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on
Vacuum based Science and Technology

in conjunction with

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organized by

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Nanotechnology
and Vacuum Technique
Koszalin University of Technology

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Dear Colleagues,

traditionally it is my pleasure to welcome you in Kołobrzeg during the 6th Symposium on Vacuum based Science and Technology, organized by the Institute of Mechatronics, Nanotechnology and Vacuum Technique, the unit of Koszalin University of Technology, under auspices of the Polish Vacuum Society (PTP), German Vacuum Society (DVG), Shanghai Vacuum Society (SVS) and held in conjunction with the 10th Annual Meeting of DVG. The Symposium organization is also supported by the Clausius Tower Association.

The mission of the Symposium, co-organized with the Baltic-Net Plasma-Tec Association, is to continue and foster cooperation within the European plasma science community. The Symposium provides a forum for presentation and exchange of expertise and research results in the field of vacuum and plasma based science.

This year again, a solemn, plenary session is dedicated to Rudolf Julius Emmanuel Clausius – an outstanding German physicist, born in Koszalin in year 1822. The session will be followed by the Rudolf-Jaeckel Prize ceremony.

During this meeting, a special emphasis is placed on nine topics:

- Plasma physics and technique
- Vacuum science, techniques and trends
- Characterization of surfaces and thin films
- Nanostructures and nanotechnology
- Nanocomposite materials and coatings
- Protective coatings for metal and wood processing tools
- Technologies and materials for biomedical engineering
- Plasma based surface treatment technologies
- New trends and concepts of plasma based deposition processes

The Symposium is accompanied by the industry exhibition attended by the representatives of leading companies offering vacuum equipment, complete solutions for plasma based technologies as well as advanced research equipment.

Please find this Book of Abstracts as a guide through the scope of Symposium topics. I hope it will attract you to attend invited lectures, oral presentations and poster session.

Please accept my best wishes of successful meeting, fruitful discussions and good time spent together in Kołobrzeg.

Witold Gulbiński
Symposium Chairman

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Rudolph Clausius - a pioneer of the modern theory of heat

Stefan L. Wolff

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Rudolph Clausius (1822-1888) played an important role advancing the theory of heat in the 19th century. His contributions concerned the development of the two fundamental principles of heat as well as the microscopic approach of kinetic theory introducing the new concept of the mean free path. He always strictly separated these two fields. When Clausius started his studies the idea of heat as a kind of a weightless substance still existed. He opened the way for modern statistical physics which is mainly connected with the names of Maxwell and Boltzmann and also for thermodynamics chiefly advocated by Planck.

We shall discuss scientific education and research of Clausius in context of the development of the theory of heat. There we focus on his time in Berlin and Zurich. Clausius started his studies at Berlin University in 1840, habilitated there in 1850 and went to the newly founded Zurich Polytechnical for his first professorship in 1855. When he was appointed to the chair in Würzburg in 1867 he had already published his most important papers on the theory of heat.

From Clausius entropy concept to bi-velocity method in linear irreversible thermodynamics

M. Danielewski

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As was shown by Schrödinger and Bertalanffy (1945), the Second Law, viewed from the classical perspective of Thomson (1852) and Clausius (1865) is not anathema to order and its interpretation since Boltzmann (1886) as the "law of disorder" is not justifiable. Ordered flows, including life, are legitimate as long as they produce enough entropy to balance its own internal entropy reduction. In the other words the order production is inescapable because order may produce entropy faster than disorder.

The central problem here is a diffusion contribution to the mass and momentum flux. It belongs to the LIT (standard linear irreversible thermodynamics) as well as to the GENERIC framework (general equation for the nonequilibrium reversible-irreversible coupling). Presented investigations focus on nonequilibrium thermodynamics and statement of Landau and Lifshitz that mass flux and momentum density must be equal (Öttinger, 2005).

A thermodynamically consistent framework is developed to combine the convection and dissipative contributions to the mass, momentum and energy fluxes in the multicomponent materials. The method, which is known as bi-velocity or Darken method, base on the postulate of the unique (independent on the frame of reference) transport of the mass due to diffusion. In this work we merge: 1) the combined statements of the first and second laws of thermodynamics (LIT) and 2) the Euler's and Liouville theorems. We derive the expression for the rate of the entropy production that does not depend on the frame of reference and is always positive. We show that the derived set of partial differential equations describing the mechano-chemical mass transport is thermodynamically consistent and can be used in advanced modeling.

Science, technology development, and commerce the circle of mutual benefit

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Science is the art of turning imagination into reality. Science pushes technology and interacts with commercial enterprises in order move the frontier of methodology and instrumentation capabilities. The technical advancement eventually supports the progress of science. Scanning Probe Technology is one prominent example out of many. Invented in the early 80's, Scanning Probe Technology has enabled an entirely new view on quantum phenomena and surface physics. It became a precursor and a driving element for nano technology. Besides other areas of applications a new market segment evolved in the analytical instrument industry. Nowadays Scanning Probe Products are available for a wide variety of applications reaching from high end research instruments over laboratory commodities to industrial tools. Special consideration to high end instrumentation and fundamental research will be given.

Applications for plasma sources in medicine

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Plasma medicine is emerging worldwide as a new independent scientific field of research. First practical studies have been interpreted to be very promising. Tissue engineering, healing of chronic wounds, treatment of skin diseases, tumor treatment based on specific induction of apoptotic processes, or dental applications are promising fields. Today applications are driving the field, while the basic scientific understanding is woeful lacking and efforts to catch up are lacking behind. Therefore, a lot of basic research needs to be done to minimize risk and provide a scientific fundament for medical therapies. Of course, therapeutic application of plasmas at or in the human body is not only a task for medicine; it is a challenge for plasma physics as well. Today, concepts of tailor-made plasma sources which meet the technical requirements of medical instrumentation are still less developed. To achieve selected effects and to avoid potential risks, the plasmas must contain certain components in well defined densities and it is necessary to know how to control them by external operation parameters. Therapeutic applications required cold, non-thermal plasmas operating at atmospheric pressure. But these plasmas are a huge challenge for plasma diagnostics, because usually they are small scale, constricted or filamentary, and transient. Regarding the manageability in everyday medical life, atmospheric pressure plasma jets (APPJ) and dielectric barrier discharges (DBD) are of special interest for medical applications. Working on open air atmospheres, an input of nitrogen, oxygen and water implying complex plasma chemistry must be expected.

The effect of the PVD coatings structure on the sintered cutting edges durability

L.A. Dobrzański, M. Staszuk

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The paper includes investigation results of structures and mechanical properties of (Al,Ti)N, (Ti,Al)N, (Al,Cr)N and Ti(C,N) coatings deposited by the physical vapour deposition (PVD) techniques onto sialon tool ceramics and sintered carbides. In the paper some investigations of the coatings structure, carried out in the scanning and transmission electron microscopy were presented. Phases composition analysis was carried out using the XRD and GIXRD methods as well as the diffraction electrons in TEM. Chemical composition analysis of the coatings was performed using the GDOES and EDS methods. The roughness of surface measurements, microhardness tests and adhesion coatings to substrates tests were also carried out. It was found out that some coatings showed a fine-grained structure. Coatings, which had contained a AlN phase with hexagonal lattice showed a considerably higher adhesion to substrate from sialon ceramics rather than the coatings contained TiN phase. Better adherence of coatings containing a AlN phase with hexagonal lattice is connected with the same kind of interatomic bonds (covalent) in material of both coating and ceramic substrate. Good coatings adhesion to the substrate from sintered carbides is connected with the diffusive mixing of the components of both the coating and substrate. In the paper an exploitative properties of investigated coatings into the technological cutting trials were also determined.

Advances and challenges in the tribological properties of nanostructured protective coatings

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Recent advances in the technological sectors of aerospace, automotive, biomedical and optical and optoelectronic applications as well as in energy and environment control stimulate research on high-performance functional coatings. The ever increasing requirements call for an "ideal" combination of the mechanical, tribological, corrosion, thermal and other characteristics that can only be satisfied by using specifically tailored coating architectures including nanocomposite, nanolaminate, multilayer and graded layer systems.

Achieving material's tribo-mechanical properties that would simultaneously satisfy the needs in different working environments is a challenge. In this presentation, we will outline approaches that allow one to design and fabricate high-performance protective coatings. First, we give an overview of the materials deterioration mechanisms related to different tribological situations; this includes (i) erosion resistance to solid particle impact, (ii) wear resistance; and (iii) corrosion characteristics quantified in terms of the corrosion current, open circuit potential, and electrical equivalent models. Second, we explain the synergistic effects encountered in real-life tribo-corrosion conditions involving a simultaneous action of multiple effects.

Good understanding of the above mechanisms of materials deterioration allows one to develop appropriate strategies to protect technologically relevant metal substrate materials. We will describe examples using SS316, SS410, TiV6Al4 substrates coated with protective systems consisting of single- or multilayer architectures including metal nitrides and carbides (e.g., TiN, TiC, CrN) and nanocomposites (TiN/SiN, TiCN/SiCN, TiSiN, CrSiN) obtained by pulsed magnetron sputtering or by plasma enhanced chemical vapor deposition.

We introduce and discuss the selection rules describing the overall film behaviour with respect to their microstructure and their basic elasto-plastic properties, namely their hardness, H, Young's modulus, E, elastic strain-to-failure, resilience, and resistance to plastic deformation, expressed, respectively, by the H/E, H^2/E, and H^3/E^2 ratios.

Application of the above protective coating systems will be illustrated by specific examples including aircraft engine components, cutting tools, biomedical implants, and others.

Tungsten-based nanocomposite coatings

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Tungsten and its compounds such as nitrides, carbides, and oxides have served for many years as important technological materials in numerous applications. In the form of coatings, these materials are frequently used as wear-resistant layers on cutting tools and friction pairs (mostly carbides), diffusion barriers in integrated circuits (mostly nitrides), electrochromic and catalytic structures (mostly oxides), to name just a few uses.

This presentation reviews the current knowledge level on fabrication, properties, and performance of tungsten-based coatings from simple binary compounds to nanostructured composite systems. Particular emphasis is given to the tungsten nitride- and carbide-based hard and tough thin-film coatings, and to the tungsten-based thin-film and nanoparticle coatings as interlayers in thin-film diamond deposition.

The discussion deals further with the recent results of our collaborative research in (i) the sputter-deposition of the tungsten nitride- and carbide-based ternary and quarternary nanocomposite coatings (W-C-N, W-C-Cr(or Al), W-C-N-Cr(or Al)); (ii) Chemical solution- and vapor-based synthesis of WO_3/C and WC_{1-x}/C nanoparticle-based layers and structures, and (iii) Chemical vapor deposition (CVD) of nanocrystalline diamond films on the interlayer of materials described in (i) and (ii). Depending on the composition and microarchitecture, these nanostructured composites and structures have been characterized by using many analytical techniques including X-ray diffraction, SEM, TEM, Raman and FTIR spectroscopy, X-ray photoelectron spectroscopy, AFM. The results of nanoindentation, tribological, and thermal stability tests of the selected tungsten-based coating systems are also presented.

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HIPIMS-processing of wear-resistant nitrides

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High power pulsed magnetron sputtering (HIPIMS), technique introduced to the Western world more than a decade ago, is presently on the way to be established among other successful thin film deposition methods. During this time the most effort has been devoted to the area of hard coatings with the focus on obtaining films with superior properties, and first commercial products are already on the market. In this paper the results from growth of polycrystalline CrN_x and $Ti_{1-x}Al_xN$ films by HIPIMS are presented and discussed. Films were deposited in an industrial coater, capable of delivering MW power pulses with the frequency in the range from 100 to 1000 Hz. Depositions were performed exclusively in the HIPIMS mode, as well as in a hybrid set up, with one target operated in HIPIMS and the other in dc magnetron sputtering (DCMS) regime. Resulting films are analyzed by x-ray diffraction, scanning electron microscopy, transmission electron microscopy, elastic recoil detection analysis, and nanoindentation. Film properties are largely affected by the choice of target that operates in the HIPIMS mode. This can be understood with the help of ion mass spectroscopy investigations that reveal significant difference between HIPIMS and DCMS sources in terms of the composition of the ion flux incident upon the growing film surface. While the latter method produces low-energy (~2 eV) ion flux dominated by Ar^+ and N_2^+ ions, HIPIMS results in a high-intensity flux of metal ions with a mean ion energy in the range from 10 to 20 eV and high-energy tail extending up to 50 eV. The presence of energetic, film-forming ions is identified as the main factor responsible for observed differences in film microstructure and resulting properties.

Superhard nanocomposite coatings: fundamentals and their industrial applications

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Hard, superhard, and functional nanostructured and nanocomposite thin films, which have been developed during the last two decades, are finding an increasing number of applications, such as wear-protective coatings on tools, hard and self-lubricant coatings for harsh and variable environment, for corrosion protection and others. Increasing interest receive materials with a high ratio of hardness to Young's modulus as mechanically adaptable coatings on machine parts, where their high compliance combined with high hardness reduce the wear. After a brief overview of the different mechanisms of hardness enhancement in nano-sized and nano-structured materials I shall concentrate on the recent progress in the understanding of the preparation of super- ($H \geq 40$ GPa) and ultrahard ($H \geq 80$ GPa) nc-TiN/a-Si_3N_4 and related nanocomposites in which 3-4 nm size TiN nanocrystals are "glued" together by about 1 monolayer thick SiN_x interface [1], that is strengthened by enhanced valence charge density [2]. Afterwards I shall briefly summarize the recent results of our combined *ab initio* density functional theory (DFT) calculations and thermodynamic modeling to elucidate which systems can form the appropriate nanostructure by self-organization upon spinodal decomposition of the solid solution. The DFT calculation of the shear strength of the interfaces, Sachs averaging, pressure enhancement of the flow stress and Tabor's relation between the hardness H and yield strength Y, $H \approx 2.84 \cdot Y$, explain why these materials can reach hardness significantly larger than diamond [3] if correctly prepared and with low concentration of defects and impurities. I shall discuss the conditions needed to obtain the high hardness enhancement and high resistance against brittle fracture [1b]. It will be shown that oxygen impurities degrade the mechanical properties, and hinder the phase segregation and formation of stable nanostructure, thus apparently increasing the "stability" of the Ti-Si-N solid solution and causing extreme high density of "dislocations", which have been reported in several recent papers (e.g. [4]). In the last paer of my lecture I shall briefly summarize the present and future industrial applications [5].

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New developments on magnetron-sputtered hard Al-Cr-oxide and Al-Cr-oxinitride thin films

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The PVD synthesis of wear and oxidation resistant aluminum oxide and derivative coatings is currently attracting large scientific and technical interest. Ternary Al-Cr-O thin films with mechanical properties comparable or superior to binary Al-O thin films can be deposited at moderate deposition temperatures. New coatings from the quaternary Al-Cr-O-N system could even offer increased strength, hardness and toughness. A combinatorial approach to the growth of Al-Cr-O-N thin films by means of reactive r.f. magnetron sputtering will be presented. For specific deposition conditions well adherent, nanocrystalline Al-Cr-O-N thin films with high Vickers hardness and elastic modulus values were grown at non-equilibrium conditions on cemented carbide and silicon substrates. Detailed results on the coatings composition, constitution, microstructure and properties will be presented and discussed in comparison to ternary Al-Cr-O thin films deposited under identical conditions.

Deposition of functional thin films for bio-medical applications by means of high power impulse magnetron sputtering

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In this contribution we present recent results for the antibacterial effect of thin titanium/copper (Ti-Cu) films in combination with results for the growth of human osteoblastic cells on the surface. Metal Cu^{2+} ions are known as antibacterial agents with cytocompatible effects in a dosage-dependent manner. Furthermore, copper is a metabolic agent which can be easily removed from a living body. Hence, our research is focused on deposition of Cu-based inter-metallic thin films on titanium alloy (TiAlV) substrates. As the second component of the investigated inter-metallic alloy we use titanium to increase film adhesion onto TiAlV surfaces and to increase the film hardness. Thin films were prepared by dual-High Power Impulse Magnetron Sputtering (dual-HiPIMS). The quality and properties of deposited films are influenced by internal plasma parameters (mainly by the energy of particles incoming to the growing film). The Ion Velocity Distribution Function (IVDF) was measured by a retarding field analyzer (RFA) with respect of film formation. It was found that films are copper rich with a density close to pure bulk Cu material. This effect, together with larger domain size, results from the high energy of sputtered particles during HiPIMS pulses.

The antimicrobial effect is caused by copper released from the metallic Ti-Cu films, which was measured by atomic absorption spectroscopy (AAS). The copper release is influenced by the chemical and physical properties of deposited films which were investigated by X-ray diffractometry and X-ray reflectometry (GIXD and XR) techniques. It was found that the total amount of released Cu was about 250 μg. Further, it was observed that copper release is relatively fast and occurs during the first 24 hours. In vitro planktonic growth tests on Ti-Cu surfaces for *Staphylococcus epidermidis* and *S. aureus* demonstrated killing of both bacteria. After the total release of copper the vitality of exposed human osteoblast MG-63 cells increased significantly. An initial cytotoxic effect of Ti-Cu films followed by growth of osteoblastic cells is demonstrated with respect of film and/or plasma properties.

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Thin film materials for LED lighting and display applications

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Light emitting diode (LED) has been becoming the new generation major lighting and large area display technology. High efficiency with low cost white LED source has become practical application for general illumination application. With development of the advanced nanostructure materials including GaN, ITO (indium tin oxide), ZnO, SnO_2, carbon nanotubes (CNTs), graphene, diamond, phosphors, metal and composites, the devices performance is improved greatly by using the materials. The excellent electrical conductivity of CNTs, graphene, Ag nanowire, high thermal conductivity of diamond and Ag nanowire, high efficiency nitride phosphors, nano metal oxide composites, and related applications in white LED devices are reviewed. The transparency and flexible LED displays are demonstrated. A novel flat package technology of high efficiency white LED module and lighting application will be introduced, and related indoor/ outdoor illumination such as office, street/road, tunnel lighting applications will be reviewed.

Keywords: thin film, phosphor, LED, lighting, display

The Al-Si-N system: from solid solutions to nanomultilayers

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When preparing transition metal nitrides with the addition of silicon, bi- and multiphase coatings containing silicon nitride are formed, as most transition metal nitrides show limited or no solubility for silicon. Using aluminum nitride instead of optically opaque transition metal nitrides, along with silicon, causes the formation of optically transparent Al(Si)N coatings. These coatings exhibit hardness values of more than 30 GPa, in a broad hardness distribution as a function of the silicon content. A thermodynamically stable solubility limit exists for silicon contents around 6 atomic %. The Al-Si-N system forms, as a function of the silicon content, either solid solutions or a two-phase nanocomposite structure. These three distinct growth zones, differing in their structural properties, can be described in a growth zone model accounting for the different nanostructures. Model systems using nanoscale multilayers show that in this materials system the absence of a major hardness enhancement can be understood in terms of epitaxial growth and the elastic properties of the single phase components. The addition of oxygen to form $Al(Si)N_{1-x}O_x$ causes, similar to silicon addition, grain refinement and a gradual disappearance of the columnar structure with increasing oxygen content. Despite very high oxygen concentrations up to 20 at% O hardness values of 25 GPa are reached. The properties of these coatings will be presented and underlying mechanisms will be discussed.

Metal alloyed DLC coatings and their tribological behavior under lubricated contact

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C-based coatings are now successfully applied in a large range of applications, involving dry sliding mechanical contact, due to the low friction they can provide. Recently, their use has been extended to different components of combustion engines even though the presence of lubricant can occur. However, there are many cases where liquid lubricants have a detrimental role in the low friction behavior of C-based coated parts. In boundary lubricated contacts, the system performance is dependent on the interfacial film resulting from the tribochemical interactions between the surface and the lubricant additives. The inertness and low reactivity of C-based coatings impedes the tribo-interaction of C-based film with oils and additives, which dictates the friction in the contact. It is expected that modification of C-based material by addition of different metals can invert this behavior. The formation of a nanocomposite structure consisting of an amorphous C-rich matrix with dispersed metal or metal carbides nanoparticles can improve the interaction with the lubricant and further extend the successful use of C-based coatings in sliding conditions to tribological applications involving liquid lubrication.

This talk will be divided in two main parts, in the first one an overview of the state of the art on the interaction between lubricants and C-based films alloyed with metals will be presented. The focus will be on the relationship between the composition of the tribolayer and the tribological performance. In a second part, experimental results on hydrogenated and non-hydrogenated carbon coatings alloyed with W, Cu and Ti, with contents lower than 30 at. % will be shown. Tribological performance achieved in dry and lubricated contacts by pin-on-disk testing will be related with the results achieved after characterization of the worn tracks after sliding tests.

Characterization OF MWCNT grown in the carbonaceous film

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In this paper we present results of characterization of multiwall carbon nanotubes grown on carbon thin film (MWCNT- film). These MWCNT-films were obtained in two steps (PVD/CVD method) and due to technological parameters of both steps they are distributed in the film surface with a different density. From the first step, PVD process, we obtained initial film, called further PVD film. Such PVD film was modified in CVD process to obtain MWCNT films.

The structure, lengths, defects and growth mechanism (top or bottom) also depend on these parameters. The structure of this film (more or less porous) is also connected to the technological parameters.

Such films, due to the density of MWCNT distribution could be applied as field emitters avoiding electrical interaction between nanotubes.

These films were studied with SEM and Raman spectroscopy methods. From SEM images of films we get information on their topography, which is changing, with technological parameters, from long MWCNT placed in solid carbon matrix to short, thick MWCNT placed in porous matrix. From EDS results we estimated Ni content changes in initial PVD films.

Raman spectra of initial PVD films and MWCNT films consist of C_{60} characteristic bands and of D-and G-bands respectively for PVD and MWCNT films. In Raman spectra some bands that could be attributed to MWCNT vibrations were also found.

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Physical properties of As-deposited and Ag-doped CDS thin films fabricated by close spaced sublimation technique

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Cadmium sulfide (CdS) polycrystalline films having different thickness were grown on corning glass substrate by Close Spaced Sublimation (CSS) technique. After then films were doped by silver (Ag) with different concentrations by the help of ion exchange technique. The structural investigations performed by means of X-ray diffraction (XRD) technique showed that the deposited films exhibit a polycrystalline structure. The structural, optical and electrical properties of these films were analyzed by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and Hall measurement. Transmission spectra were studied by UV-VIS-NIR spectrophotometer. The research is focused on comparative study of physical properties of as-deposited and Ag-doped CdS thin films.

Synthesis of thick superhard nc-TiN/a-Si_3N_4 coating by a new high density plasma gas pulsed reactive magnetron sputtering

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Nanocomposite nc-TiN/a-Si_3N_4 coating is a new very interesting and important coating due to a unique combination of its properties. First of all it is its hardness which can be even greater than that of diamond, however other ones as, e.g., a great thermal stability or a high resistance to oxidation, are equally important for numerous industrial applications. At first it was deposited by means of a low pressure CVD by Stan Vepřek et al. in 1995, next also by a low pressure arc discharge or a magnetron sputtering (MS) or a mixed arc-MS process and recently also by a HIPIMS technique. Taking into account several disadvantages of the above mentioned techniques (as, e.g., a low deposition rate of the HIPIMS or not satisfactory adhesion specific for MS) a new method has been elaborated in the Lodz University of Technology based on a high density plasma gas pulsed reactive MS (patent application in 2010). The method turned out to be a very effective one due to a number of advantages:

$\Rightarrow$ a high deposition rate ~10 μm/hour at a mean value of a magnetron discharge power density ~ 0.2 $kW \cdot cm^{-2}$ at a distance of ~ 100 mm between the specimen and the magnetron target;

$\Rightarrow$ a much higher optical radiation intensity of the high density plasma gas pulsed magnetron discharge in comparison with the one of a DC MS discharge;

$\Rightarrow$ no arcing during the gas pulsed MS;

$\Rightarrow$ supernanohardness (40-47 PGa) and supernanomodulus (~ 560 GPA) of the deposited nc-TiN/a-Si_3N_4 coating;

$\Rightarrow$ a very good adhesion of the nc-TiN/a-Si_3N_4 coating to Vanadis 23 or CNMA sintered carbide substrate (L_{CII} > 100 N);

$\Rightarrow$ nanocrystallinity of the TiN grains in the synthsized coating (~ 4 nm diam.);

$\Rightarrow$ nearly ideal axial [111] texture of the TiN grains with the texture axis exactly perpendicular to the substrate surface;

$\Rightarrow$ overstoichiometric nitrogen content in the coating (~ 56 at. %)

$\Rightarrow$ friction coefficient against a Si_3N_4 ball decreasing with temperature from 0.5 at ambient temperature to ~ 0.2 at 900 ^{0}C;

$\Rightarrow$ high plasticity of the superhard coating at very high contact stresses.

On the ground of these promising features a rather broad programme of machining tests with use of the SANDVIK CNMG 120408 H13A sintered carbides with the new type nc-TiN/a-Si_3N_4 coating and, in parallel, with the Balinit A one (deposited by Oerlikon-BALZERS, for comparison) has started in June 2011.

Effect of substrate temperature on ZnO thin film deposited using RF magnetron sputtering

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Intrinsic ZnO is an attractive material for large variety of applications. It is a wide-band gap oxide semiconductor with a direct energy band gap of about 3.37 eV. The goal of the present study is to obtain a suitable films to be used as window layer in Cu(In,Ga)Se_2 (CIGS) solar cells. Structural and optical properties of thin film zinc oxide (ZnO) reactively sputtered on glass substrate using radio frequency (rf) magnetron have been studied in this work as a function of substrate temperature (100-400^{o}C) during deposition. During the deposition two sequence of temperature was used. In the first referred as Sample A, the temperature was raised from 100 to 400 in steps of 100 during the deposition. In other sequence referred as Sample B the deposition temperature was reduced from 400 to 100 during deposition. During both the sequence at each temperature the deposition was carried out for 5 min. Both the samples (Sample A and B) were then annealed in vacuum at 500 ^{o}C for 30 min in vacuum. The films were characterized using UV-VIS, X-Ray Diffraction and Scanning Electron Microscopy (SEM). The XRD pattern shows that the sample B grown using second sequence has improved crystallinity as compared to Sample A. Annealing in vacuum increases the peak intensity showing an improvement of the film crystallinity. The other results of UV-VIS and SEM are discussed in detail.

Influence of the deposition parameters on physico-mechanical properties of Cr-C and Mo-C coatings

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An investigation of the influence of parameters of the pulsed vacuum-arc plasma deposition of Cr-C and Mo-C coatings on their physico-mechanical properties has been carried out. The coatings were deposited on P6M5 high-speed steel substrates.

Changing of a pulse repetition rate in the plasma sources equipped with metal and graphite cathodes allows the manipulating of composition, surface roughness, and friction coefficient of the coatings. For example, when the rate of discharge pulses in the plasma source with chromium cathode changes from 5 to 10 Hz, the chromium content in the coating increases by a factor of 2 (from 2 to 4 at.%). In a case of molybdenum cathode operated at 10 Hz, the change of the discharge rate on the graphite cathode from 5 to 10 Hz leads to ~6 times decrease in molybdenum content in the coating.

Decreasing of the metal content in the coatings through the variation of the discharge pulse rate increases the surface roughness 3.4-3.5 times. The Mo-C coatings are generally rougher (R_a = 27.8 nm) than the Cr-C coatings (R_a = 9.4 nm). Tribological investigations in the conditions of dry friction during an early stage of friction cycling indicated the uniform adhesive wear of an upper layer of the coatings. After 3500 friction cycles the Mo-C coatings showed weak wear, while Cr-C coatings demonstrated the fatigue wear concurrently with adhesive wear. The fatigue wear was expressed as fragmentary delamination of the coating from the substrate due to unsatisfactory adhesion. At a higher deposition rate of the metal, the coefficients of friction of chromium-carbon and molybdenum-carbon systems were 0.08 and 0.1, respectively.

It was concluded that chromium-carbon and molybdenum-carbon nanocomposite coatings can possess high durability and low coefficient of friction. They show a promise for technological applications as hardening coatings and solid lubricants in the machining and automotive industry.

Mid-frequency PECVD of a-SiCN:H films and their structural, mechanical and electrical properties

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The mid-frequency pulsed plasma enhanced chemical vapour deposition (PECVD) of hydrogenated amorphous silicon carbonitride (a-SiCN:H) was investigated to prove the suitability of these films as a mechanical stiff insulator for the integration of piezoelectric fibres in microstructured aluminium plates. For a-SiCN:H deposition trimethylsilane ($SiH(CH_3)_3$; 3MS) and nitrogen in mixtures with argon were used. The films were characterised for their deposition rate, elastic modulus and hardness (nanoindentation), mechanical stress, elemental composition (ERDA) and breakdown field strength.

The breakdown field strength of µm-thick a-SiCN:H films is in the range of a few MV/cm. At pressures of a few Pa the deposition rate reached values up to 6 µm/h. It is limited by the power absorption in the 100 kHz bipolar-pulsed discharges. Varying the pressure from 2 Pa to 15 Pa at a 3MS flow rate of 50 sccm has only little influence on the film composition: it changes from $Si_{0.28}C_{0.39}N_{0.08}:H_{0.25}$ to $Si_{0.27}C_{0.36}N_{0.07}:H_{0.30}$. With increasing pressure during deposition the elastic modulus of the films only slightly increases from about 100 GPa to 120 GPa, whereas the compressive film stress decreases from -1.2 GPa to -0.55 GPa. Reducing the 3MS flow rate from 50 sccm to 10 sccm (at 8 Pa deposition pressure), the carbon and the hydrogen concentration in the films are reduced by about 10 at. %, the Si-content is only slightly reduced but the N-content is more than tripled. By contrast, the changes in the mechanical film properties are comparatively small. This displayed once more, that the a-SiCN:H film properties are not simply correlated to the stoichiometry.

Hardness and microstructure of coatings deposited using reactive magnetron spattering of CrSi compacts

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The CrSi compacts containing 10, 20, 30, 35 and 40 at. % Si sintered from mixed elemental powders were used as targets for reactively deposited magnetron (Cr,Si)N coatings. The silicon substrates were kept either at ambient temperature or heated up to 600^{o}C. The microstructure observations were performed using TECNAI FEG (200kV) or JEOL 3010 (300kV) transmission electron microscopes. The thin foils were cut using QUANTA Dual Beam Focused Ion Beam (FIB) system. The hardness was measured using CSM tester.

The coatings deposited at 600^{o}C using CrSi10 target presented fully crystalline columnar microstructure of ~45 nm. Increasing silicon content in targets to 20 and 30% resulted in refining of their columnar microstructure down to 35 and 25 nm diameters. The coatings obtained with even higher silicon addition, i.e. from CrSi35 and CrSi40 targets showed mixed amorphous-crystalline and fully amorphous microstructure. The deposition performed at non-heated substrates using CrSi10 target caused formation coatings with amorphous layer close to the substrate. The deposition in the same conditions using targets with increasing silicon content helped to produce coatings with widened amorphous layer up to the surface for CrSi40. The measurements of composite coatings performed using Gatan Image Filtering (GIF) technique indicated that both in coatings deposited on heated and non-heated substrates the crystallites and amorphous areas are at least enriched in Cr and Si, respectively.

The coatings obtained on substrates kept at 600^{o}C from CrSi targets with 10, 20 and 30 at. %Si showed hardness increase from 20 to 30 and to 35 (occasionally up to 40) GPa. Still higher silicon additions, i.e. 35 and 40 at. % Si, caused drop of the hardness to ~30 and ~10 GPa. The coatings deposited at substrates kept at ambient temperature were of approximately the same hardness level of ~20 GPa, except those obtained from the Cr40Si targets. The hardness of the latter coatings was only ~10 GPa, what probably was caused by deposition instabilities frequent for targets with so high silicon content.

The performed observations indicate, that hardness increase up to super-hard materials level in (Cr,Si)N coatings obtained in reactive magnetron spattering is achieved rather due to crystallite size refining. The presence of nano-composite crystalline-CrN/amorphous-Si_3N_4 microstructure was confirmed both in coatings deposited at ambient temperature or at heated substrates as the silicon addition in CrSi targets exceeds 30 at%. However, the formation of amorphous material in any detectably amounts in present experiments was always connected with drop of coatings hardness.

Time-resolved diagnostics of hybrid dual-HiPIMS discharges

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The contribution is focused on time-resolved diagnostic of unipolar hybrid-dual High Power Impulse Magnetron Sputtering discharge. The newly developed sputtering system is based on a combination of dual-HiPIMS (the system where two magnetically and electrically confined magnetrons are alternately operated in HiPIMS mode, f_H = 100 Hz, duty cycle 1 %, delay between pulses 15 μs) with mid-frequency (MF) discharge operated at f_M = 94 kHz, duty cycle 30 %. The most important feature of hybrid-dual-HiPIMS system is the MF pre-ionization effect which causes/allows: (i) a significant reduction of working pressure by more than one order of magnitude, (ii) an increase of HiPIMS power density, (iii) an increase of electron and ion energy, and (iv) an increase of deposition rate. In this way some unwanted features of HiPIMS discharges can be removed and at the same time the energy of particles incoming to the film is higher (lower pressure, higher pulsed power density).

The time–resolved measurements of Ion Velocity Distribution Functions (IVDFs) were performed by means of a retarding field analyzer (RFA). It was found that ion energies during HiPIMS pulses are enhanced (about 15-20 eV) while in MF discharge they are almost negligible (~ 0.5-1.5 eV). Ions arrive at the RFA about 25-30 μs after the HiPIMS pulse ignition. The effect is caused by the diffusion time of ions produced near by the cathode and measured by the RFA detector situated in the substrate position. The study of plasma transport effects and plasma expansion dynamic in hybrid-dual-HiPIMS system was done by fast optical emission imaging (OEI). The optical filters with specific wavelength were emloyed during OEI investigation and the expansion dynamics of particular species was distingished. OEI was also combined with time-resolved optical emission spectroscopy. Combination of all described methods allows for a complex study of basic phenomena in hybrid-dual-HiPIMS systems.

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Plasma Optics, a new input into plasma technology

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The charged particle fluxes in a low pressure plasma chamber are controlled by the internal distribution of the plasma potential. For often used cylindrical plasma vessels of comparable diameter and height the equipotential planes are sphere-like leading to concave potential planes which de-focus the ion flux to an extraction system or a sputter target at the plasma edge. The idea of "plasma optics" is to remove such drawbacks by matching the potential distribution in the plasma to the actual application. It will be shown that this is achieved when choosing an appropriate geometry of the plasma chamber.

Concave potential planes can thus be turned to an ion collecting convex form. This results, e.g., in a considerable increase of the ion current into the extraction system of an ion beam source. The advantage of plasma optics will be exemplified , in particular, for plasma based Secondary Neutral Mass Spectrometry SNMS. A distinct enhancement of the signal intensities and, hence, of the detection power is achieved by properly shaping the equipotential planes in front of the sample head and the extraction optics.

Full range XHV cold cathode gauge

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Ionization vacuum gauges are currently the preferred sensors for total pressure measurements in fine-, high-, and ultra-high vacuum. The two most widely-used types of ionization gauges are hot cathode and cold cathode gauges, respectively. While in the first case ionization occurs due to thermionic electrons, in the latter case crossed electromagnetic fields are responsible for the ionization. Thus the cold cathode gauge is a vacuum meter which is mechanically robust, insensitive to venting by accident as well as to vibrations. Disadvantages of this sensor type are residual stray magnetic fields and increasing contaminations of the electrodes after long term operation. Also, the plasma discharge is difficult to initiate and maintain at low pressures. In order to improve the performance of this type of gauge we simulated ionized particles in crossed electromagnetic fields in vacuum. They show a pressure dependent behaviour of the discharge which can be compensated by proper dimensioning of the detector unit. Furthermore it is inevitable to optimize the cathode materials with low sputter coefficients for an improved long term operation.

We will present the results of a design of an optimized cold cathode gauge. Major improvements have been successfully demonstrated in terms of lower pressure limit with pressure readings down to the XHV region (10^{-12} mbar), a lower magnetic stray field, and an improved long term operation. Theoretical and measured data will be presented and discussed.

The PVD technologies development directions determined on the base of foresight research results

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The goal of this paper is presentation of comparative analysis results concerning the most perspective technology groups included in common called Physical Vapour Deposition (PVD) during the next 20 years. In the framework of carried out research the value of the given technologies against the environment background has been determined and the development strategies for them, together with strategic development tracks has been defined. Moreover, for each from 10 analysed technology groups the technology roadmap has been created. A technology roadmap is a graphical comparative analysis tool for choosing the best technology group in terms of selected criteria. In the last part of the paper the practical implementation possibilities of the given technology groups taking into account market products and industry branches are presented. In carried out research raw data collected during the three iterations of wide foresight expert research concerning the priority technologies in surface materials engineering area having the best development perspectives or key importance in industry has been used. The research results shows the best long-term development perspectives for CAD and RMS, however the strategic positions of PPM, ED-PVD, PLD and IBAD are also promising.

Comparative studies of surface morphology and surface chemistry of the differently prepared SnO_2 thin films

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In the last several years the tin dioxide SnO_2 thin films have drawn a great interest because of its high sensitivity to both oxidizing and reducing gases, low costs of production, and potential application for the resistivity-type gas sensor devices.

Among various techniques for the preparation of SnO_2 thin films Rheotaxial Growth and Thermal Oxidation (RGTO), RF Ion Sputtering (RIS) and Spin Coating have been successfully implemented.

In our recent studies some basic information on the surface morphology, chemistry and electronic properties of SnO_2 thin films deposited by RGTO and RIS methods have been obtained.

In this work the results of a comparative studies by Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and X-ray Photoelectron spectroscopy (XPS) on the correlation between surface morphology and surface chemistry of the SnO_2 thin films prepared by RGTO, RIS and SC methods are presented and discussed.

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Electrical properties of composite films with columnar inclusions

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Composite films are very interesting materials for their extraordinary mechanical, electrical and optical properties. These properties can be strongly influenced by geometry of inclusions embedded into a matrix. We are dealing with particles of a columnar shape in our contribution.

A correlation between a slant of inclusions and a resistivity of the structure was experimentally observed and measured. We study this phenomenon with a self-made computer experiment. The model consists of generation of the structures with columnar inclusions, their morphological and resistivity analysis. The generation of the structures is done with the Monte Carlo method, the morphological analysis uses the theory of percolation methods (the modified burning method) to determine an ohmic conductivity network, so-called infinite cluster, and electrical properties are studied with the network analysis methods.

Our model corresponds with the experimental measurements and shows how the slant of inclusions influences the electrical resistivity. It is shown that the electrical resistivity increases with the angle of deposition, i.e. with the angle of inclusions slant. These observations are analysed and discussed.

Functional Zr-containing coatings

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The paper reports on hard coatings containing Zr, as main or additional element, obtained by the cathodic arc method.

The deposition system consists of three cathodes, using metallic mono-element or alloyed targets, operated in a mixture CH_4 and N_2, at a pressure of about 8.10^{-1} Pa. Different characterisation methods were used for coatings investigation: AES, EDX, or GDOES (elemental composition), XPS (chemical composition), XRD (phase composition, grain size), microhardness tester, surface profilometry (thickness and stress) and AFM (surface roughness), scratch test (adhesion), and pin-on-disc tribometry.

The incorporation of small amounts of different metals (Ti, Al, Hf, Nb) in the structure of the ZrCN basic system led to improved hardness and tribological performance, for the coatings obtained by both deposition methods. Also, we considered the addition of Zr as alloying element to different carbonitride compounds (TiCN, TiAlCN, TiNbCN), resulting in the improvement of hardness, adhesion and tribological performances.

All the coatings exhibited a cubic fcc structure, with a (111) prefered orientation. The films with a low concentration of metals tend to become amorphous, as confirmed by Raman spectra. For all coatings, the presence of Zr as main or additional element, resulted in a hardness enhancement, which was more pronounced for the stoichiometric coatings, as compared to the overstoichiometric ones. The hardness increase may be explained by lattice deformation, solid solution strengthening, defect hardening mechanisms and favourable valence electron concentration. Some representative applications of different coatings are presented.

Measuring thin film mechanical parameters without substrate influence: possibilities and limitations

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We are investigating the determination of Young´s modulus and yield strength of bulk materials and thin films by nanoindentation with both spherical and sharp indenters. Our approach is based on the comparison of experimental data with the results of analytical modelling of the elastic fields in the sample. While the indentation of spherical indenters can be modelled directly, in case of sharp indenters the shape of an adequate „effectively shaped indenter" [1] has to be determined corresponding to Schwarzer [2] and used for the elastic modelling. This type of method enabled the determination of mechanical parameters even for very thin films for a variety of materials including DLC, TiN and B-C-N [3]. On the other hand, for soft materials (e.g. metals) the concept failed.

In this work we report on the investigation of a series of standard samples for hardness measurement made of 90MnCrV8 steel which covered a range of HV 240 – 840 corres- ponding to a ratio of Young´s modulus and yield strength, E/Y, between 65 and 360. Nano-indentation with pile-up correction based on AFM measurements was performed using a Berkovich indenter and the data were evaluated by the procedure given in [2]. Reference values for Young´s modulus and yield strength were obtained utilising surface elastic wave and uniaxial compression tests, resp..

In the region E/Y from 65 to about 80 the yield strength delivered by our method was found to be about twice the reference yield strength. Then, the ratio increased, reaching four times the reference value for E/Y = 360. For a borosilicate glass sample (E/Y = 14), however, the values agreed well. We conclude that a sufficiently low E/Y is essential for the applicability of the „effectively shaped indenter" approach for yield strength determination.

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STM study of the adsorption of Pb ON Mo (110). Comparison with the growth of Au, Ag and Sn on Mo (110)

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Scanning tunnelling microscopy (STM) has been used to investigate the growth behaviour of ultra-thin Pb films on the Mo(110) surface at room temperature. The analysis of STM measurements indicates that for a coverages $\theta < 1$ ML two-dimensional growth of the first Pb monolayer (wetting layer) took place. Above $\theta > 1$ ML, the three-dimensional growth of the Pb islands with strongly preferred atomic scale 'magic height' and flat top is observed. At coverages between 1 ML $< \theta \leq 2$ ML, only islands containing two atomic layers of Pb are observed. At coverages between 2 ML and 3 ML, islands containing two and four atomic layers of Pb are observed. At higher coverages $\theta > 3$ ML, the island height distribution shows peaks at relative heights corresponding to N = (2, 4, 6, 7 and 9) of Pb atomic layers. STM results below 1 ML show coexistence of two well ordered surface superstructures ε_1 and ε_2 in the first lead layer. The lengths of unit vectors of this structures and the angles between them are 5.2 Å, 4.3Å, 84^o and 3.8 Å, 4.1 Å, 92^o, respectively. Results presented for growth of Pb will be compared with growth of Ag, Au, and Sn on Mo(110).

Detection of small protein surface coverages on plasma cleaned titanium by ToF-SIMS

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Adsorption processes of the model protein bovine serum albumin on chemical cleaned pure titanium surfaces are studied by time-of-flight secondary-ion-mass-spectrometry (ToF-SIMS). The dependence of the surface coverage on the protein concentration in the aqueous solution may be described by the well known Langmuir isotherm. The obtained characteristic adsorption parameters, such as the Langmuir constant were compared to the corresponding X-ray photoelectron spectroscopy (XPS) and Bicinchoninicacid-method (BCA) measurement and we found a reasonable agreement. It has to be kept in mind, that due to their limited sensitivity only relatively high coverages are accessible by XPS and BCA. In contrast, SIMS allows the detection of small protein coverages even down to a concentration range where the adsorbed protein molecules do not interact with each other and the exact theoretical description of the adsorption kinetics is less complicated. But the residual protein coverage remaining after the chemical cleaning of the samples hampers the extension of SIMS to the lower coverage range.

Therefore, a plasma cleaning step of the surface is introduced and its characterization by ToF-SIMS and secondary neutral mass spectrometry (SNMS) measurements is presented. That cleaning process reduces the protein background signal by an order of magnitude to an absolute value of 1.5%, thus allowing adsorption experiments with the precision needed for proper characterization of the adsorption process. Thus it was possible to determine significant data for the corresponding Langmuir constants and adsorption rate constants as well as their temperature dependency.

HIPIMS+ bringing the HIPIMS technology from laboratory to the industry

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HIPIMS+ is an industrial technology based on HIPIMS, which provides a fully integrated solution for deposition of metallic and metal nitride PVD coatings. In comparison to classical magnetron sputtering, HIPIMS+ offers the possibility to additionally tune the properties of the coating by changing the plasma composition and energy. This is achieved by properly choosing parameters, such as shape, duration and frequency of the pulses. In combination with controlling the bias voltage on the substrate, the coating growth can be influenced to produce films with tailored properties, such as intrinsic stress, morphology, macro hardness and color. All this facilitates the development of coatings that meat specific application needs. In this paper, the implementation of the HIPIMS+ technology in an industrial coater is discussed. The role of the process parameters in the coating properties is illustrated for TiAlN, TiN and CrN. Comparison between the performance of HIPIMS+ coatings on one side and DC magnetron sputtered and arc evaporated coatings on the other side is shown.

Multielement carbide coatings for tribological and mechanical applications

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In recent years, high-entropy alloys (HEA), consisting of 5–13 elements with almost equiatomic concentrations, have received considerable attention because of their remarkable properties such as high hardness even after annealing, high strength, good fatigue and corrosion resistance, and high thermal stability. Considering the HEA superior qualities various compounds (e.g. nitrides, carbides) of HEA are also expected to exhibit valuable properties. So far there are several reports on HEA nitride coatings, some with remarkable high hardness.

The paper presents two types of HEA carbide coatings, based on TiAlCrNbY and TiZrNbHfTa, obtained by reactive magnetron sputtering method, using mono-element metallic targets and methane as reactive gas. Coatings characterisation was done by various techniques: EDX (elemental composition), XPS (chemical composition), Raman spectroscopy (carbon bonds), XRD (phase composition, grain size), microhardness tester, surface profilometry (thickness and stress) and AFM (surface roughness), scratch test (adhesion), and pin-on-disc tribometry.

All coatings consisted of a mixture of carbides, intermetallic compounds and carbon, depending on the $CH_4/(CH_4+Ar)$ flow ratio, and exhibited a fine grained and smooth surface morphology (2 – 9 nm), with grain sizes less than 10 nm.

The (TiAlCrNbY)C coatings exhibited hardness values smaller than those commonly reported for the binary or ternary carbides, but the tribological performance was good, especially concerning the dry friction behaviour, with values as low as 0.05. For the multielement (TiZrNbHfTa)C coatings the highest hardness value was of 27.5 GPa, with an wear rate of 0.8×10^{-6} mm^3/Nm and dry friction coefficient of 0.15.

Due to their good friction and wear performance, the multi-element coatings under consideration are promising candidates for protective coatings to be used in various tribological applications.

Electronic structures of organic-inorganic interfaces studied by AC and DC conductance techniques

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Organic-inorganic interfaces are gaining growing attention in organic photovoltaic and organic optoelectronic applications as each component of the interface offers unique attributes. A thin organic film of 8-hydroxychinolin aluminum (Alq_3) was deposited by vacuum evaporation on an *p*-type Si substrate. The fabricated Al/Alq3/p-Si/Al structures was carried through an ageing process to stabilize the parameters. Electronic structures of interfaces, including electronically functional organic materials, were studied by ac and dc conductance techniques for the systems tris (8-hydroxyquinoline) aluminum(III) (Alq_3) and p-type silicon . The forward and reverse bias current-voltage (*I-V*), capacitance-voltage (*C-V*) and conductance-voltage (G/ω-*V*) characteristics of Al-Alq3-pSi-Al structures were measured at different temperatures (80-390K) and in frequency range from 42Hz to 5MHz. In order to see the influence technological properties on main structure parameters such as zero-bias-barrier height (Φ_{bo}), ideality factor (n), series resistance (R_s) of structure and interface states (N_{ss}), the forward and reverse bias *I-V*, *C-V* and G/ω-*V* characteristics were investigated in the dark and under various levels of illumination. These main electrical parameters were obtained as function of the temperature and illumination levels.

We have observed very strong luminescence of all investigated Alq_3 samples even at room temperature. PL spectra were measured in the temperature range from 15K to 300K using helium refrigerator. Thermal quenching of photoluminescence was also studied. Optical constants like refractive index, layer thickness and absorption coefficient were calculated from transmission and reflection spectra. We have assumed that PL spectrum of Alq_3 is composed of some electronic transitions to different vibrational levels of ground electronic state. In solid state this oscillatory structure is not clearly visible because of strong interaction between molecules. In these materials distance between vibrational levels is about 0.2 eV. Transitions with phonon repetitions were studied with the help of Gaussian fitting in order to determinate position of single peaks

Investigation of interface of diamond/n-Si structures by conductance techniques

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The diamond layers were synthesized using Hot Filament CVD (HF CVD) technique from a mixture of methanol and hydrogen onto n-type Si substrates . The forward and reverse bias current-voltage (*I-V*), capacitance-voltage (*C-V*) and conductance-voltage (G/ω-*V*) characteristics of Al-diamond-nSi-Al structures were measured at different temperatures (80-390K) and in frequency range from 42Hz to 5MHz. In order to see the influence technological properties on main structure parameters such as zero-bias-barrier height (Φ_{bo}), ideality factor (n), series resistance (R_s) of structure and interface states (N_{ss}), the forward and reverse bias *I-V*, *C-V* and G/ω-*V* characteristics were investigated in the dark and under various levels of illumination. These main electrical parameters were obtained as function of the temperature and illumination levels. Both the density of interface states N_{ss} and series resistance R_s were found to be strongly temperature dependent. The effect of R_s on the *C* and *G* is more pronounced in the studied temperature range. The experimental *C–V–T* and G/ω–*V*–*T* characteristics of these structures show the expected behavior due to N_{ss} in equilibrium with the Si semiconductor. The temperature dependent *C–V* and G/ω–*V* characteristics confirm that the R_s and N_{ss} play an important role and strongly affect the electrical parameters of diamond/Si structure. Presented in this paper results indicate that at forward biases, the physical mechanism of forward capacitance is very complex and the C–V method needs some correction. Usually, the literature only reports the data for the measured capacitance of a diode under parallel mode and in some cases this has been mistaken for junction capacitance. In fact, the values of measured capacitance and conductance must be considered simultaneously in order to get accurate diode parameters involving junction capacitance, series resistance, ideality factor and so on.

Conductivity analysis of graded composite films

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Composite and nanocomposite materials have found a very wide range of applications. Understanding the relationships between their morphological and electrical properties is important. We deal with a two-phase composite/nanocomposite structure formed by conductive particles embedded into a dielectric matrix, in the paper. The conductive particles usually create inclusions of various shapes - it depends on the conditions and technology used for their preparation.

The paper describes computer experiments which aim is morphological and conductivity analysis of both homogeneous and graded composite/nanocomposite films. The morphological analysis serves to the following analysis of the electrical properties. The hard-sphere model is used for a generation of the composite structures. Efficient methods of mathematical morphology are chosen to describe the morphology of the three-dimensional composite films. A novel method of the so-called fuzzy clusters was introduced to analyse the electrical properties of the films.

The results of the simulations show that at least a partial reconstruction of the three-dimensional information from a two-dimensional image is possible using the proper morphological analysis. The most interesting conductivity features can be observed near a percolation threshold where the mechanism of the charge transport is changing and the electrical conductivity varies through a large scale. The dependence of the conductivity of the composite films on their morphological characteristics is discussed in the paper.

Effect of bias voltage on the properties of CrCN and CrN coatings deposited

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The bias voltage is one of the important technology parameters influenced mechanical properties of PVD coatings. Chromium nitride and chromium carbonitride coatings were deposited on HS6-5-2 steel substrates by cathodic arc evaporation technique. The relationships between one of deposition parameter, negative substrate bias voltages V_s (10 V–300 V) and the coatings characterization such as microhardness, stress, adhesion of the coatings, elastic strain to failure (H/E) were investigated. X-ray diffraction showed a microstructure containing mainly CrN cubic phase along with the Cr_2N for V_s=-300 V (in case of CrN coating). Scanning electron microscopy indicates a dense columnar microstructure. Residual stresses were measured by substrate curvature technique. The CrN coatings show a compressive residual stress that increases from 1.0 (V_s = -10 V) to 2.1 GPa (V_s = -70 V). At higher bias voltages, a decrease of the compressive residual stress is seen. Similar relation but for higher stress values is observed for CrCN coatings. Nanoindentation showed a maximum hardness of 25 GPa for CrN and 25 GPa for CrCN coating at -150 V of bias voltage. The critical loads of CrN coatings in a scratch test decreased monotonically from 95 N to 78 N with increasing negative substrate bias. The critical loads of CrCN coatings were nearly constant, about 78 N.

Plasma based SNMS – recent results using ToF-spectrometry

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Secondary neutral mass spectrometry SNMS, i.e. post ionization of sputtered particles by electron impact in a noble gas ECWR-plasma, is a well known method for the quantitative analysis of thin film structures, powders and bulk samples. The so called plasma or electron gas method of SNMS features high depth resolution by low energy primary bombardment and excellent suppression of secondary ions. In connection with the effective postionization this is responsible for the possibility of easy and robust quantification of the obtained mass spectrometry signals down to the ppm range. Until now plasma SNMS instruments are usually equipped with quadrupol mass filters, but recently a new plasma SNMS instrument using a Time of Flight mass spectrometer ToF was developed.

Due to the parallel detection capability of a ToF, follow-ups of spectra can be measured now in a short time with each single spectrum containing full information about the whole mass range. Furthermore the ToF-SNMS offers a good transmission even in the range of high masses. Creating depth profiles from the spectra, these prospects are used to investigate thin metallic layers consisting of different alloys. With the ToF-instrument no preselection of isotopes is necessary and the whole spectrum is available for further signal processing i.e. background subtraction, summation over all isotopes of an element, in-situ acquisition of associated molecules and so on. Contrary to the quadrupol mass filter such simultaneous measurement is almost impossible and depth profiling suffers from the fact that the subsequent collection of many signals competes with depth resolution and sensitivity. In the high mass range the good transmission of a ToF also benefits the detection of larger molecules or clusters and fragments of molecule chains which are formed during sputtering of organic compounds. The characteristic of the new instrument will be demonstrated by appropriate examples of several sample materials including layered structures.

Microstructure of laser textured PVD coatings on tool materials

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Optimisation of manufacturing processes in mechanical engineering which involve high surface loads, machining speed or high working temperatures is today under intensive investigation worldwide. Recent advances in laser technology open new roads for modification of surface tribological properties, by generation of the solid lubricant reservoirs in hard coatings. The application of CrN, TiAlN and Ti(C,N) PVD coatings deposition and their laser surface texturing to permit storage of solid lubricants using the dimple reservoir concept on tool steels was studied as possibly technology to improve the work life of tools made from them. Microstructure and selected properties examination were carried out. It was discovered that the laser texturing of PVD coatings with optimum area for dimple reservoirs when combined with a low cost solid lubricant application, is a useful and cost effective tool for wear and friction control.

Assessment of PVD/CVD onto sintered tool materials according to foresight methodology

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The goal of this paper is to assess the strategic development directions of manufacturing monolayer, multilayer and gradient coatings in the processes of physical/ chemical vapor deposition onto sintered tool materials with cemented carbides, cermets and tool ceramics substrates. The coating kind applied to the substrate was adopted as the criterion for technology division, thus obtaining eight technology groups for carried out researches. In the framework of foresight-materials science researches: a group of matrices characterising technology strategic position was created, materials science experiments using: light microscope, confocal microscope, transmission and scanning electron microscopes, X-ray spectrograph EDS, spectroscope GDOS, X-ray diffractometer, hardness tester, microhardness tester, work-stands for testing of roughness, adhesion and cutting properties were conducted and technology roadmaps were prepared. High potential and attractiveness were shown of the analysed technologies against the environment, as well as a promising improvement of mechanical and functional properties as a result of covering with PVD/CVD coatings. It leads to the justification of including these technologies into the set of priority innovative technologies recommended for application in industrial practice. Researches results presented in this paper are the part of a bigger research project aimed at selecting, researching and characterizing priority innovative material surface engineering technologies.

The influence of temperature on s-phase coatings deposition by reactive magnetron sputtering

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S-phase is a phase with very high hardness and good corrosion resistance which demonstrates a large potential for many practical applications. This phase can be obtained using various methods, including gas and plasma nitriding of austenitic stainless steel as the most common ones. Metastability of S-phase is a principle problem related to this process because presence of chromium nitride can seriously deteriorate corrosion resistance of such layers. Reactive magnetron sputtering is a one of methods which allows S-phase layers to be obtained at a very low temperature. The paper presents the results of the investigations on S-phase coatings obtained at various temperatures from the range 25-500°. A special attention is paid to microstructure of the coatings and their phase composition. The phase composition was evaluated using X-ray diffraction (XRD and GXRD). EMPA (EDS and EDS) and GDOS techniques were used to study element composition of the layers. Microstructure was investigated by means of scanning electron microscopy.

Ti-B/ Ti-Si-C coatings formed by IBAD and PLD techniques on steel substrates

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Ion beam assisted deposition (IBAD) and pulsed laser deposition (PLD) techniques were used to form, in room temperature, thin mono- and dual-layered (Ti-Si-C and Ti-B/Ti-Si-C) coatings on AISI 316L steel substrates using Ti_3SiC_2 and TiB_2 compound targets. In the IBAD method the dynamically formed layer was bombarded by beam of Ar^+ ions at energy of 15keV. Chemical and phase composition, structure and morphology of deposited coatings were characterized by scanning electron microscopy (SEM, EDS) and transmission electron microscopy (TEM, EDX, SAED). The bond configurations were studied by confocal Raman micro- spectroscopy, using the laser beam with length of the 532nm. Raman spectra were recorded in the low (LR) or in high (HR) resolution modes, in room temperature. Mechanical properties and tribological behavior of coated and uncoated substrates were examined in nanoindentation and ball-on-disc tests, respectively.

Tribological properties of magnetron sputtered MoO_3-Ag coatings at high temperatures

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Low friction, wear resistant coatings based on molybdenum oxide and silver can fulfil the demands of industry concerning coatings for friction couples working at high temperatures in atmospheres containing oxygen. The coatings have been deposited onto quenched and tempered Vanadis 23 HS steel, alumina oxide plates and silicon wafers Si(p) by means of a nonreactive magnetron sputtering of two targets – one of pure silver and one of molybdenum oxide with silver rod of 3 mm diam. placed in the area of strongest, toroidal erosion of the target. In order to achieve a good adhesion a gradual Ag-MoO_3 interlayer has been introduced between the substrate and the coating beginning from a pure Ag layer. The tribological properties of the coatings have been investigated in a temperature range $20^0C \div 550^0C$ by means of a ball-on-disc test using a high temperature THT CSM tribometer and studying profiles of the wear tracks after tribological tests. The chemical and phase composition as well as the quality of adhesion of the coatings have been studied with use of EDS, X-Ray diffraction, Raman spectroscopy and Daimler-Benz test, respectively. Directly after deposition the coatings consist of silver and amorphous molybdenum oxide and have poor tribological properties: a high friction coefficient ~0.95 and a very high wear rate. A gradual improvement of the tribological properties has been achieved by annealing of the coatings. After 3 hour annealing at a temperature above 450°C the coatings consist mainly of a silver molybdate Ag_2MoO_4, their friction coefficient decreases to 0.14 and the resistance to wear increases to a great extent. It looks like that magnetron sputtered MoO_3-Ag coatings can be successfully applied as low friction ones and well resistant to wear onto machine and engine parts and elements working as friction couples at temperatures as high as 550^0C.

Influence of Mo Concentration on structure and properties of Mo-dopped Bi_2O_3 thin films obtained by PLD technique

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The paper presents the results of investigations of Mo-doped Bi_2O_3 thin films obtained by PLD technique, using Nd:YAG laser. Bismuth oxide is the material having wide application in the electronic and optical industry. The objective of our investigation is stabilization of high temperature δ phase to lower temperature, which permits take advantage of interesting properties of this material (good ion conductivity, changing conductivity with temperature) widely. The Mo concentration and process parameters influence on the structure and properties were studied. The laser energy, the substrate temperature and the oxygen pressure in the vacuum chamber during deposition by PLD process influence strongly the chemical composition and morphology of obtained films. The SEM, TEM , EDS and XRD investigations are presented in present paper. The adhesion to the substrate (scratch tests), nanohardness and electrical conductivity of obtained thin films were studied. The results of investigations carried out indicate that it is possible to carry stoichiometric composition of pure and Mo doped Bi_2O_3 alloy from target to substrate and it is possible to use produced by PLD process thin films to e.g. gas sensors, catalyst production.

Influence of gas mixture composition and pressure on the properties of Ar-O_2-Zn plasma during ZnO sputter deposition in DC and RF modes

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Owing to its semiconductor and oxide properties, including a wide band gap of ~3.4 eV and a high exciton binding energy of 60 meV, zinc oxide (ZnO) is widely recognised as a material suitable for a wide array of applications in transparent electronics, photonics, sensors and piezoelectric devices. Physical Vapour Deposition via reactive magnetron sputtering is a technique commonly used for ZnO growth. Recent developments in the technology of magnetron sputtering reactors enable them to reach ultra high vacuum base pressures at substrate temperatures ~1000^{o}C. Furthermore a development of process control measures, such as *in-situ* diagnostic tools has taken place. This, combined with low cost and high scalability of sputtering make it favourable for ZnO thin film growth.

Our group has been studying thin ZnO film sputter deposition extensively using ex-situ characterisation of the deposited films. The structural properties of the obtained films differ greatly depending on the oxygen content in the plasma and on the pressure of the gas in the chamber during deposition. In this work, in order to gain better knowledge of the growth process, we applied in-situ diagnostics, focusing on characterisation of the plasma discharge during deposition. A Langmuir probe for the determination of electron and ion densities and electron temperatures of the plasma and optical emission spectrometers for studying the species composition of the plasma have been used.

This research reports on the optical and electric characterisation of a plasma discharge during ZnO sputter deposition in an Ar-O_2 atmosphere from Zn and ZnO targets under DC and RF power supply modes, respectfully. The influence of the oxygen content in the Ar-O_2 mixture as well as of the total gas pressure on the plasma parameters and optical emission spectra is discussed. With the addition of more oxygen into the mixture, the temperature of the electrons in the plasma is found to drop and rise for the RF and DC processes, respectively. The electron density values for both processes were found to be similar (~10^{17} m^{-3}), however the RF process had a greater ion density (~10^{18} m^{-3}) than the (~10^{17} m^{-3}) DC one.

Optical and electrical properties of ZnO thin films grown by sol-gel method

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The ZnO thin films have been successfully produced on p-type Si by the dip-coating method. The photoluminescence (PL) and cathodoluminescence (CL) spectra for ZnO layers which after deposition on Si substrates at room temperature were heated at different temperatures contained various emission features, which changed their intensity and positions with heating temperature. The structural properties of the ZnO thin films were carried out using x-ray method. The effects of the thickness variation and annealing temperature on the crystallinity parameters were observed. Photoluminescence measurements were carried out at temperature range 12K-350K under excited by a HeCd laser at λ=325nm (E=3.815 eV).

To determine the individual peak position and its intensity within a spectrum, we reconstructed the spectrum using multiple standard Gaussian equations. Near band edge (NBE) emissions at about 378 nm are observed in the thin films annealed at the temperatures higher than 250^{o}C; however, for low annealing temperatures we do not observed free exciton line. At 300 K, the intensities of the excitons emission at 3.28 eV (378 nm) and deep level (DL) peak at 2.30 eV (540 nm) are approximately equal.

I-V, C-V, Q-DLTS, PL and CLS measurements were performed on thin ZnO films fabricated on (001} surfaces of Si substrates. by dc and ac spectroscopy. The electrical response of grains, grain boundaries, and contacts of the ZnO film was obtained. Proper equivalent electrical circuit of the ZnO film composed of a single parallel resistor capacitor and inductor network connected with a series resistance was proposed.

Fractionation and characterization of Pd nanoparticles in the Pd - C composite films obtained by PVD method

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The results of fractionation and structural investigation of Pd nanoparticles in the Pd-C nanocomposite films are presented. The investigations were performed with electron microscopy methods (SEM, TEM). The films were obtained in PVD process.

The PVD process was originally elaborated in Tele & Radio Research Institute and procedure base on PVD process from two separated sources: one containing pure 99.95% fullerene C60, and second source containing palladium acetate. In a result of the technological procedure we obtained Pd-C films on different substrates. This films were removed from the substrate and dispersed in toluene and ethanol solution (50/50). Subsequent fractions of Pd nanoparticles of different sizes were separated by sedimentation process. Next, the suspension was dried, deposited on silicon plate and annealed at 650°C in an atmosphere of argon for 30 minutes. Thus prepared samples were investigated by electron microscopy methods.

The size and structure of these Pd nanoparticles were studied with transmission electron microscopy (TEM) and scanning electron microscopy (SEM). SEM and TEM images showed uniformly distributed Pd nanoparticles with different sizes. The analysis of the size distribution lead to conclusion, that the Pd nanoparticles can be assigned to classes (defined by the average size): small - 23nm, medium – 40, big - >40nm. This analysis was performed using visual impression of the distribution of size data i.e. histograms of the size of Pd nanoparticles were applied to set a mentioned classes.

HRTEM images showed polycrystalline character of Pd nanoparticles.

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Investigation of MBE GROWN inverted gaas quantum dots

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Nowadays, the growth of self-assembled quantum structures has been intensively investigated for basic physics and device applications. It is very important to understand their growth process and the knowledge about their shape is particularly significant. The archetypal system of these nanostructures is the lattice-mismatched quantum dot system, where the strain induced process leads to the formation of quantum dots. In this field, the self-assembled lattice matched inverted quantum dot emloying droplet epitaxy like technology is an interesting and novel alternative to estabilished technology of strain-driven quanrum dot formation. In this paper, these inverted GaAs quantum dots embedded in AlGaAs/AlAs layered structure are studied. The shape and the composition of these nanostructures investigated by transmission electron microscopy method. Temperature dependent photoluminescence spectra were measured int he range of room temperature and 4K. The calculated electronic structure are compared with the photoluminescence data.

The elimination of current oscillations in the coaxial plasma accelerator during the synthesis by impulse plasma deposition method (IPD)

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This paper presents the effects of the elimination of current oscillations within the coaxial plasma accelerator during the IPD process on morphology, phase structure and properties of synthesized coatings. Current observations of waveforms have been made by use of oscilloscope. For experiments, as a test material, the titanium nitride TiN coatings synthesized on silicon and high-speed steel substrates were used. Coatings morphology, phase composition and wear-resistance properties were determined. The character of current waveforms in the plasma accelerator electric circuit plays the crucial role during the coatings synthesis process. The elimination of the current oscillations leads to the obtaining ultra-fine-grained structure of titanium nitride coatings and to the disappearance of the tendency to structure columnarisation. Coatings obtained during processes of a non-oscillating character are distinguished by better wear-resistance properties.

Chemical and electrical properties of HMDSO plasma coated polyimide

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In this work, surface properties of polyimide (PI) films coated by thin layers deposited from pure hexamethyldisiloxane (HMDSO) vapours in low frequency powered plasma reactor have been investigated. The polymer thin layers were elaborated at different plasma treatment times (from 2 to 30 min). The surface characterization of the coated PI film is performed using attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR), scanning electron microscopy (SEM), water droplet contact angle measurements and surface potential decay (SPD). ATR-FTIR analysis showed the apparition of Si-CH3, Si-O-Si and Si-C peaks. The increase of Si-CH3 makes the film more hydrophobic. The contact angle measurements show that the hydrophobic properties of the PI films are greatly enhanced after HMDSO plasma coating; the water contact angle was increased from 63° for untreated film to 115° after 10 minutes of HMDSO plasma deposition. Scanning electron microscopy images showed a homogenous coating without crack suggesting a good adhesion of the coating to the PI substrate. Surface potential evolution after corona charge deposition showed slower charge decay for coated PI film, indicating the retention of deposited charges at the surface. Correlation between these different analysis techniques results has been discussed.

Particle simulation of sheath and presheath dynamics in multicomponent plasma

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Recently, plasma processing became commonly used technology in industry, especially in fabrication of integrated circuits. An oxygen plasma or mixtures of oxygen with rare gases are often used in selective etching processes e.g. to remove a photoresist layer or in cleaning. The low-temperature plasma simulations can be also helpful for interpretation of measured I-V characteristics of Langmuir probes.

Presented model simulates an interaction of Ar/O_2 plasma with immersed solid substrates. The formation of sheath and presheath is investigated dynamically and also some static sheath parameters for more complex geometries are shown. We observed plasma properties after a step change of voltage and during several periods of harmonic and rectangular-shaped substrate bias. The differences in plasma behaviour are described for the bias frequency lower and greater than the plasma ion frequency. Within the scope of dynamic simulations, the influence of each charged species can be studied separately. Therefore, we could separate the carriers of the same sign of charge, but with different masses, e.g. electrons and O^- ions. The static results describe particle fluxes and number densities around a rectangular-shaped trench, which can be interesting for the ion-driven anisotropic plasma processes.

Input parameters of the simulation were cross sections of 29 collision processes included in the model, data from kinetic models and data measured in a laboratory. Presented simulation is a two-dimensional PIC/MCC model, i.e. Particle-in-Cell scheme with advanced Monte Carlo collision procedures. The efficiency of simulations was improved by several software and hardware methods, e.g. parallel computing. Output data include both local parameters (local energy and angular distributions, ions and electron fluxes, number densities, etc.) and global parameters (electrical current, electrostatic potential).

Influence of repeller electric field in high–pressure ion source on ion–molecule reactions in argon/propane mixtures

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The following paper presents result of measurements of ion–molecule reactions in the gas mixtures of argon with propane for different compositions. In the earlier works, the authors presented the results of ion-molecule reactions for several gas mixtures [1–4]. To observe such reactions pressure inside the ion source should be relatively high. Relative ion current intensities for primary and secondary ions were measured as a function of total mixture pressure (changed from 0.7 Pa to 33.3 Pa) and gas concentration (changed from 10% to 90%) in the mixture. Measurements were carried out using a quadrupole mass spectrometer with a high–pressure ion source and differential vacuum system. Primary ions were produced by electrons with energy of 300 eV and next they react with neutral gas molecules to form secondary and higher rates ions. One of the criterion to distinguish primary ions from those arising in the secondary processes is different pressure dependence of the relative intensities of these ions. Another method is based on the influence of the repeller electric field on the residence time inside the ionization chamber. This last method was used in the paper presented here. The repeller potential was varied over the range 2 – 12 V and the total gas pressure inside the ion source, for all measurements, was 1.33 Pa.

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Fragmentation and kinetic energy release distribution of ions produced from methanoL CH_3OH

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Ionization and fragmentation processes of methanol (CH_3OH) were monitored by using a double focusing mass spectrometer of Nier-Johnson geometry (electric sector field is preceded by magnetic sector field) [1-3]. Such configuration of mass spectrometer allows to obtain not only basic information such as mass spectrum or ionization energy, but also kinetic energy release distribution (KERD) and mean life time of some fragment ions [3-5].

In this work, for observed fragmentation reaction paths, kinetic energy release were determined. For measurement of kinetic energy release (KERD) for the CH_3OH^+ and CH_3^+ ions, MIKE technique was used. For the molecular ions fragmentation processes were observed in a following way: CH_3OH^+ parent ion is decaying to $CHOH^+$ ion and two neutral hydrogens. Whereas, the fragment CH_3^+ undergoes further fragmentation to CH^+ ion and 2H.

For all this fragmentation processes mean value of kinetic energy release was calculated. We have obtained 0,016 eV and 0,052 eV for the $CHOH^+$ and CH_2^+ ion, respectively.

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LHC experimental beam vacuum system

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The Large Hardron Collider (LHC) has been in operation since 2008. About 20 km of the 27 km circumference is operated at cryogenic temperature, the remainder at room temperature. The counter circulating beams are collided in 4 points at the centre of the experiments ATLAS, ALICE, CMS and LHCb. Each experimental beam vacuum system is about 44 m long. The experimental beam pipes were baked and the internal Non-Evaporable Getter (NEG) pump activated for ALICE and LHCb in 2007, those for CMS and ATLAS in 2008. Since then, the beam pipes were vented up to 9 times to atmosphere using ultra pure Neon gas and re-pumped without re-activating the NEG. The LHC has increased significantly the luminosity so that since the end of 2010 dynamic beam vacuum effects are seen. New beam pipes will be developed in order to increase the transparency to particles and to optimise the radiation properties. One of the candidate structural materials is carbon-carbon composite. The experimental beam pipes layout and the pressure profiles will be presented as well as an overview of the ongoing developments.

Electronical and optical properties of the Y_2O_3 films deposited by reactive magnetron sputtering from yttrium target in Ar/O_2 atmosphere

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Presently, the low cost trend in photovoltaics is followed by decreasing of the thickness of crystalline silicon solar cells. Therefore, the quality of surface passivation becomes more important. Field effect passivation and reduction of the interface trap density (D_{it}) are two mechanisms that allow to provide a high passivation quality.

The main goal of our work is research of surface passivation of p-type silicon wafers by using yttrium oxide (Y_2O_3) films formed with reactive magnetron sputtering technology. Yttrium oxide is a prospective material for anti-reflecting and protective coatings. Y_2O_3 thin films have high values of electric resistivity, dielectric permitivity, electric strength and they also have low dielectric losses and good transparency in a wide spectral range with a little light diffusion.

For optimal device performance the Y_2O_3 films should possess specific electrical and optical properties. The photovoltaic industry uses ever thinner wafers to significantly reduce the Si content per wafer. Therefore, the surface-to-volume ratio increases and consequently surface passivation of bulk Si solar cells gains importance. The Y_2O_3 is a promising material which is believed to contain a high negative charge density. Physical properties which are strongly influenced by the micro-structural qualities of the films such as crystalline or amorphous state, crystallographic orientation, crystallite size, strains and stresses have been analysed by X-ray diffraction (XRD). The passivation effect of Y_2O_3 was monitored by measuring the minority carrier effective lifetime using the microwave photoconductance decay (MW-PCD) method and optical properties have been investigated by spectroscopic ellipsometry (SE).

Study of organosilicon/O_2/CF_4 plasmas for $SiOC_XF_Y$ thin films deposition

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Thin films have been deposited by plasma-enhanced chemical vapor deposition (PECVD) using a mixture of hexamethyldisiloxane (HMDSO), tetrafluoromethane (CF_4) and oxygen (O_2) gases in a microwave excited DECR plasma reactor (Distributed Electron Cyclotron Resonance). Optical emission spectroscopy (OES) has been used to study the glow discharge environment in variable CF_4 flow ratio. A large number of species has been detected in the plasma created in HMDSO/O_2 and CF_4 gas mixture, such as H, F, CO and OH. The emission intensity of these species is dependent of the mixture composition. Using Fourier transform infrared transmission spectroscopy (FTIR), chemical and structural properties of the elaborated films were investigated as a function of fluorine-doping concentrations in the precursor (HMDSO/O_2/CF_4). It has been revealed that Si–O, Si–F and Si–OH are the major bonding in the deposited films and their concentration was strongly linked to the gas precursor composition. On the other hand, it has been observed that the growth rate decreases with the increase of CF_4 flow ratio in the mixture precursor. This evolution in the deposited films growth has been explained by a contribution of F species to an etching process, more pronounced when the CF_4 concentration was increased.

Negative ions formation from SF_6 gas by means of thermoemission ion source

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Results of studies of the negative ions formation from SF_6 are presented in this work. The investigations were made using the mass spectrometer (MS) with magnetic sector field. The major part which was invented and constructed in this MS is an negative ion source. The new negative ion source comprises the following elements: (1) the gas supply tube, (2) the ionization chamber, (3) the filament, (4) the ion beam forming system of electrodes and (5) a pair of external magnets. Negative ions are produced by the surface ionization. During this process the gas surrounds and steaks heated filament. At special conditions (temperature) and properties of the filament (work function) studied molecule can dissociate. Fragments obtained could attach electrons and form anions.

In our investigations seven ion species: SF_5^-, F^-, SF_6^-, SF_4^-, SF_3^-, SF_2^- and F_2^- with ions currents intensities ratios 1000:150:80:10:5:0,5:0,2:0,1 respectively, were measured. From the energetic point of view the SF_6^- anion can be formed by the direct free electron attachment to the SF_6 molecule. This suggested that in the ion source also free electron are accessible. The other ions may be generated both in the fragmentation process of SF_6^- and by the thermal dissociation followed by the electron capture by fragments formed. Background signal from F^- (after the gas admission was stopped) suggest HF formation on the wall of ion source.

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Computational simulation of metal ion propagation from plasma to substrates with uneven surfaces

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The deposition of thin layers on surfaces of solids may be achieved by various ways. The use of ions, instead of neutral particles, has got significant advantages. As the motion of ions is influenced by electric and magnetic fields and by collisions with neutral particles, the flux and the energy distribution of ions reaching the substrate can be controlled to gain desired results of deposition. This features are especially important if the geometry of the substrate is rather complex, i.e. with tranches, protrusions, hollows etc. Besides the experimental and theoretical approach, these effects can be studied by computational simulations.

In our contribution, we present a computational study of metal ion propagation from a low-temperature plasma to planar substrates covered by a variety of protrusions. The presence of such protrusions influences the sheath formation and subsequently trajectories and energies of ions. The study is based on a hybrid model, which achieves the solution by coupling iteratively fluid and particle simulations with reasonable demands on computer performance. The efficiency of the model is highly important, because the geometry requires the fully 3D approach. The presented model is approximately by two orders of magnitude faster than a standard Particle-In-Cell model.

The effect of PVD coatings on the structure behaviour of non-ferrous alloys

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Gradient/monolithic coatings (TiCN/CrN, Cr/CrN/TiN) were deposited onto magnesium alloy (Mg-Al) and aluminum alloy (Al-Si-Cu) substrate by cathodic arc evaporation method. A thin metallic layer (Ti and Cr) was deposited prior to deposition of gradient coatings to improve adhesion. The microstructure and adhesion of the investigated coatings were studied. It was found out that the microstructure of the PVD coatings deposited by the cathodic arc evaporation method is composed of fine crystallites and that their average size is in the range of 15÷20 nm, depending on the coating type. The investigated coatings demonstrate the denser structure. The investigations were performed using scanning and transmission electron microscopy for the microstructure determination. By mind of the transmission electron microscopy the high resolution and phase determination was possible to obtain. The morphology was studied as well the lattice parameters for the layer matrix and substrate phase identification using diffraction methods was applied. The investigated samples were examined metallographically using electron microscope with different image techniques, also EDS microanalysis and electron diffraction was made. As an implication for the practice a new layer sequence can be possible to develop, based on PVD technique. Some other investigation should be performed in the future, but the knowledge found in this research shows an interesting investigation direction. The originality and value of this combination of TEM investigation for PVD deposited surface layer on magnesium and aluminium alloys makes the investigation very attractive for automotive and other industry branches.

Microstructure and properties investigation of thin films $BaCeO_3$ deposited by laser ablation

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$BaCeO_3$ (BCO) ceramics and related perovskite type compounds were intensively studied because of their high temperature potential applications (e.g. for fuel cell and electrocatalysis technologies). They were regarded as very promising candidates as solid electrolytes in electrochemical devices such as solid oxide fuel cells (SOFCs) and gas sensors. These perovskite type structures were highly interesting mainly because of their high ionic conductivity. More recently, $BaCeO_3$ exhibited heterogeneous photocatalytic activities for water splitting.

The $BaCeO_3$ films were grown by pulsed laser deposition on Si [100] substrate, using an Nd-YAG laser (λ=266 mm). The substrate was heated from 600°C up to 800°C and the films were deposited in oxygen pressures 5 Pa. To characterize the structure and properties of the films we used XRD, SEM, FTIR and Electrical Impedance Spectroscopy.

The catalytic properties of these films in presence of air-carbon monoxide gas flows are studied by Fourier Transform Infrared spectroscopy (FTIR): the conversion rate of CO into CO_2 is analyzed as a function of temperature. The catalytic activity has been determined from the CO_2 FTIR absorption band intensities. This activity reaches a maximum value at 400°C. The electrical properties are studied using electrical impedance spectroscopy in the temperature range from 300°C to 600°C. The Nyquist representations are semi-circles, characteristic of electron and ionic conduction. A series of electrical transitions are observed from 300°C to 600°C. They are in good agreement with structural transitions.

The cross sectional investigations of porous carbon films containing palladium nanocrystallites

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Transmission Electron Microscopy (TEM) investigations of carbonaceous films containing palladium nanoparticles were carried out. The interest in this type of films is caused by the possibility of using them as an active layer in sensors detecting the hydrogen and some of its compounds. The investigated films were obtained in PVD (Physical Vapor Deposition) followed by CVD (Chemical Vapor Deposition) processes. In PVD process carbonaceous film with Pd nanocrystallites were deposited on silicon substrates under the dynamic vacuum of 10^{-5} mbar. Two separated sources of palladium acetate $Pd(C_2H_3O_2)_2$ and fullerene C_{60} powder (99,9%) were used to obtain initial PVD film. Next, such PVD film was modified in CVD process in which the decomposition of the xylene over the films' surface at a temperature of 650ºC was occurred.

For TEM research, we have prepared cross-sections specimens (lamella) of both samples obtained after PVD process and PVD/CVD process using the Focus Ion Beam (FIB). First, the film surface has been protected by the platinum layer. Then the protected layer was cut out using the gallium ions beam. This method was not destructive for the studied samples. Finally, the lamella was soldered to the standard Omniprobe Lift-Out grids with 3 pots. TEM research of cross-sections determined the films' thickness, which were ~ 200 nm and ~ 300 nm for PVD and PVD/CVD films respectively. The thickness of the PVD/CVD films is connected to an incorporation of xylene and formation of porous structure. From our study information about the voluminal distribution of Pd nanoparticles was found out for both types of film. Furthermore, for PVD/CVD films aggregation of small (~ 2nm) Pd nanocrystallites around the larger ones were observed. These large palladium particles had been defected and were covered with graphite's shell.

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Manufacturing and FEM modelling of the NC-TiC/steel composites prepared by selective laser melting

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The innovative method of the nanocomposite materials manufacturing has been developed, in which the SLM (Selective Laser Melting) technique is used. The TiC nanoparticles obtained by sol-gel synthesis were used as a filler and the 316L stainless steel was taken as the matrix. The FEM model of such nanocomposite is being developed, which aims at the exact knowledge of its mechanical behavior and the reason of the specific properties distinguishing it from the classic composites.

Time-resolved optical emission spectroscopy studies of medium frequency magnetron sputtering plasma

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The pulsed (Medium Frequency, MF) magnetron sputtering deposition processes were investigated using Optical Emission Spectroscopy in Time-Resolved mode (TR-OES). Metallic targets of copper and aluminium of 50 mm in diameter were sputtered in the argon atmosphere using 100 kHz MF power supply (the single sputtering pulse duration was about 10 μs). The atomic and ionic lines intensities of working gas (argon) and sputtered material (separately copper and aluminium) were observed with time resolution of about 200 ns using self-designed Time-Resolved add-on option for the standard OES system. The average target power density during the experiments was about 500 W/cm^2.

The aim of conducted research was to study the temporal behaviour of high power pulsed magnetron sputtering plasma. The TR-OES lines intensity waveforms together with magnetron current and voltage waveforms were searched for the "footprint" of the selfsputtering phenomenon at standard argon sputtering.

The materials for sputtering were chosen basing on their different self-bombardment parameters – the selfsputtering yield at 500 eV of incident ion energy. In case of the copper the selfsputtering yield is about $Y_{Cu}\approx 2$ atoms/ion and it is enough for the initiation of the self-sustained sputtering mode of magnetron operation (if threshold target power density is reached). In case of the aluminium the selfsputtering yield is about $Y_{Al}\approx 0{,}7$ and it is theoretically to low for the initiation of self-sustained sputtering mode.

Key words: pulsed magnetron sputtering, plasma diagnostics, time-resolved optical emission spectroscopy

AlGaN/GaN based field plated heterostructure – hight electron mobility transistors: Numerical analysis

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The high voltage operation with high current density makes GaN devices the best high power devices so far, the tremendous improvement in the breakdown voltage of GaN high electron mobility transistors (HEMTs) was experimentally demonstrated by employing a Field-Plate structure [1]. A theoretical study of the effects of the critical geometries of the Field-Plate (FP) on the breakdown voltage of GaN HEMTs was performed using two-dimensional simulations [2]. This paper investigates the Field Plated-high electron mobility transistors (HEMTs) using a numerical analysis of the two-dimensional coupled Boltzmann distribution-Poisson equations. Using this numerical model, we have found that, the FP allows to modify the profile of the distribution of the electric field at the gate edge on the drain side and to reduce the peak of the electric field, thus increasing the breakdown voltage consequently an improvement of the device's performance.

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The directed modification of structural and functional parameters of mesenchymal stem cells by means of nanostructural oxide coatings deposition on glass and plastic substrates

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Recently, various stem cells, including mesenchymal stem cells (MSCs), have great potential in the tissue engineering area due to their biological capacity to differentiate into specific lineages and next advanced therapies applications. The estimation of phenotype characteristics of mesenchymal stem cells passaged on various substrates provides the important information about their therapeutic effect under development of the graft versus host diseases (CVHD). There is a possibility to study the expression of MSCs genes, which rate may change under the influence of different stimulus such as surface structure and composition parameters. The various oxide coatings Al_2O_3, ZrO_2, deposited by magnetron sputtering method (MS) and ZrO_2, Ta_2O_5, deposited by means of electron beam evaporation method (EB) on the glass and plastic substrates (Petri dishes) were passed for biological researches. The coatings structure, chemical and impurity composition was investigated by XRD and XPS methods. The evaluation of cell survival, morphocytologic, cytohistologic parameters, as well as studying of expression rate of genes, characterizing functional activity of MSCs was made. MSCs phenotypical characteristics were determined by cytofluorimeter FACS Calibur with using fluorochromal monoclonal antibodies to CD73, CD106, CD44 structures. The CD105 fractures were extracted from cultivated MSCs by means of antimouse CD105 MultiSort Kit (PE) for next phenotype evaluation by cytofluorimetry. The results show the potential of oxide nanostructural coatings deposited on glass and plastic substrates to selectively enrich the cell cultures with the cells expressing the markers of MSCs, increase the rate of gene expression and propose the new methodical approach to MSCs application for clinical treatment of CVHD.

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Comparison of low pressure glow discharge and dielectric barrier discharge in CO_2-laser mixture by optical emission spectroscopy

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These days, the CO_2 lasers are used in many technologies, including medicine and material processing industry. Besides original low-pressure low-power lasers pumped by DC glow discharge, the high power atmospheric pressure lasers are in focus nowadays. Our contribution studies both low pressure (133 Pa - 1330 Pa) DC glow discharge and dielectric barrier discharge (5 kPa – 100 kPa) in mixtures of helium, nitrogen and carbon dioxide (as used in CO_2 lasers) by the means of optical emission spectroscopy.

In the emission spectrum of the discharges, we can find bands of the first and the second positive systems of the nitrogen molecule. From these bands it is possible to deduce energetic balance and the vibrational temperature.

In our contribution, the vibrational temperature of dinitrogen is determined by the means of optical emission spectroscopy from the second positive system band of the nitrogen molecule for various discharge currents in DC glow discharge and for various gap widths in DBD. Using these two discharges we covered whole pressure range from 133 Pa up to atmospheric pressure. The dependence of vibrational temperature on nitrogen ratio in the mixture is also investigated.

Our measurements were complemented with measurements of electrical properties of discharges - longitudinal electric field power for DC glow discharge and Lissajous' figures for DBD.

Study of initial stages of thin film growth by means of computer simulation and image analysis: advanced atomistic modelling

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During deposition of metal films on dielectric substrates, the following stages are observed: nucleation, creation of individual islands, their growth and coalescence and finally formation of semicontinuous and continuous layers. For the discussion of processes which take part in the initial growth stages, the computer modelling is well suited. Various types of models with different complexity have been described - ranging from analytical models based on numerical solution of rate equations, through simplified hard-disk and soft-disk models to the most advanced atomistic models. The atomistic models are typically time-consuming but enable us to involve more realistic assumptions in their construction.

In our laboratories we prepared the atomistic model which combines two approaches - the molecular dynamics and Monte Carlo techniques. The first part, simulating the nucleation process, is based on the molecular dynamics method. The computational domain consisted of several layers of atoms with temperature of the system is controlled by the Nosé-Hoover thermostat. The forces between individual atoms were obtained from inter-atomic potentials of the type Lennard-Jones and Sutton-Chen. The results of this part were used as input data for the kinetic Monte Carlo simulation of further growth stages. The first results obtained by this model were presented on the SVST-5 conference, Kaiserslautern 2010.

The present contribution describes the further development of our model. In both parts of the atomistic model various parameters with physical meaning were introduced - substrate temperature, deposition rate, activation energies, substrate defects, etc. A detailed analysis of the influence of these parameters is performed with the help of algorithms of image analysis based on both mathematical morphology and integral transforms. In the final part of the contribution, the results are compared with experimental data.

Sensitivity analysis of morphological methods in thin film physics

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In some fields of science such as solid-state physics, metallurgy, astronomy, etc., the systems consisting of large number of objects are often studied. The image analysis of such systems can bring us various characteristics, the most important being the characteristics describing the spatial distribution of objects in two or three dimensions. Exact description of studied system can bring important information about internal processes in such systems. In thin-film physics the two-dimensional structures correspond to thin metal films prepared on dielectric substrates, where a Volmer-Weber mechanism of film growth takes place, and the three-dimensional structures correspond to metal/dielectric composite films. The basic information about film properties can be derived from the analysis of their TEM micrographs.

The choice of the methods used in image analysis depends on physical characteristics of studied objects. In thin film physics, for the study of discontinuous metal films as well as for the study of composite films, the methods based on the theory of mathematical morphology are the most convenient. In order to analyse possibilities and limitations of several both well-known and new morphological methods, a simple computer experiment was prepared. The morphological algorithms were tested with the help of images with known properties obtained from structures simulated by hard-disk model as well as from simplified experimental structures of discontinuous and semicontinuous metal films.

As a result of this analysis, the morphological methods and their numerical features were considered in the sense of robustness and sensitivity. In the final part of our contribution prepared computer tool was applied to the study of the results of advanced atomistic models of both continuous and pulsed deposition of thin metal films.

Growth of Pb on $Ni_3Al(111)$ and $Al_2O_3/Ni_3Al(111)$ studied by STM

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Scanning tunneling microscopy (STM) has been used to investigate the nucleation of lead clusters on the $Ni_3Al(111)$ and $Al_2O_3/Ni_3Al(111)$ substrate as a function of coverage and sample temperature. For the $Ni_3Al(111)$ substrate the analysis of STM measurements indicates that for a coverage $\theta < 1$ ML two-dimensional growth of the first Pb monolayer (wetting layer) took place. Above $\theta > 1$ ML, the three-dimensional growth of the Pb islands mainly with hexagonal shape and the flat top is observed. In case of $Al_2O_3/Ni_3Al(111)$ the three-dimensional growth of the Pb islands is observed. For individual Pb islands the dependence of the islands height and diameter on the bias voltage has been measured.

Control of titanium oxide thin films deposition during reactive pulsed magnetron sputtering process

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Titanium oxide thin films are transparent in visible range of the electromagnetic spectrum, have semiconducting and photocatalytic properties as well as they are mechanically resistant. They are used in a wide range of applications such as optical, dielectric, self-cleaning and others coatings. The methods of high rate deposition of this compound are one of current research subjects. There is a need, especially in industrial applications, for improve of efficiency, as well as for a simple and reliable control system.

The titanium oxide thin films were deposited by pulsed magnetron sputtering using WMK-50 source and DPS power supply. Described in the paper, *in situ* control method is based on observations of power supply parameter (circulating power) [1]. This parameter is extremely sensitive to any changes in discharge plasma impedance, especially to ion induced secondary electron emission. However, it was already reported that titanium oxide deposition exhibited some extraordinary electrical characteristics of the target [2]. This material showed a minima and maxima of the cathode voltage as the target gets more and more poisoned. This fact complicates the use of voltage as a control parameter, since the same cathode voltage represents two different degree of target poisoning. Voltage changes correspond to analogous behaviour of circulating power.

In presented paper, the influence of process parameters and target oxidation on the process control was investigated. The results were supported with film composition and optical parameters measurements.

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Optical emission spectroscopy in Pulsed Laser Deposition of Silicon

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The generation of homogenous plasma plume is necessary in pulsed laser deposition of a smooth thin film. The plasma plume ideally should consist of neutrals, ions, atoms and molecules only but it is difficult to avoid the presence of nanoparticle/nanocluster which may contribute to a nano-structured thin film. In this work, we investigate the effects of nanosecond laser wavelengths in the ablation of polycrystalline silicon and laser fluence between 1 – 6 J/cm^2 for thin-film deposition in vacuum (<10^{-6} Torr) at room temperature. The laser wavelength ranges from the ultra-violet to infrared, by using a KrF laser (248 nm, 25 ns) and a Nd:YAG (355nm, 532nm, 1064 nm, 5 ns) laser. Time-integrated optical emission spectra (Fig. 1) showed the generation of excited neutrals and ionized Si species for laser fluence between 0.5 – 11 J/cm^2. It was found that the threshold fluence F_{pl}, for strong plasma emission varied with laser wavelength of (248 nm, 355 nm, 532 nm, 1064 nm), possibly explained by the onset of phase explosion. Large amount of nanoparticles were generated for 355 nm and 532 nm deposition above F_{pl} (Fig. 2), but for the case of 1064 nm, the decrease in the normalized density of nanoparticles at high laser fluence suggested that laser-plasma interactions could possibly brought about the disintegration of nanoparticles. The deposited films were characterized by using Raman spectroscopy, scanning electron microscopy and atomic force microscopy.

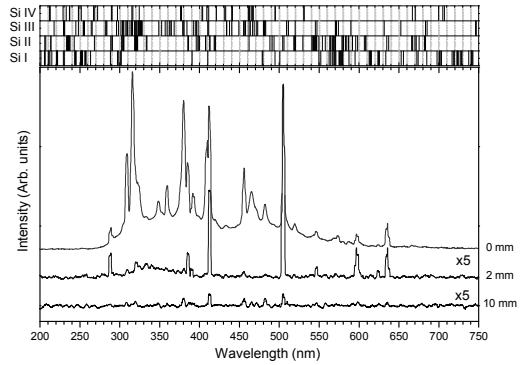

Fig. 1 Optical emission spectra of Si plasma generated by 1064 nm laser at 0, 2 and 10 mm from the target.

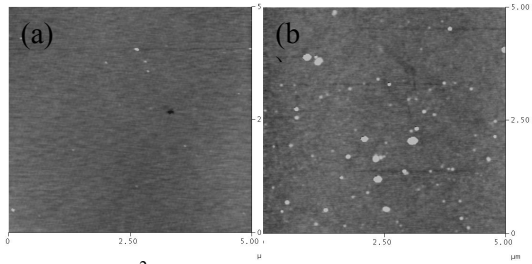

Fig. 2. AFM of films deposited at 3 J/cm^2 by a (a) 248 nm laser and (b) 532 nm laser with nanoparticles from 20 nm to 200 nm.

Surface characterization of diamond layer by XPS method

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A 230 micron thick polycrystalline layer has been prepared in this study using a Microwave Plasma Chemical Vapour Deposition (MPCVD) technique. The growth of diamond layer was carried out on silicon substrate using DF-100 MPCVD reactor system with use of gas mixture composed of methane and hydrogen. The total flow rate of the gas during the process was 800 sccm, the power of microwave energy was 3.6 kW, and the substrate surface temperature was 820^{o}C. Nucleation centers on the silicon substrate were provided by the ultrasonic bath treatment in the dispersion of detonation nanodiamonds in ethanol. The deposition rate of diamond layer of 1.0 micron/hour was achieved. The resulting layer was characterized using X-ray diffraction and X-Ray Photoelectron spectroscopy (XPS, PHI-5000 Versaprobe). The results of XPS obtained before and after the diamond surface sputtering using an argon ion gun to study the quality of the material and to determine the presence of non-diamond carbon chemical bonding are discussed. The applications of thick polycrystalline diamond plates are also reviewed. This collaborative work has been financially supported by the Ministry of Science and Higher Education of Poland (grant No N N508 478338) and by U.S. National Science Foundation (US-NSF) Grant #DMR-0806521. XPS instrumentation used in this study was supported by the US-NSF Grant # DMR-0922910.

Properties of the nc-TiC/steel composites manufactured by SLS/M method

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Nanostructural powders belonging to Ti-C system have been received in non-hydrolytical sol-gel synthesis. The powders have been applied in SLM process in order to produce nanocomposite materials in steel matrix. In present work the composition, structure and morphology along with the results of hardness measurements and oxidation kinetics of nanocomposites in air in temperature range 20-1500K, have been presented. During investigation the following analytical techniques have been applied: XRD, TEM, TG-DSC-MS, RS, SEM and micro- and nanoindentation techniques. For working out the kinetics of oxidation process of nc-TiC powders artificial neural networks have been used. Good dispersion of titanium carbide in steel matrix and significant increase hardness and oxidation resistance in dry air were obtained using purified, high stoichiometry nc-TiC for nano-composite manufacturing by SLM method.

The experimental investigations of Mo-C multilayered CVD coatings

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Production processes of multi-layered Mo-C coatings by the method of chemical vapor deposition (CVD) with the use of organometallic compounds were developed. Coatings are applied on technical purpose steel DIN 1.2379 (Х12Ф1) and DIN 1.7709 (25Х2МФ (ЭИ10)) heat-treated ball with the high class of surface roughness (>10). The average deposition rate was 50 μм/h. The optimal conditions of coatings deposition for different technological schemas were defined.

Metallographic investigations of the obtained coatings were carried out.

Tribological studies of the friction and wear characteristics of sliding friction in conditions of boundary lubrication of Mo-C multilayered CVD coatings shows, that coatings have low friction coefficients (0.075 - 0.095) at loads up to 2.0 kN and showed high resistance to wear and are effective in increasing the stability of the pair for precision friction pairs of hydraulical units.

Key words: CVD processes, multi-layered coating.

Spectroscopic study of a pulse arc plasma flows in presence of acetylene

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Plasma flows for deposition of diamond-like carbon films are generated with the help of four-electrode device with graphite cathode in a vacuum chamber. The pulse-periodic arc discharges in vacuum as well as at acetylene pressure of 0.2 to 2 Pa are considered. The main discharge current was 4–8 kA, pulse duration was about 200 μs, and repetition frequency of the pulses amounted to 1–2 Hz. Optical emission spectra of pulsing cathodic-arc carbon plasma in a wavelength range of 400–650 nm were studied at various partial pressures of acetylene in the discharge chamber for various conditions of observation. For example, at observation along the plasma flow at acetylene pressures of 0.2, 0.5 and 1.0 Pa intensity of C_2 molecular band at 563.55 nm increases by a factor of 6, 8 and 11, respectively, in comparison with a case of vacuum discharge. Intensities of ion lines CII and CIII vary no more than by ±15 %. When displacing the observation line from the discharge axis (i.e. from cathode spots area) sharp decrease of carbon ion emission is observed while radiation of C_2 molecules practically does not change. At observation across the plasma flow emission of C_2 molecular bands predominates over carbon ions both for vacuum discharge and discharge in acetylene. However in the case of acetylene addition over the partial pressures range 0.2 to 1.5 Pa intensities of CII, CIII, H_α and H_β spectral lines increase by 1.5–3 times. From comparison of vibration-rotation structure of the model and experimental spectra of C_2 molecular band at 563.55 nm it was found that the gas-kinetic temperature of plasma amounts to ~ 0.1 eV while vibrational temperature is about 1 eV. The electron temperature of plasma, derived from probe measurements, is on the level of 50 eV.

The cutting properties and wear of DLC coated high-speed steel planar knives

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Exploitation tests, analysis of the cutting properties and wear of DLC coated high-speed steel tools after milling the medium-density fibreboard (MDF) was a purpose of the work. The DLC coatings were produced with the modified cathodic vacuum arc method. An analysis was conducted of the investigations into the influence of the selected deposition parameters of DLC coatings on the accepted optimization criteria with the use of the Taguchi module. It was established on the basis of the statistical analysis of the research results that in order to ensure a high adhesion of DLC coatings to high-speed steel substrates, a thick Cr sublayer (0.3 μm) and a DLC coating is to be used, which is deposited at a high argon pressure (0.25 Pa); no substrate bias (the floating potential) is to be used. The DLC coated high-speed steel planar knives are characterized by lower wearing the cutting edge.

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