S1 Dynamics of the Plasma Edge

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Understanding, simulating and modelling the plasma edge, defined as the edge gradient region together with the scrape off layer, are important steps in creating a predictive capability for present and future fusion devices. The plasma edge determines to a large extend the confinement and is the region where fundamental changes in plasma confinement have their origin, such as the LH transition. Furthermore transport into the SOL in the form of large events, like ELMs, is severely restricting the operating space of ITER and machines beyond.

Numerical simulations have in the last decade come to the point, where comparison with experiment begins to become realistic. Here results from 3D flux tube simulations of electromagnetic turbulence using scale separation between background and fluctuations are presented, demonstrating the basic mechanisms of flow generation from turbulence. However, in realistic geometry the flow energy in these simulations never exceeds the energy content of the fluctuating part, demonstrating the lack of ingredients to form an edge transport barrier within such models.

Further outward in the SOL scale separation is not at all applicable. Thus, the fluctuations have to be treated on the same footing as the "background" profile evolution. Dropping this assumption results from a most simple 2D interchange system compare favourably with experiment. This shows that a large part of the observed dynamics in the SOL is more determined by the lack of scale separation than by the wealth of dynamics neglected in deriving this simple model.

In conclusion, some of the ingredients still missing to address the fundamental interaction between turbulence and profiles at the plasma edge are discussed.

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S1 Turbulence Spreading and Anomalous Transport

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The anomalous turbulent transport in magnetized plasmas is traditionally described by models based on linear stability properties together with mixing length arguments to determine the particle and heat fluxes. These models, which only account for the local properties of the plasma and the dynamics, have been rather successful in describing the stationary pressure profile in response to various heat and particle sources. However, they fail to describe more complex transport phenomena such as up-gradient transport and in particular transient transport events in response to local perturbations as, e.g., edge cooling.

We shall here discuss an alternative model, accounting for non-local effects, for describing anomalous transport. The approach is based on the concept of turbulent spreading, i.e., the turbulence itself is transported and may spread into regions that are linearly stable. The fluxes of the thermodynamically variables are determined directly by the intensity of the turbulent fluctuations and even in the linearly stable regimes the transport may reach anomalous levels. The coupling of the turbulence spreading process with particle and heat transport is shown to provide close to marginal global plasma profiles even in the presence of radially localized sources. Inward pinches and non-local transport behavior are natural features of this model.

The model has been applied to the heat modulation and cold pulse propagation experiments in the JET tokamak. For parameters that fit the heat modulation results we found a cold pulse propagation that is faster than obtained from standard transport models, but not as fast as observed experimentally.

*Appendix of M.L.Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006)

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S1 How to Build a Tokamak

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This seminar describes the basic design options and principles necessary to able to build a tokamak, starting from a specification of the toroidal plasma current and the plasma shape.

The talk covers the functions and principle loads of the main components of a tokamak, namely the toroidal and poloidal field coils, power supplies, support structure, vacuum vessel and plasma limiters. Aspects covered begin with the choice of coil topology (eg the advantages and disadvantages of having inter-linked toroidal and poloidal field coils), moving on to mechanical stress considerations and potential problems in coil design such as unintended magnetic field asymmetries (eg feeder-bar geometry). The pros and cons of different power supply options (speed and control versus cost), support structure geometries (affecting port access), materials used in the vacuum vessel construction (strength versus eddy currents), and limiter or divertor armour (thermal shock, plasma chemistry) are elaborated.

In the course of the talk, particle losses caused by magnetic ripple, the creation of magnetic islands by resonant magnetic perturbation error fields, Finite Element Analysis, cyclic fatigue, poloidal flux consumption, disruption halo currents, and the rudiments of vessel conditioning will also be shown as important considerations in the overall design process. Regarding the actual construction work, a little will be said about planning and the need for good quality assurance and metrology of the growing assembly, to be confident that the precision intended in the design is achieved in practice.

Although focused on tokamak design, most of the talk is relevant to any other type of magnetic confinement plasma physics or fusion research device, since the principles of topological constraints, magnetic field coil stresses and heating rates, vacuum vessel considerations, and plasma-facing material issues are all common throughout the magnetic confinement community.

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S1 Status of the COMPASS Tokamak Reinstallation in IPP AS CR

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The COMPASS-D tokamak, originally operated by UKAEA at Culham, UK, is being reinstalled at the Institute of Plasma Physics (IPP) AS CR. The COMPASS (**COMP**act **ASS**embly) device was designed as a flexible tokamak in the 1980s mainly to explore the MHD physics. Its operation (with D-shaped vessel) began at the Culham Laboratory of the Association EURATOM/UKAEA in 1992.

The COMPASS tokamak will have the following unique features after putting in operation on IPP Prague. It will be the smallest tokamak with a clear H-mode and ITER- relevant geometry. COMPASS is equipped with a unique fully configurable set of copper saddle coils for resonant perturbation techniques. ITER-relevant plasma conditions will be achieved by installation of two new neutral beam injection systems (2 x 300 kW), enabling co- and counter- injections. Re-deployment of the existing LH system (400 kW) is also envisaged. A comprehensive set of diagnostics focused mainly on the edge plasma will be installed.

The scientific programme proposed for the COMPASS tokamak installed in IPP Prague will benefit from these unique features of COMPASS-D and consist of two main scientific projects - edge plasma physics (H-mode studies) and wave-plasma interaction studies.

Presently, the COMPASS tokamak has been dismantled, transported to IPP Prague, installed into a new tokamak hall. The main systems (power supplies, cooling, vacuum, CODAC etc.) have being designed, manufactured and are being commissioned. The first plasma is expected at the end of 2008.

The COMPASS-D tokamak will offer an important research potential as a small, flexible and low-cost facility with ITER-relevant geometry.

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S2 Multiwire X-Pinch Research on S-300 Instalation

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On S-300 installation (3 MA, 0,15 Ohm, 100 ns), a series of experiments on plasma dynamics research of compression X-pinch at currents up to 2,3 MA have been executed. In experiments the multiwire X-pinch loadings were used of identical size (10 mm long, with 6 mm base width) from various materials and various weights.

The analysis of the achieved results allows to conclude, that in a range of values of currents on S-300 installation, the load mass should have scaling, according to which for good compression and formation of a radiating hot point with high parameters, the running weight of X-pinch loading m_{exp} should correlate with a discharge current ($m_{theor} \sim m_s I^2$ where $m_s = 3$ mg/cm).

In the experiments generated X-pinch radiation was registered in a range of parameter values m_{exp} / m_{theor} from 0,63 up to 1,5.

The research is supported by the contract «Sandia National Laboratories – RRC Kurchatov Institute» №707492 and grants «Scientific school» SC-5819.2006.2 and RFFI 05-02-17532.

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S2 PFZ Fusion Neutron Source at the CTU in Prague

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At the CTU in Prague a small device was constructed in combination of plasma focus and z-pinch principle (PFZ) for the study of deuterons producing neutrons from fusion D-D reaction at the rise time of the current 200 kA in 2 μs. As the diagnostics we use the calibrated Rogowski coil for measurements of discharge current, the high voltage probe for measurement of fast voltage variations, the silicon PIN detectors filtered with mylar foil for measurement of soft x-rays in the range 200-1000 eV, the soft x-ray mikrochannel-plate detector split into 4 quadrants, which transmitted radiation in a window above 10 eV with the exposure time 2 ns and the delay between exposures 5 ns, the time integrated XUV spectrometer, two BC-408 scintillation probes of 5 cm thick, equipped with fast photomultipliers, to perform detailed time-resolved measurements of hard x-rays above hundred keV (penetrating a few mm of steal and lead shield) and neutron emission and the diagnostic laser beam for visualization of the pinched plasma.

A special interest is devoted to the development of methods of the reconstruction of neutron energy spectra in base on the time-of-flight analysis. From the reconstructed neutron energy spectra the energy distribution function of fast deuterons is calculated.

The important part of investigation work is devoted to the theoretic research of an influence of magnetic field on the dense magnetized plasma, and to the study of heating of the neutron source with fast deuterons due to Coulomb interactions and internal magnetic field.

In the PFZ device we test the methods and diagnostics used in the collaboration with the Institute of Plasma Physics and Laser Microfusion in Warsaw and with the Russian Research Center Kurchatov Institute in Moscow at the study of the x-ray and neutron radiation. The upper mentioned research is solved in the frame of student bachelor, master and PhD works. The results of this research, i.e. developed diagnostic tools and techniques for the study of high temperature plasma, will be applied in other laboratories in Prague, namely at the laser system PALS.

Presentation of this contribution was supported by the Czech Technical University in Prague Research Project No. CTU 0814213.

* * *

S2 Plasma Focus Discharge. Physical Processes and Application in Technologies

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In the report the results of the experimental study of plasma processes in Plasma Focus installations of different types and with energies stored in capacitors from 4 kJ to 2.8 MJ will be presented. The basic attention in the report will be given to the research of dynamics of plasma, current-plasma structures and dependence of the output of hard radiations on energy and current. The reasons of restriction of the output of hard radiations on installations of MJ level will be considered.

In the report possible applications of installations of a plasma focus type in technologies also will be discussed.

This research has been supported by the RFBR, grants # 06-02-17398-a, # 05-08-50052 and # 07-08-12096.

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S2 Hot Spots and Filaments in the Pinch of a Plasma Focus: An Unified Approach

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To date, no MHD-based description of the tiny, relatively stable, well-ordered structures (hot spots, filaments) observed in the pinch of a Plasma Focus (PF) seems to be feasible. This is due to their unique combination of high particle density (10^{22}-10^{28} m^{-3}), small radii (10^{-2}-10^{-5} m, $\leq c / \omega_{p\ ion}$), relatively long life-time (1÷100 ns > resistive MHD decay time) and geometrical complexity. Large particle density leads to short electron and ion collision times (≤ ns). The latter suggest that local thermodynamical equilibrium (LTE) holds locally within any arbitrary small mass element at all times (we neglect here non-LTE features like beams of accelerated particles, etc.). This very fact leads to an inequality involving thermodynamic quantities like temperature, pressure…–namely, Glansdorff and Prigogine's 'general evolution criterion'. In turn, the general evolution criterion puts a constraint on the steady states a plasma may relax to, no matter what its chemical composition and its turbulence are like. This constraint takes the form of a variational principle, involving both Joule and viscous heating and invoking no Onsager symmetry. The principle reduces to constrained minimisation of the sum of Joule and viscous heating power under the assumption of flat temperature profile, adopted here for simplicity. The equations of motion of an electrically conducting, viscous magneto-fluid provide the constraints. We assume unmagnetised ions (ion collision frequency > ion Larmor frequency) and allow Ohm's law to include both Hall and fluctuation-related terms. The solutions of the Euler-Lagrange equations of our variational principle satisfy Kirchhoff's constrained minimisation of Joule heating power -with the constraint of electric charge conservation- in an electric conductor at rest. Furthermore, they reduce to Hartmann's flow in the bulk of an electrically conducting fluid with scalar electric conductivity, moving perpendicularly to a superimposed magnetic field in slab geometry. Finally, they satisfy approximately a generalised version of Turner's constrained minimisation of the sum of magnetic and kinetic energy -with the constraints of given magnetic helicity and given generalised helicity- in an electrically conducting fluid with relatively small magnetic interaction with external currents and with electromagnetic fluctuations in Ohm's law. (If no interaction with external currents occurs, MHD virial theorem is satisfied exactly). PF pinch is a good example of such fluid. As particular cases, relaxed states satisfy Taylor's constrained minimisation of magnetic energy –with the constraint of magnetic helicity- and Froehlich's version of Ginzburg-Landau's variational principle in the large-density and low-density limit respectively. Spontaneous filamentation occurs in the Ginzburg-Landau-like state. The radial size of a filament is $\approx c/\omega_{p\ e}$. Magnetic interactions among filaments allow energy diffusion across a plasma with $\beta = 0.11$ with diffusion coefficient $\approx 0.88\ D_{Bohm}$. The familiar Collisional Vlasov High Beta scaling is also retrieved. Our results suggest the following scenario for the PF pinch. Fully developed MHD instability leads to turbulence, which in turn enhances energy transport and flattens ∇T. As ∇T vanishes, spontaneous filamentation occurs, with Bohm diffusion. Any further, density-raising process (e.g. radiative collapse) leads to point-like, large-density hot spots where the magnetic field satisfies Taylor's principle. In spite of their quite different topology, both filaments and hot spots seem therefore to be extremals of the same variational principle.

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S2 Computational Studies of the IPD Discharge with Internal Cathode

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During the Impulse Plasma Deposition (IPD) process of surface engineering plasma is generated in the working gas due to a high–voltage high–current discharge, ignited within an interelectrode region of a coaxial accelerator. Current sheet spreads out within both the inter–electrode space and behind the front face of the electrode system. Owing to the concentration of the electric field lines at the electrode, the electric arc forms an electron beam directed toward the electrode front end. The electrode surface undergoes massive erosion due to both sputtering and the thermal effects. Thus the electrode system becomes an efficient source of the coating material components. At the outlet of the device, plasma consists of the ionized atoms of the working gas and the eroded electrode material. Using the IPD process coatings of a diamond–like carbon, c–BN, oxides (e.g., Al_2O_3), amorphous and nanostructured high–melting materials, the intersitial phases (e.g., the titanium nitride) and multicomponent metallic alloys could be deposited on various non–heated substrates.

A continually growing demand for deeper understanding of the process was the reason to investigate the plasma flow phenomena numerically. The paper reports computational studies of the IPD accelerator with internal cathode. The detailed structure of a discharge region was described by a two–dimensional, two–fluid magnetohydrodynamic model. Equations are solved numerically on a fixed Eulerian mesh by using a modified Lax–Wendroff scheme. Obtained results have shown the differences of the process dynamics when compared with the discharge in electrode system with positive polarization (the rod anode and external cathode). One can observe a separation of working gas plasma (nitrogen) in the outer region of the discharge area and the titanium plasma from the evaporation zone in the front of the central electrode face. The most important are the conditions in which the compound materials are mixed and synthesized – distribution and parameters of the mass swept on the current sheet surface. Within this area nitrogen plasma is enriched with the erosion products, e.g., titanium for titanium nitride coatings. It has been found previously that obtained layers have nonuniform phase composition and morphology when the regions on the accelerator axis and away from it are compared.

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S2 Effect of Nonequilibrium (non-Maxwellian) Part of Ion and Electron Distribution Functions on Neutron Yield and Compression of Thermonuclear Target

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Neutron yield in thermonuclear fusion reaction mainly defined by degree of compression of thermonuclear target material and details of form of ion distribution functions for deuterium and tritium. Effects of nonequilibrium part of electron distribution function on compression of target material, as well as effect of nonequilibrium part of ion distribution function on neutron yield in thermonuclear reaction are discussed in the report. Nonequilibrium part of distribution function of ions and electrons appears in case of impulsive high flux energy impact, such as: light beams (laser ICF), heavy ion beams (beams ICF) or in Z-pinch, i.e. in short-lived plasma formation. In defined conditions presence of nonequilibrium peculiarity in equilibrium plasma particles distribution function modifies neutron yield cardinally.

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S2 Study of Plasma Parameter's Distribution upon Electrical Wire Explosion

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The current-driven explosion of fine wires is often used to study properties of dense plasma (for example, conductivity in paper A.W. DeSilva and J.D. Katsouros, Phys. Rev. E **57**, 5945, 1998). At best, the time dependences of current, voltage and volume of a sample are known in such experiments. Assuming that all energy discharged into the circuit is deposited in the plasma generated by the exploded wire, one can calculate the increase of its total internal energy and, consequently, specific parameters (for example, conductivity, density and etc.). In these experiments, it is very important to maintain a homogeneous distribution of plasma parameters in the discharge channel, but control of the plasma parameters' distribution has never been achieved in experiments. Search of manners of homogeneity maintaining of plasma parameter's distribution is one of several motives for studying the current distribution in wire-explosion products. Studying the initial stage of wire array explosion is another motive. Information about distribution of plasma parameters was obtained from optical and radiograph images.

Our experimental data show that expansion dynamics and homogeneity of wire-explosion products depend not only on the amount of energy deposited into the wire before the secondary breakdown but also on where the current flows after secondary breakdown. If the secondary breakdown develops inside the wire-explosion products and the energy is continuously and homogeneously deposited into the wire-explosion products, one can study the properties of plasma generated by exploded wire. However, the current also may flow in the plasma channel generated in surrounding media (see, for example S. I. Tkachenko et al. Phys. Plasmas **14,** 123502 2007). Therefore, it would be impossible to study the wire-explosion plasma properties using direct experimental data as in paper A.W. DeSilva and J.D. Katsouros cited above. The same can be said for the case of inhomogeneous deposition of energy even when current flows inside wire-explosion products.

Work supported by the RFBR 05-02-17533 and by the Human Capital Foundation.

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S2 New Generation of FID Pulse Generators with Giga- and Terawatt Peak Power for Z-Pinch, Accelerator, Laser and X-Ray Systems

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Traditional pulse generators with giga- and terawatt peak power are built using gas discharge switches (spark gaps). However, short life time, high instability, low pulse repetition rate are largely limiting their application in industry.

FID GmbH has developed a new generation of all solid state FID switches which in almost all features are superior to know thyratrons and spark gaps.

Operating voltage of FID switches can be from 1 kV to 100 kV, switching time of less than 1 ns, peak current of more than 100 kA, time stability and jitter is better of 20 ps. At the same time FID switches have high efficiency, high pulse repetition rate, compact size and almost unlimited life time.

On the basis of new FID switches several types of pulse generators with different pulse shape, peak power and PRF has been developed. The pulsers of the FPG 100KX series have the amplitude from 100 kV to several megavolts with peak current from 1 to 100 kA. Rise time can be in range from 0,1 ns to several nanoseconds while the pulse width can be from 1 ns to several hundreds of nanoseconds. Jitter is not more than 30-50 ps. Energy in pulse can be from one joule to tens of kilojoules. A smooth adjustment of amplitude of the output pulse is possible in range of 20-100% of maximum amplitude.

The pulsers of the FPG 100KX series have high efficiency, compact size and are capable of operating at high repetition rate.

On the basis of FPG 100KX with the amplitude of 1-10 MV compact Z-pinch systems can be built with peak current from hundreds of kiloamperes to tens of megaamperes, rise time of several nanoseconds and pulse width of about 10 ns.

Series of pulsers for accelerator, laser, and plasma chemistry applications with the output amplitude of 10-50 kV, pulse width of 1-10 ns and PRF in continuous mode of up to 10 MHz has been developed.

A series of compact modular pulse generators for linear accelerators with output amplitude of 100-200 kV, pulse width of 1-10 ns, PRF of up to 1 kHz and typical dimensions of 300x200x100 mm has been developed. Jitter of these models is not more than 20-30 ps. Computer control allows synchronous operation of hundreds and thousands of such modules.

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S1 Carbon Impurity Transport Studies in Tokamak Discharges

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A progress in understanding of cross-field transport of carbon impurity has been achieved involving an advanced diagnostics in the investigation of the stationary tokamak plasma regimes. A core impurity transport is an important subject in fusion research for determining role of the impurity peaking – impurity accumulation. Impurity accumulation increases radiation losses in core plasma, dilutes the plasma and can lead to disruptions.

An overview of the experimental observations which allow to compare the particle and carbon profiles behaviour in L-mode as well in additional heated discharges (demonstrated in TCV tokamak experiments) is presented in view of developing and upgrading of diagnostic methods of impurity transport investigation. Special attention is given to those which have sufficiently high temporal resolution to resolve the dynamics of plasma density profiles and could be implicated in carbon profiles study.

At most tokamaks, charge exchange spectra were usually obtained in a wide variety of plasma conditions using a diagnostic neutral beam enhanced CXRS signal fitted with a Gaussian profile, taking into account the spectrometer instrumental function. The steady state radial profiles of fully ionized carbon C^{6+} released from wall tiles were obtained by integrating the fitted active component of the signal emission (transition n=8-7, 529.1 nm) corrected for the neutral beam attenuation and the changes of CX rate coefficient along the beam. The temporal resolution of CXRS system, like a Thomson scattering system, is limited by the low repetition rate of the system and is usually inadequate for resolving fast evolution of the impurity density profile on transport time-scale.

The study of the transport phenomena during MHD activity requires diagnostics with high temporal resolution (≤ 100 μs). The local emissivity is a strong function of the electron temperature, the electron density and the impurity mixture. The radiation power is usually monitored by many chords soft x-ray system in core plasma and fast bolometric AXUV photodiodes system, which allow the study of fast transport at the plasma edge with temporal resolution of tens μs range. Such systems provide line integrated measurements which are tomographically inverted to obtain local emissivity distribution.

In stationary Ohmic and ECR heated L-mode discharges (in TCV), the profiles of carbon are always peaked, with a clear dependence of $\nabla n_c / n_c$ on $<j>/j_0 q_0$. The observed peaking of the carbon density profiles exceeding the peaking of the plasma density profiles, and phenomenon of impurity accumulation of anomalous (rather than neoclassical) origin is observed.

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S6 The New Versatile Ion Source (VIS) for High Power Proton Accelerators

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The characteristics of the ideal injector for high power proton accelerators has been studied in the past with the TRIPS ion source built at INFN-LNS, Catania and now in operation at INFN-LNL, Legnaro. The beam production must obey to the request of high brightness, stability and reliability. The new Versatile Ion Source (VIS) is a permanent magnet version of the TRIPS source with a simplified and robust extraction system. It operates up to 80 kV without a bulky high voltage platform, producing multi-mA beams of protons and H2+. The description of the source design and the preliminary performance will be presented. An outline of the forthcoming developments is given, with particular care to the use of a low loss dc break and to the use of a travelling wave tube amplifier to get an optimum matching between the microwave generator and the plasma.

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S6 Use of an Atmospheric-Pressure Dielectric Barrier Discharge Reactor with Anodized Internal Electrode for Chemical Synthesis Applications

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Given its nature as a highly reactive medium, plasmas have found increasing application in industry, as tools for surface treatment/modification and for synthesis/degradation of chemicals. A discharge used widely in these latter applications is the dielectric barrier discharge (DBD), which can be operated at atmospheric pressure or higher. The filamentary nature of such discharges when a nude electrode is present can cause disadvantages for their operation. Such problems are usually eliminated by adding a second dielectric barrier to the internal electrode, at the cost of higher breakdown voltages and hence higher power consumption. In the present work, the operation of a DBD coaxial cylindrical reactor with an anodized internal electrode is proposed. The anodization process generates a thin (1 – 10 μm) self-supported oxide layer on the surface of a metallic rod; this oxide layer serves as a second dielectric in the reactor (the first being the quartz reactor wall), and greatly reduces filament formation in the discharge. Since the layer is thin, reactor power consumption remains within the same level, and much lower than in the case of a double thick-wall reactor. In addition, the porous structure of the oxide layer formed by anodization makes it an ideal support for catalytic particles. Results on the characterization of anodized aluminium, titanium and zirconium electrodes and the operation of a DBD reactor with these electrodes in the synthesis of ammonia from nitrogen/hydrogen mixtures are presented.

S6 Effect of the Frequency Tuning on the Electron Cyclotron Resonance Process within an Ion Source

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In an Electron Cyclotron Resonance Ion Source, a plasma is magnetically confined and fed by means of an electromagnetic radiation with proper frequency and power. Some experiments have shown that even small frequency variations of this feeding electromagnetic wave, can produce large changes in the source behaviour, that can be observed in terms of broad variations of the output ions current. While the dealing with this phenomenon should require the determination of the electromagnetic fields in the chamber when the plasma is therein confined, an effective explanation of it has been achieved by the observation of the fields variations with frequency within the vacuum filled chamber. In particular, it was shown that the effectiveness of the resonance process depends on the electromagnetic field distribution on the related resonance surface. In this work we have considered an asymmetric model for the description of the magnetostatic fields used to confine the plasma, that can be easily created by means of a few experimental measurements of them within the source chamber. We have studied analytically the related resonance surface area and the volume of the space confined by it. Furthermore, we have observed how the electromagnetic field distribution on the resonance surface varies because of even small frequency changes. Therefore, we have shown the dependence of the particles energy and confinement on these variations, under the hypothesis of a very low density plasma, so that it is possible to consider the chamber as it is in vacuum.

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S6 Immersed Arc-Plasma Treatment of Mineral Wastes

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In the paper, a new approach to utilisation of mineral wastes using electric arc has been presented. A model of mineral arc-plasma immersed in the furnace feed charge has been elaborated for this purpose. The theory of utilisation of materials by electric arc has been verified by experimental tests in the laboratory furnace. Properties of the end-product – vitrified slag, are also presented in this paper.

It has been proved that it is possible to lead a continuous process of utilization and conversion of mineral waste material using an electric arc, which is generated inside this material between an immersed electrode and a crucible.

This could be a step forward to elaborate and control an effective technological process of continuous casting with the ability of maximal absorption of arc energy by the feed charge. It should considerably increase the energetic efficiency of the waste treatment process.

The aim of this work is to present theoretical and experimental research of modelling of mineral waste pyrolytic treatment process and to demonstrate some test results of the following wastes treatment: medical ash, medical ash with different inorganic additives and medical ash with Polychlorinated Byphenyls.

This research has been supported by the European Commission within the research project: "A Generic Plasma - Arc Process for Toxic Waste Destruction with Co-Generation of High Value Construction Materials" in 5TH Framework Programme - acronym WASTILE.

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S6 Performance Optimization of HDP-CVD with Multiple Responses Using Response Surface Methodology (RSM)

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Performance optimization plays a crucial role in the process design of semiconductor manufacturing. Due to the ubiquitous complexity and nonlinearity of plasma process, the process characterization and optimization of high density plasma-chemical vapour deposition (HDP-CVD) for the desire to achieve rigorous production goals and achieve the best possible efficient fabrication is the key to success in current semiconductor manufacturing industry. Utilizing statistical analysing method of response surface methodology (RSM), this paper investigates three steps for the process optimization: 1) first-order model or screening experiment; 2) path of steepest ascent (PSA); and 3) second-order model. This paper proposes the method of prediction modeling for characterizing and optimization of HDP-CVD process with respect to responses of deposition rate (Å/sec) and within wafer uniformity (%) are performed. A 2^{5-1} fractional factorial design with 3 center points was employed to characterize the process, in which the variables that were varied including a top and bottom RF power, top and bottom SiH_4 and O_2. Three major variables, such as top RF power, top and bottom SiH_4 were chosen for the next steps through fitting the first-order models. To compute a path of steepest ascent (PSA), the weighting factor values of 0.2 and 0.8 were added to the predictive models of deposition rate and uniformity, respectively. The k=3 Box-Behnken design (BBD) was employed for the purpose of which is to optimize the process. Finally, process performance optimization is generated to simultaneously satisfy the weighted multiple response of interest using performance index (PI) which was calculated by the similar method with PSA. By the PI method, we can select the best recipe including only significant terms. From the result of PI method, we calculated the new optimized recipe. The proposed recipe of which top SiH_4, bottom SiH_4, and top RF power are 37 sccm, 57 sccm, and 4600 W and two removed factors of bottom RF power and O_2 are fixed to 1200 W and 185 sccm using the PI method.

S6 Effect of Electron Magnetic Trapping in a Plasma Immersion Ion Implantation System

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Plasma Immersion Ion Implantation (PIII) is a fast and efficient surface modification technique specially developed for treatment of complex shaped three-dimensional objects. In a PIII process, a negatively biased target is immersed in plasma generated in a vacuum chamber. When the target is pulsed at a high voltage with negative polarity, electrons in the plasma are driven away and uncover a region of positive ions (known as ion matrix sheath), where the quasineutrality breaks down. Then on a time scale of about the inverse ion plasma frequency the resulting electric field in the sheath accelerates the ions to a high energy toward the target. Because the sheath surrounds the target conformably, all sides of a 3D workpiece are simultaneously implanted and at normal incidence. The ion flux during the negative high voltage pulse is maintained by the continual expansion of sheath-plasma edge, exposing new ions that are accelerated toward the target.

Since the main ion acceleration occurs in the sheath, sheath behavior is extremely important in PIII related processes. For example, to ensure a conformal implantation it is important to maintain the sheath thickness small enough compared with the workpiece characteristic size. In some cases, this can not be easily accomplished due to hardware limitations.

One possible way of controlling the sheath thickness is the use of transversal magnetic field. The magnetic field strength can be chosen such that plasma electrons beyond the sheath edge become strongly magnetized, while the motion of heavy ions remains essentially unperturbed. In recent years, a great deal of interest has arisen in the possibility of using magnetic field for controlling PIII process. In this work we describe a two-dimensional computer simulation of magnetic field enhanced plasma immersion implantation system. Negative bias voltage of 10.0 kV is applied to a cylindrical target located on the axis of a grounded vacuum chamber filled with uniform nitrogen plasma. A several tens of Gauss static magnetic field with main vector component along the axial direction is created by a pair of external coils. In this way a system of crossed **E**x**B** field is generated inside the vessel forcing the electrons to rotate in azimuthal direction. In addition, the axial variation in the magnetic field strength causes axial electron trapping. The vacuum chamber is filled with background nitrogen gas to form plasma in which collisions of electrons and neutrals are simulated by Monte Carlo algorithm. It is found that high density plasma region is formed around the target due to the intense background gas ionization by the magnetized electrons drifting in the crossed **E**x**B** fields. Effect of the magnetic field on the sheath dynamics and the implantation current density of the PIII system is investigated. Due to the magnetic mirror effect the magnetic, the axial distribution of the magnetic field is also important for the PIII processing. By only changing the magnetic field axial profile (by separation of the coils) an enhancement about 30% of the ion dose can be achieved. The results of the simulation show that the magnetic mirror configuration brings additional benefits for the PIII process, permitting more precise control of the implanted dose.

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