar radiation. The discharge allowed for a suitable concentration of chemically reactive gaseous particles and free electrons, while the tuneable concentrated solar radiation made it possible to adjust the sample temperature, irrespective of the plasma parameters. A suitable concentration of reactive particles allowed for the excellent chemical reactivity of the gaseous medium, while a large flux of electrons allowed for the appropriate surface charging. The sample temperature was adjusted in the range where the transition from active and passive oxidation is expected at given pressures, i.e., between 1500 and 2000 K. The material remained unchanged up to about 1600 K, but higher temperatures up to about 1900 K caused the growth of nanoparticles. At temperatures above 2000 K all the nanoparticles vanished. The morphology of the nanoparticles depended on the temperature. At the lowest part of the suitable temperature range the nanoparticles grew from nucleation sites unevenly distributed over the sample surface, while elevated temperatures allowed for the synthesizing of dense nano-spikes on the entire surface. The suitable range of temperatures for synthesizing one-dimensional nanoparticles was only about 100 K. The lower-temperature limit was explained by the poor diffusion of Si ions through the oxide, while the upper limit was attributed to active oxidation, causing the removal of such structures.

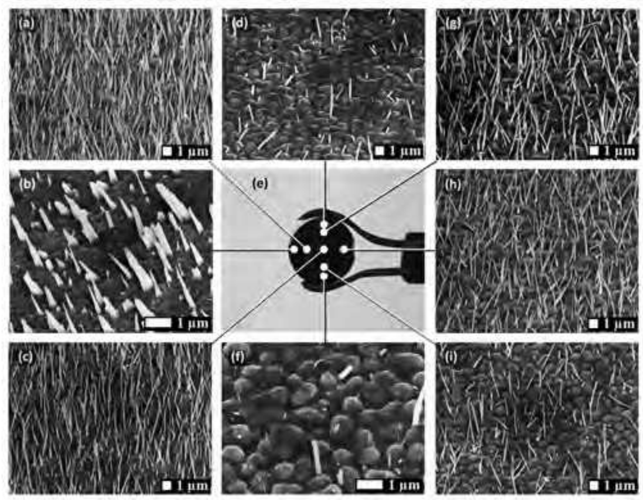

Figure 8: Distortions in the distribution of plasma-synthesized copper oxide nanowires on copper electrodes due to variations in ion fluxes.

Aminosilanes are used for surface modification and adhesion promotion. They have the ability to form a durable bond between organic and inorganic materials. A surface modified with aminosilanes has many applications: it can be used in chromatography, as a biosensor in medicine, for attaching metal nanoparticles, and for the detection of specific gases and explosives, etc. In general, it was believed that the aminosilane-modified silicon surface is homogeneous, but this is not always the case. A possible heterogeneity in the surface morphology and the chemistry may be present, and it may significantly influence the application of modified surfaces. Therefore, we investigated the influence of different solvents on the 3-aminopropyltrimethoxysilane (APTMS) modification of Si wafers. In our study we used five solvents with different polarities. We carried out the silanization in a non-polar solvent (toluene), polar aprotic solvents (acetone, N,N-dimethylformamide and acetonitrile) and a polar protic solvent (ethanol) for various deposition times and temperatures. The surface composition, chemical bonding and morphology were characterized by XPS, ToF-SIMS, AFM and SEM methods. Our results show that with the use of the appropriate solvent we can significantly influence the morphology of the modified surface and consequently its adhesion/adsorption properties. Silanization carried out in acetonitrile and toluene leads to the formation of a rough surface with a large density of APTMS polymerized molecules in the form of islands. The surfaces modified in N,N-dimethylformamide were smoother, with a lower density of APTMS islands. When using acetone and ethanol as a solvent we prepared a smooth, thin, modified surface, with a very low density of the APTMS islands.

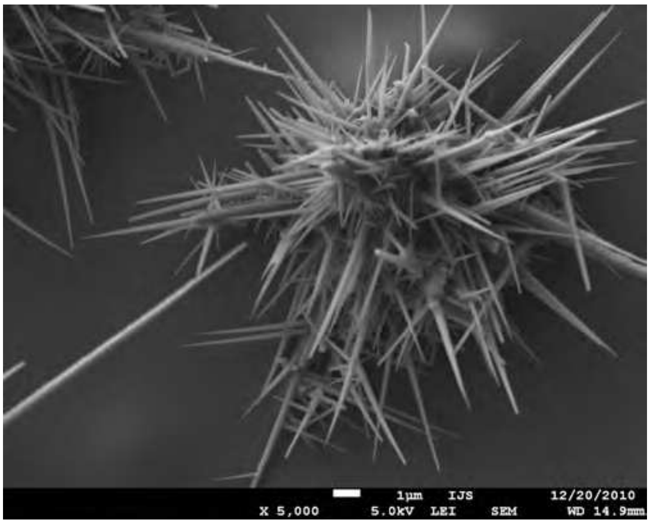

Figure 9: Nano-spikes grow from nucleation sites upon treatment of SiC with oxygen plasma at 1800 K

Some outstanding publications in the past year

1. Gorjanc, M., Mozetič, M.: Modification of fibrous polymers by gaseous plasma: principles, techniques and applications. Saarbrücken: LAP Lambert Academic Publishing, 2014Gorjanc, M., Jazbec, K., Šala, M., Zaplotnik, R., Vesel, A., Mozetič, M.: Creating cellulose fibres with excellent UV protective properties using moist CF4 plasma and ZnO nanoparticles. *Cellulose,* ISSN 0969-0239, 2014, vol. 21, iss. 4, 3007-3021
2. Peršin, Z., Maver, U., Pivec, T., Maver, T., Vesel, A., Mozetič, M., Stana-Kleinschek, K.: Novel cellulose based materials for safe and efficient wound treatment. *Carbohydrate polymers*, ISSN 0144-8617. [Print ed.], jan. 2014, vol. 100, 55-64
3. Cheng, X., Murphy, W., Recek, N., Yan, D., Cvelbar, U., Vesel, A., Mozetič, M., Canady, J., Keidar, M., Sherman, J. H.: Synergistic effect of gold nanoparticles and cold plasma on glioblastoma cancer therapy. *Journal of physics. D, Applied physics*, ISSN 0022-3727, 2014, vol. 47, no. 3, 335402-1-335402–8
4. Vesel, A., Kolar, M., Recek, N., Kutasi, K., Stana-Kleinschek, K., Mozetič, M.: Etching of blood proteins in the early and late flowing afterglow of oxygen plasma. Plasma processes and polymers, ISSN 1612-8850, 2014, vol. 11, no. 1, 12-23

5. Deng, X., Leys, C., Vujošević, D., Vuksanović, V., Cvelbar, U., De Geyter, N., Morent, R., Nikiforov, A.: Engineering of composite organosilicon thin films with embedded silver nanoparticles via atmospheric pressure plasma process for antibacterial activity. *Plasma processes and polymers,* ISSN 1612-8850, 2014, vol. 11, no. 10, 921-930
6. Jakša, G., Štefane, B., Kovač, J.: Influence of different solvents on the morphology of APTMS-modified silicon surfaces. Applied Surface Science, ISSN 0169-4332. [Print ed.], 2014, vol. 315, no. 1, 516-522
7. Jovanović, Z., Spreitzer, M., Kovač, J., Klement, D., Suvorov, D.: Silicon surface deoxidation using strontium oxide deposited with the pulsed laser deposition technique. *ACS applied materials & interfaces*, ISSN 1944-8244. [Print ed.], 2014, vol. 6, issue 20, 18205-18214

Awards and appointments

1. Dr. Gregor Primc: 1st award for innovation "Laser Fiber Optic Catalytic sensor". The award was given at 7th International Technology Transfer Conference

Organization of conferences, congresses and meetings

1. 9th EU-Japan Joint Symposium on Plasma Processing (JSPP2014) and EU COST MP1101 Workshop on Atmospheric Plasma Processes and Sources, Bohinjska Bistrica, 19–23 January 2014
2. COST Action: TD1208: Training School Title: Chemistry initiated by electrical discharges with liquids, Ljubljana, 3–6 February 2014

Patent granted

1. Ita Junkar, Miran Mozetič, Alenka Vesel, Uroš Cvelbar, Metka Krašna, Dragoslav Domanovič, Method of treatment of biomedical polymeric prosthesis for improvement of their antithrombogenous propeties, AT513072 (B1), Österreichisches Patentamt, 15.2.2014.

INTERNATIONAL PROJECTS

1. EFDA-JET 2013 Experimental Campaigns
   Dr. Aleksander Drenik
   Ministry of Education, Science and Sport
2. EFDA-JET 2013 Analysis of Mixed Materials on ITER-like Wall Samples Using XPS/AES
   Dr. Vincenc Nemanič
   Ministry of Education, Science and Sport
3. 7FP - IP4Plasma; Industrial Innovations Based on EU Intellectual Property Assets in the Field of Atmospheric Plasma Technology
   Asst. Prof. Janez Kovač
   European Commission
4. COST MP1101; Biomedical Applications of Atmospheric Pressure Plasma Technology
   Prof. Uroš Cvelbar
   COST Office
5. COST TD1208; Electrical Discharges with Liquids for Future Applications; COST Training School on Liquid Discharges
   Prof. Uroš Cvelbar
   COST Office
6. NATO Grant; SPS 984555; Atmospheric Pressure Plasma Jet for Neutralisation of CBW
   Prof. Uroš Cvelbar
   Nato - North Atlantic Treaty Organisation
7. Development and Investigation of Optimal Regimes of RF Conditioning of Uragan-2M Vacuum Chamber Walls using Optical and Probe Methods of Plasma Diagnostics
   Prof. Miran Mozetič
   Slovenian Research Agency
8. Characterization of Non-equilibrium Plasma for Modification of Nano and Biocompatible Materials
   Prof. Miran Mozetič
   Slovenian Research Agency
9. Ultra Nanoporous Nanowires of Metal Oxides
   Prof. Uroš Cvelbar
   Slovenian Research Agency
10. Characterization of Processing Plasma with Catalytic and Cutoff Probes
    Prof. Miran Mozetič
    Slovenian Research Agency
11. Advanced Physical Techniques for Modification of Polymer and Composite Functionalities for Biomedical Applications
    Prof. Miran Mozetič
    Slovenian Research Agency
12. Guided Nanoherding of Quantum Dots
    Prof. Uroš Cvelbar
    Slovenian Research Agency
13. Molecular Imaging of Biological Samples Using MeV Ions and keV Clusters for TOF-SIMS Spectrometry
    Asst. Prof. Janez Kovač
    Slovenian Research Agency
14. Deposition of Coatings on Plasma Prepared Medical Stents
    Prof. Uroš Cvelbar
    Slovenian Research Agency
15. Synthesis and Characterization of Pt Nanocatalysts at Metal Oxide based Supports for Fuel Cells Application
    Asst. Prof. Alenka Vesel
    Slovenian Research Agency
16. Ion and Laser Beam induced Formation of Biocompatibile Alloys in Multilayered Thin Film Structures
    Asst. Prof. Janez Kovač
    Slovenian Research Agency
17. Measurements of Plasma Parameters in Capacitive and Inductive RF Discharges
    Prof. Uroš Cvelbar
    Slovenian Research Agency
18. Characterization of Gaseous Plasma for Nanoparticle Synthesis
    Asst. Prof. Alenka Vesel
    Slovenian Research Agency
19. ECS Electrochemical Society
    Prof. Uroš Cvelbar
    Slovenian Research Agency
20. Plasma Facing Components-1-IPH-FU, EUROFUSION
    Dr. Aleksander Drenik
    European Commission
21. Education-ED-FU, EUROFUSION
    Prof. Miran Mozetič
    European Commission
22. JET Campaigns-JET1-FU, EUROFUSION
    Dr. Aleksander Drenik
    European Commission
23. Medium Size Tokamak Campaigns-MST1-FU, EUROFUSION
    Dr. Aleksander Drenik
    European Commission

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. Organic-Inorganic Thin Film Structures for Electronics Components
   Asst. Prof. Janez Kovač
2. Development of Advanced Processes for Attending High Efficient Nano Modified Textile Materials
   Prof. Miran Mozetič
3. Multifunctional Nanostructured Films for Artificial Implants - Corrosion and Tribo-corrosion Processes
   Asst. Prof. Janez Kovač
4. Synthesis of Nanowires for Regenerative Energy Cells
   Prof. Uroš Cvelbar
5. Colour, Absorption and Protective Nanolayer Coatings for Aluminium Alloy
   Asst. Prof. Janez Kovač
6. Self-lubricating and Wear Resistant PVD Hard Coatings based on (V,Cr,Al,Ti)N for Hot-working Processes
   Dr. Peter Panjan
7. Development of the Functional Textiles used fot the Treatment of Diabetic Foot (Malum perforans)
   Prof. Miran Mozetič
8. New Materials for Printed Sensors and Indicators and their Integration in Smart Printed Matter
   Asst. Prof. Alenka Vesel
9. Interaction between Fully Dissociated Moderately Ionized Ammonia Plasma and Glass-fiber Reinforced Polymers
   Prof. Miran Mozetič
10. Nanostructures and Related Composites for Detection of Hazardous Gaseous Molecules
    Prof. Uroš Cvelbar
11. Functionalization of Biomedical Samples by Thermodynamic Non-equilibrium Gaseous Plasma
    Prof. Miran Mozetič
12. Toward Ecologically Benign Alternative for Cleaning of Delicate Biomedical Instruments
    Asst. Prof. Alenka Vesel
13. Functionalization of Polymer Cardiovascular Implants for Optimal Hemocompatibility
    Asst. Prof. Alenka Vesel

NEW CONTRACTS

1. Advanced Functional Implant
   Dr. Ita Junkar
   Ekliptik, d. o. o.
2. Environmentally Friendly Cleaning of Components for Large Vacuum Systems
   Prof. Miran Mozetič
   Vacutech Vacuum Technologies and Systems, d. o. o.
3. Characteristics of Gaseous Plasma in Gaps
   Prof. Uroš Cvelbar
   Kolektor Sikom, d. o. o.
4. Investigation of Evaluation Methods for Vacuum Insulation Panel Performance Testing in Accordance with Draft of ISO Standard
   Dr. Vincenc Nemanič
   Stirolab, d. o. o.
5. Investigation of Melamine Foams as the Core Material in Vacuum Thermal Insulation
   Dr. Vincenc Nemanič
   Melamin Chemical Factory, d. d.

VISITORS FROM ABROAD

1. Dr. Thomas Gries, University of Lorraine, Lorraine, France, 23–25 January 2014
2. Prof. Tara Desai, IAEA, Wien, Austria, 16–18 March 2014
3. Dr. Andre Anders, Lawrence Berkley National Laboratory, Berkley, USA, 3–6 April 2014
4. Dr. Oleh Baranov, Kharkov Aviation Institute, Kharkov, Ukraine, 15–31 May 2014
5. Prof. Ho-Sung Yoon, Kyungpook University, Daegu, South Korea, 29–31 May 2014
6. Prof. Thomas Sabu, Mahatma Ghandi University, Kerala, India, 2–4 June 2014
7. Dr. Joanna Izdebska, University of Warsaw, Warsaw, Poland, 2–4 June 2014
8. Dr. Davor Peruško, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 1–6 June 2014
9. Dr. Suzana Petrović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 1–6 June 2014
10. Prof. Hong Young Chang, KAIST, Daejeon, South Korea, 20–26 June 2014
11. Dr. Byung Kuen Na, KAIST, Daejeon, South Korea, 20–26 June 2014
12. Dr. Rachmat Wibowo, Primož Eiselt and Heinz Schmidt, Plasmait Gmbh, Lebring, Austria, 24 June 2014
13. Dr. Petr Slobodian, Tomas Bata University, Zlin, Czech Republic, 21–27 July 2014
14. Dr. Yumiko Akanuma, Nissan Motor Co., Ltd., Kanagawa, Japan, 22–24 September 2014
15. Prof. Val Vullev, University of California, California, USA, 17–19 October 2014
16. Akhil Chandran Mukkattu Kuniyil, University of Novi Sad, Novi Sad, Serbia, 7–28 October 2014
17. Dr. Jorge Andres Lopez Garcia, Tomas Bata University, Zlin, Czech Republic, 1 September–31 October 2014
18. Dr. Danijela Vujošević, Institute for Public Health of Montenegro, Podgorica, Montenegro, 6–9 November 2014
19. Dr. Marko Karlušić, Ruđer Bošković Institute, Zagreb, Croatia, 20–21 November 2014
20. Dr. Danijela Vujošević, Institute for Public Health of Montenegro, Podgorica, Montenegro, 17–22 December 2014

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