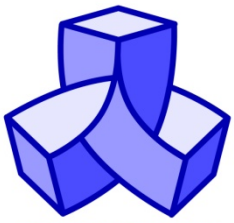


**Project no.026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Final activity project report

Period covered: from 01.07.2006 to 31.12.2009 Date of preparation: 12.02.2010

Start date of project: 01.07.2006 Duration: 42 months

Project coordinator name **Zoran Petrovic**
Project coordinator organization name **Institute of Physics**

# EXECUTIVE SUMMARY

The Centre for Non-equilibrium Processes has achieved significant results in the reporting period of its activity in several research fields including information technologies based on nano science and sustainable development. The present project promoted the Centre into the leading institution covering applications based on non-equilibrium processes in the West Balkans, and it will be the basis for further integration into European projects and international collaboration.

We have been working in four different but related fields:

-studies of non-equilibrium plasmas motivated by the development of 40 nm technologies for integrated circuits related to plasma and fast neutral etching;

-interaction of non-equilibrium plasmas with surfaces to achieve nanostructured hydrophobic surfaces and treatment of biological materials;

-development and diagnostics of plasmas of interest to achieve growth and control of nanotubes on surfaces and nano particles in gas phase;

-suspended particles as atmospheric pollutants.

**The main objectives of the project and how they were achieved:**

*1. To sustain the level of achievement that was already reached for the experimental group and to provide them with facilities to compete with the increasingly well equipped laboratories in Europe and around the world.*

We have improved considerably our standing in the international community by publishing a large number of papers at a continuously increasing level during previous 3-4 years (starting from 22 papers in 2006 in the ISI journals annually to more than 30 in 2009), by attracting invitations to give invited lectures at renowned international

conferences (ranging from 8 to 20 annually during the realization of the project), by invitations to join editorial boards of major international journals (5) and by invitations to join scientific and/or organizing committees of major international conferences.

In addition, the number of citations which has been rising steadily had a significant increase in the past three years. Starting from around 150 in 2006, the number of citations was greater than 250 in 2008 while in 2009 it was more than 400. The level of international and national recognition is also obvious from the number of awards and acknowledgments:

- **Nevena Puac**, has been awarded a prize by **'Academic Radoslav K. Andjus' Fund** for **best young researcher science's publication in physiology and biophysics** in 2006/2007;

- **Zoran Mijic**, has won **"Ljubomir Cirkovic" award** for the **best MSc thesis** for the year 2007;

- **Ana Bankovic**, has won **"Ljubomir Cirkovic" award** for the **best BSc thesis** for the year 2007

- **Nevena Puac**, has been **awarded for the best PhD thesis in the field of Materials science** by the Yucomat (Serbia and Monte Negro materials science society) for the year 2007;

- **Mira Anicic**, was awarded for **Excellency and Best Student Talk** at Fourth International Summer School and Workshop: "Nuclear Physics Methods and Accelerators in Biology and Medicine" July, 2007, Prague, Czech Republic;

- **Marija Radmilovic**, won the **award** of the Institute of Physics for the **scientific results for 2008**.

- **Mira Anicic** was awarded for the **best poster presentation** by Conference Committee of the Fifth International Workshop on Biomonitoring of Air Pollution in Buenos Aires, Argentina, September 2009;

- **Organization of 20th ESCAMPIG** was awarded to the Institute of Physics Belgrade in July 2008 and the conference will be held in the summer 2010;

- **Dragana Maric** replaced **Gordana Malovic** as a new member of the international scientific committee of the **Escampig** conference;

- **Zoran Petrovic** became fellow of the Serbian Academy of sciences and arts in 2009.

- Two of the PhD students were invited to give invited lectures at major International conferences: **Sasa Dujko** (62nd Gaseous Electronics Conference (GEC) in Saratoga Springs, NY USA and **Ana Bankovic** (25th International Workshop on Low Energy Positron and Positronium Physics & 26th International Symposium on Electron-Molecule Collisions and Swarms conferences in Toronto, Canada);

- **M**embers of our COE have become associate members of the Australian COE Center for antimatter – matter studies and a COE of Keio University in Japan on new technologies in microelectronic industry for the 21st century. Members of the COE were also invited to give lectures at a number of renowned universities including Ruhr University Bochum, Australian National University, Flinders University Adeaide Australia, Keio University Japan University of Ulster Jordanstown UK, Ecole Polytechnique Paris France.

*2. To provide facilities for good quality experimental research into nonequilibrium processes that have application in nanotechnologies and environmental monitoring and control of particles suspended in the atmosphere.*

We have achieved this goal by using the funds of the project to upgrade our equipment and to purchase two major pieces of equipment which were missing in order to be at the level of internationally recognized laboratories. We have completed the purchase and installation and had brief introductory courses by the engineers from the manufacturers for:

- MiniPal 4 - Energy Dispersive XRF Spectrometer (PANalytic-Holland) and
- HIDEN Analytical EQP 1000 Sampling Mass Spectrometer and Energy Analyzer (Hiden UK).

In the meantime, thanks to our success with this project we have secured additional funding from our government and managed to obtain additional equipment. The two sets were integrated during the second year of project providing a system with much more power and flexibility. Thus new avenues of research opened and so did new chances to start collaborations. The third year was devoted to initializing research and international collaborations using the equipment purchased through the project and additional equipment from the national investment programme of Serbia. The availability of mass energy analyzer operating at atmospheric pressure created interest in several laboratories to perform measurements in our laboratories thus opening new possible joint projects. Proton Transfer Reaction Mass Spectrometer (PTR-MS) enabled us to include volatile organic compounds (VOCs) measurements in environmental research. New research area has been opened with promising application in various fields as medicine, biology, enology etc. We had interest from foreign scientists from Bulgaria, UK, Germany, France, Hungary, Bosnia and Hercegovina, Macedonia and more countries to visit our laboratory, not for the purpose of presenting a lecture but in order to participate in measurements and take advantage of the equipment.

*3. To foster young researchers with both wide and deep knowledge and high-level research skills.*

As a part of meeting this goal five young researchers (Ana Bankovic, Nikola Skoro, Andreja Stojic, Mirjana Perisic and Sasa Lazovic ) have been engaged in the COE and have had an opportunity to start their research careers. While only three may benefit directly from the funds of the COE at any moment, we managed to find some extra funding from national funds and include them in exchange and other activities and enable them to be employed in the Institute. They have completed their BSc-MSc theses in the center and started their PhD studies. Most of them have already published their first, albeit brief conference papers and some have published papers or have their manuscripts accepted in major international journals. They passed successfully the exams on Master or PhD studies. Two of them have defended their Master theses and two are finalizing them. Students that started their work in the first two years covered by the project have progressed very well. Two PhD theses (Ana Bankovic, Nikola Skoro) are expected to be defended in the next few months and the third theses by the end of the year 2010 (Sasa Lazovic).

Within the activities of the COE, five PhD thesis (Velibor Novakovic, Nevena Puac, Vladimir Stojanovic, Milovan Suvakov, Sasa Dujko) six BSc thesis (Zoran Mijic, Mira Anicic, Milovan Suvakov, Dejan Maletic, Aleksandra Nina, Snjezana Dupljanin) have been defended, and several Diploma works as well.

While students from the previous years attained their positions in the national projects new students (Marija Savic, Srdjan Marjanovic, Ivanka Djordjevic, Aleksandar Bojarov, and Dejan Maletic) have passed through courses led by the members of the COE and are preparing for their engagement in the center.. At the same time all had continued training and were involved in COE activities. All togather **ten students** have been involved in the training and project activities

One student from the region (Bosnia), Snjezana Dupljanin has commenced her work on the project two and half years ago for her Masters and PhD theses with the members of the COE and already has published one paper in an internationally renowned journal while one more is accepted and one submitted with a positive review of the referees. Last year another student from Macedonia has started his work and in addition to several conference papers one paper in ISI journal has been published while defense of the Master's thesis was postponed from December 2009 to January 2010 due to his illness.

The policy to promote young scientists by taking advantage of the funds from the Project has been extended to all stages of scientific careers. It is important to note that the young researchers with (Dragana Maric, Marija Radmilovic, Gordana Malovic, and Olivera Sasic) and even without (Sasa Dujko, Ana Bankovic- as mentioned above) PhD were more often invited to give invited lectures in the past three years than before. So not only young researchers gained necessary skills but they also gained some degree of international recognition.

*4. To improve the training of the staff of our centre and of the students and young researchers by inviting distinguished European scientists in fields of interest for extending our research into more topical areas.*

In the past 42 months the strong activity in this respect continued. A series of lectures on physics of positrons (SJ Buckman, J. Marler, R. White) was organized both in our institute but also at the national science fair and at the academy of science thus broadening the impact of our activities. Needless to say this approach increased our visibility in our country and several articles in press recorded this event.

We also had visitors presenting lectures, joining our experiment or active theoretical studies but also interacting with our students while working in the laboratory rom Australia (Casten Makochekanwa -originating from Zimbabwe), from Bulgaria (Valentin

Mihailov), from Hungary (Kinga Kutasi), from Czech Republic (T Hedder), UK (H. Varambhia), Denmark (JP Marler- formerly from USA), and more A number of highly ranked physicists in senior positions (Bill Graham chairman of the GEC and ESCAMPIG committees and Paul Maguire from University of Ulster center for nanotechnologies) also visited our laboratories and participated in experiments, paper preparation and training of students. Thus our students were able to hear lectures of the leading scientists and to have direct contact with them, even to present their work to them. In some cases the connection was made for a continued collaboration.

In addition to the visitors to the Laboratory Under sponsorship of FP6 Project, international workshops and symposium have been organized with more than 50 invited speakers from the leading centers for plasma processing in the world. All members of the COE not only students took advantage to attend a number of excellent lectures and to some training consisted of presenting their results and having their results judged against the work coming from the leading centers in the field.

All students with the exception of the new Masters students have attended relevant international conferences as a part of their training and career planning. As mentioned above Ana Bankovic attended International symposium on Electron Molecule Scattering and swarms in Toronto a satellite of ICPEAC where she presented an invited lecture, Sasa Lazovic attended International symposium on plasma chemistry in Bochum, while Nikola Skoro attended Conference on atmospheric pressure plasmas in Belgium.

Opportunity presented itself to send three of our students to a summer school in this field in Germany where they interacted with leading lecturers in the field and many of their fellow students. They also presented their work at that summer school.

*5. To improve mobility by sending our young and senior scientists to EU laboratories those have relevant expertise. Networking would be improved by performing joint experiments or research in general but it can only be initiated and coordinated through exchange.*

Some aspects of networking were covered in the previous section as most visitors took part not only in joint experiments or other activities but gave lectures and interacted directly with students which are the best training for a scientific carreer. As a part of networking we started collaboration with Brno University and two of their students visited our laboratories and participated in joint experiments where our new diagnostic technique (partly purchased through the funds for this project) was applied to their plasma source. Networking also started with the Norwegian University of Science and Technology in Trondheim, Norway and Frank Laboratory of Neutron Physics, Joint Instituite of Nuclear Research, Dubna, Rusia, where students have been send and stayed in 2007 and 2008 for collaborative scientific works. Postdoctoral appointment in Micro- and Trace Analysis Center (University of Antwerp - Department of Chemistry), Antwerp, Belgium has started and is still going on. On the plasma side our active collaboration continued with Nanotechnology and integrated Bio Engineering Center of the University of Ulster (UK), Ruhr University Bochum (Germany), Institute for solid state physics Budapest (Hungary), Institute for solid state electronics of the Bulgarian Academy of science (Bulgaria), Polytechnical University Lisbon (Portugal), Ecole Polytechnique (France), Institut Jozef Stefan Ljubljana (Slovenia) and numerous centres in USA, Australia and Japan.  Some of thoseactivities were supported by the COE.

*6. To improve the global (and local) visibility of our Centre and promote it into a leading experimental centre in West Balkans. To prepare proposals for EU funding*

Major indications of the visibility of the centre during the reporting project period came also from a large number of invitations to give lectures, prepare special chapters in scientific monographs, large number of citations.

Under sponsorship of FP6 Project, international workshops and symposium have been organized with more than 60 invited speakers from the leading centers for plasma processing in the world.

- First International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment, August 2006, Kopaonik, Serbia
- The 5$^{th}$ EU-Japan Joint Symposium on Plasma Processing, 7-9 March, Belgrade, Serbia
- Second International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment, 23-26 August 2008, Belgrade and Novi Sad, Serbia;
- Electron and ion transport in ionized gases- a specialized workshop at ICPIG 2009 CANCUN Mexico, and
- Kinetic phenomena in non-equilibrium plasmas, a specialized workshop at GEC 2009 at Albany NY USA).

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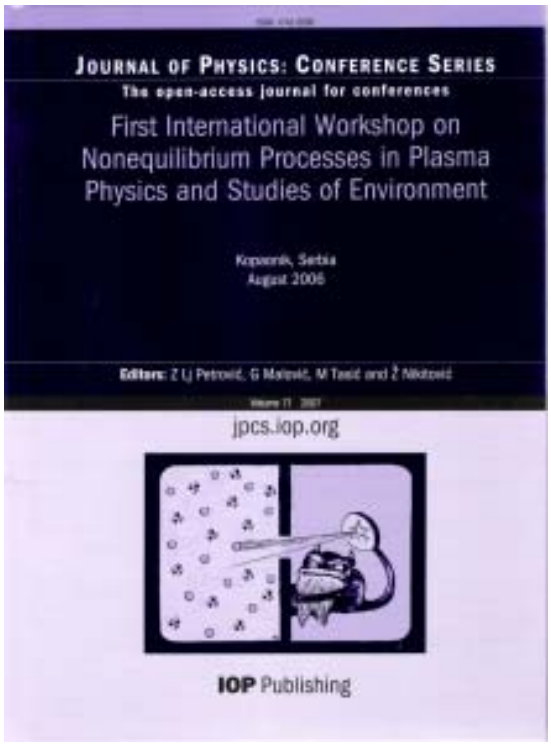
**Three special volumes of the Institute of Physics UK Conference Proceedings** with invited and review papers from the conference and workshops have been published online and are available for free download:

http://www.iop.org/EJ/toc/1742-6596/71/1

http://www.iop.org/EJ/toc/1742-6596/162/1

http://www.iop.org/EJ/toc/1742-6596/86/1

In addition, hard bound volumes of all proceedings appeared as well.


JOURNAL OF PHYSICS: CONFERENCE SERIES
The open-access journal for conferences
First International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment
Kopaonik, Serbia
August 2006
Editors: Z Lj Petrović, G Malović, M Tasić and Ž Nikitović
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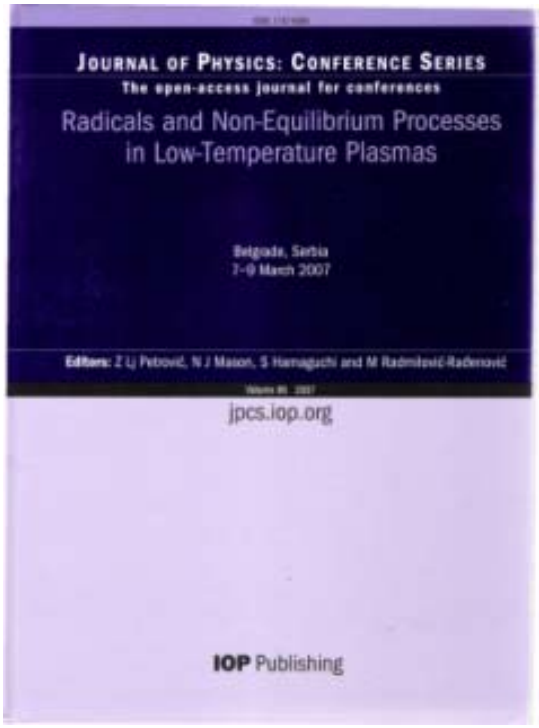
JOURNAL OF PHYSICS: CONFERENCE SERIES
The open-access journal for conferences
Radicals and Non-Equilibrium Processes in Low-Temperature Plasmas
Belgrade, Serbia
7–9 March 2007
Editors: Z Lj Petrović, N J Mason, S Hamaguchi and M Radmilović-Radenović
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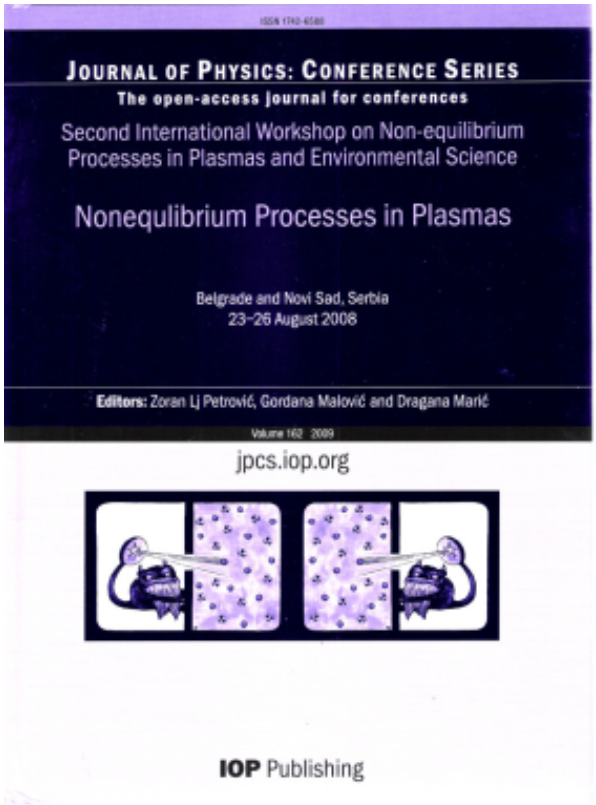
JOURNAL OF PHYSICS: CONFERENCE SERIES
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Belgrade and Novi Sad, Serbia
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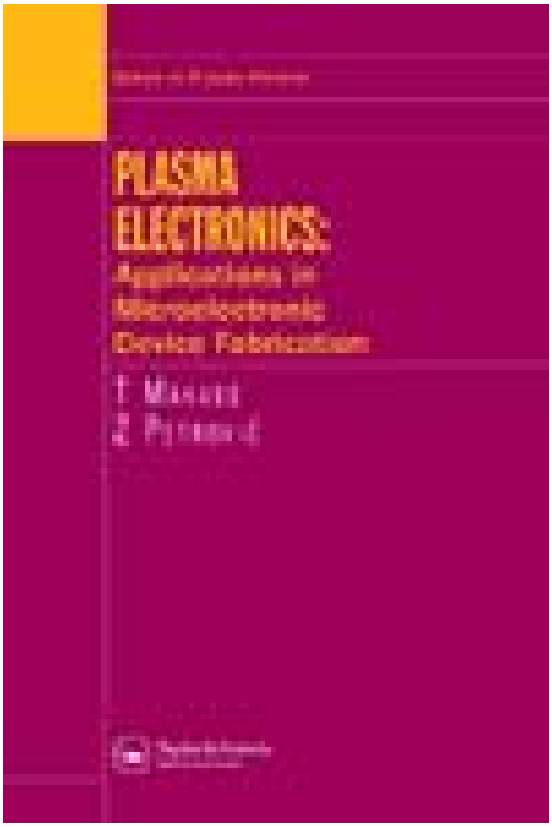
PLASMA ELECTRONICS:

A significant result was the publishing of the book:

**PLASMA ELECTRONICS**:

Applications in Microelectronic Device Fabrication

**T.Makabe**, Keio Univeristy, Japan and **Z.Petrovic**,University Of Belgrade

Taylor and Francis CRC Press New York 2006

Specialized web site (http://www.ipb.ac.rs/~cep/ipb-cnp/) was designed and operated expanding the standard presentation and opening possibilities for exchange of data, joint research, active training and better visibility has been operating. Newsletter was mailed during this period and became a regular feature in our activities. The newsletter was well received and we had numerous comments and no requests to be taken off the mailing list.

We have also maintained, and even improved, our presence at international conferences which can be seen by the number of the members of our group, including students, participating in international conferences, by 28 invited and topical lectures presented at leading international conferences and symposia in the field of plasma science, atomic and molecular physics, nanotechnology and environmental science, and invitations for more lectures in the following year.

We have continued our activities to modify the previously prepared projects that met with some degree of success in the previous year. Several regional projects and EU funded projects are carried out with participation of some of the members of COE centre.

We also worked on preparation of a project on positron transport modeling and some of our members became part of a project on plasma treatment of textiles. One major proposal for EU funding was prepared and submitted but was not successful.

As a result of our activities number of citations increased by a factor of three during the duration of the project.

**Management activities**

In order to achieve the goals of the project and of the COE the management and the entire group have been involved in the following activities:

- organization and running of the Centre of Excellence, management, advisory and steering committee, committee for purchases ;
- obtaining additional funds, space and organizing improvement of the facilities; integration of the newly purchased equipment with other equipment into complex experimental systems and into our scientific program;
- organization of training, teaching, and the continued search and recruitment of new students;
- provide a logo and other artistic support for a better visibility of the COE (a logo was developed for the center by the leading Serbian designer Rastko Ciric and another symbol was developed for the workshop depicting the Maxwell's demon- a symbol of non-equilibrium);

- making maximum efforts to improve networking and international collaboration, managing the ongoing networking activities;

- increasing the impact of our research and of the COE project by steering the activities towards issues that would have maximum impact, in this case the focus gradually shifted towards medical applications (new lines of research opened with new facilities: breath analysis and positron energy deposition modeling in biological tissues).
- addressing all issues especially the gender issues and the mechanisms to help women scientists maintain their scientific careers at the level in accordance with their abilities.

- preparation of the intermediate and annual reports, financial reports and three year report

- initiation of new project proposals.

The main problems that had to be overcome were in the changing of regulations in the country and in the Institute of Physics, in the need to improve laboratory space and other facilities and in the continuous brain drain which deprived us of the best students including some students that have commenced their graduate studies in the Centre. The main problems that had to be overcome in the third year was the drastic drop in funding from the local government and maintenance of programs for the FP6 project in the situation of the shortage of funds, reduced chances to take students onto government funding and major delays in funding by the government. Thus we had to extend the period of the FP6 project in order to secure sufficient funding to carry out planned activities that would be eventually covered by the FP6 project after reports are submitted and accepted.

To remedy the brain drain and reduced possibilities to hire students on government projects our COE managed to attract two of our former students who obtained PhD one in EU (Slovenia) and the other in Australia to return.

Additional problem that was dominant in the last year of activities was the reduced funding from the national sources due to the financial crisis.

**Exploitable and publishable knowledge and the dissemination of results**

The most important results are development of a data base for electrons, positrons and negative ions which may be exploitable and publishable as well as the new knowledge on application of the plasma needle, secondary electron yields in two frequency plasmas for etching and development of integral monitoring of gaseous and particle pollutants in air followed by the use of X-ray fluorescence spectrometer and Proton Transfer Mass Spectrometer as new on line tool for volatile organic compounds (VOCs) identification. All measurements were followed by the application of multivariate receptor modeling (PCA, PMF, UNMIX) and air back trajectories analysis for identification of the main pollution sources. Two more data bases were opened in the past year, one on positron cross sections and transport and one for electron transport and cross sections in reactive gases. In the third year we have added new data sets for electrons in $N_2O$ and for several other gases.

As for the dissemination of results we have organized three workshops and a symposium in August 2006, March 2007, and August 2008 and published books of proceedings with selected review articles and progress reports. We also participated in organization of a symposium in Japan and two specialized workshops sections in the official programme of major conferences Gaseous Elecgtronics Conference (Saratoga Springs USA- October 2009) and ICPIG (Cancun, Mexico- July 2009). Web site of the project operated and was extended; we distributed the newsletter and published several specialized review articles.

New management scheme, improved experimental facilities and organization also gave a new motivation for improved research. This scheme also facilitated collaboration within the centre between the environmental science and plasma science oriented sections. To improve visibility and to further the dissemination of the results we have published some of the data in high ranking journals. Presentations at conferences also

served the purpose to initiate networking and other collaborative efforts and to train young researchers in all aspects of scientific endeavor.

78 papers were published in internationally recognized journals, one book was published by internationally reknown publisher, 9 chapters in books and proceedings, delivered much more than 27 invited lectures, 81 papers and abstracts presented at scientific conferences

In the line of the main focal points of the projects it is worth noting that we have especially increased our presence in the target field of nanotechnologies. The project coordinator (ZP) has been invited to present an invited lecture at the first international conference on Plasmas in nanotechnologies (Piran Slovenia September 2009) and to prepare a chapter in a book on plasma technologies edited by a group of USA scientists that will be published by Springer. The Chapter (one of 9 chapters) has been submitted and it is a major review (53 pages in the book) of the application of plasma nanotechnologies both top down and bottom up. The coordinator (ZP) has been invited into the steering committee of ICPCNanoNet EU project funded under FP7; he participated in their meeting, gave an invited lecture and participated in other activities.

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**Secretarial**: Vesna Vucic, Ilija Marelja

**Students**: Dejan Maletic, Srdjan Marjanovic, Marija Savic, Ivanka Djordjevic,

Aleksandar Bojarov

# SECTION 1

## PROJECT OBJECTIVES AND MAJOR ACHIEVEMENTS

### GENERAL PROJECT OBJECTIVES

To sustain the level of achievement that was already reached for the experimental group and to provide them with facilities to compete with the increasingly well equipped laboratories in Europe and around the world. Without this support the level of publications in high quality journals would be reduced either in quality or in number or both. Maintaining the high level of publications our group has set to be a measurable result of this project. Other aspects of recognition are also important including membership in international scientific committees, memberships on editorial boards of major journals, invited lectures at international conferences and invitations to visit and give lectures in major international laboratories, joint international projects and many more. Citation is also an important tool for measuring the esteem of a certain group. In the whole reporting project period we have published 78 papers in journals from the ISI lists, delivered much more than 27 invited lectures and initiated or participated in several international projects (COST, Serbia-Slovenia, Serbia-Bulgaria, DAAD-German bilateral projects, Serbia-Hungary,).

- To provide facilities for good quality experimental research into non-equilibrium processes that have application in nanotechnologies (nano-electronics, nano-structured surfaces and nano-tubes) and environmental monitoring and control of particles suspended in the atmosphere. This was achieved by buying additional equipment that improved the existing experimental foundation and allow us to gradually move to closely related topical fields of research. This has an important

implication on the impact of the research, both internationally and nationally. Impact may be measured in the development of new technologies, by conducting research inspired and supporting novel technologies, by training young specialists, by improving the general conditions and acceptance for the science in one's environment. In the reporting period the new equipment was integrated with the newly purchased equipment from other funds and modifications in order to implement the equipment were made. Active application of the new equipment is well under way in several different directions. EQP mass analyzer is integrated in the system for studying atmospheric plasmas and has been used continuously for more than a year, giving several papers and leading to new invited lecture invitations and joint measurement proposals. The x ray system has been integrated in the set of existing tests done on pollutants but new applications like protection or archaeological finds has been turned into a project proposal.

- To foster young researchers with both wide and deep knowledge and high-level research skills, who will be able to be leaders in both fundamental studies, applied research and introduction of new technologies. This was done by employing young researchers and gives them an opportunity to attain a permanent position in the Institute. While only three benefited directly from the funds of the COE at any moment we managed to find some extra funding from national funds and include more students in exchange and other activities..

- Plan was also to take advantage of the increased training activity to include more students and also to open new avenues of research to maximize (and optimize) the impact and future activities of the group. While students from the previous years attained their positions in the national projects new students were engaged through the COE. At the same time all had continued training and were involved in COE activities. All togather ten students have been involved in the training and project activities

- To support Environmental Physics Laboratory which is the local centre for physical monitoring, microanalysis and studies of gaseous and particle air pollutants. The project should help laboratory to maintain its leading position, its connection to European air pollution monitoring and regional systems with special emphasis on the dynamics of pollutants in the Mediterranean region. Using a Low Volume Air Samplers for sampling of PM10 and PM2.5 (particles less than 10 and less than 2 microns in diameter) and with the upgrade of the analytical equipment with XRF technology, and Proton Transfer Reaction Mass Spectrometer (PTR-MS), the Centre will be able to become a reference laboratory integral monitoring of air pollutants. The air-back trajectories model has been applied for determination of main sources of pollution in the Belgrade area. Based on the studies in the field, and transport modeling a reliable database has been formed and will used as the input parameters for epidemiological studies on the health status of the population in urban areas and are basic ones for evaluation of the health risk due to ground level air contamination. One of the important aspects of this segment of our activities is integration into international monitoring schemes and projects where both service for our country is performed and also integration into international systems is enabled.

- An important indirect benefit to the laboratory as reported in the previous period was that additional funds were obtained from the national government based on the success in attracting EU funds and a unique instrument for this part of Europe has been purchased, the Proton Transfer Reaction Mass spectrometer (PTRMS). While this instrument completes the set for air pollution monitoring (it is actually available at only few points around the globe) it also enabled us to open new avenues of research like applications of the system in the medicine and biology and diagnostics of volatile organic compounds in a number of situations (food industry, pharmaceutical industry,). This line of research and this monitoring facility has been integrated in other research programmes and has been really active and successful in the reporting period.

- Members of our group have achieved experience in development of plasma etching devices through collaboration with a leading academic group in this field in Japan and they also had an access to the achievements provided in Industrial research facilities. Our goal would be to transfer a part of that knowledge and use it to achieve a high visibility in this field in Europe and assure our position as the leaders in this field in West Balkans. For that purpose a basic plasma etching experimental reactor is being built. It will have two frequency operation and will be pulsed. In order to make good quality publications would require highly specialized diagnostics, and the proposed plasma monitor is the key element that is beyond our means. The measurable verification would be the completion of this reactor with plasma monitor. Due to failure of the manufacturer to deliver the parts the completion of the plasma etcher has been postponed but now purchase of the system has been completed in the third reporting period. The system is being finalized and the first measurements commenced.

- To improve the training of the staff of our centre and of the students and young researchers by inviting distinguished European scientists in fields of interest for extending our research into more topical areas. This contributed to an improved mobility of scientists and networking within European scientific domain. It was verified by the number of seminars, short courses, and attendance to workshops that have been provided due to this project. In addition integration of young students into standard scientific practices was important aspect of training. Thus participation in conferences, direct communication with distinguished foreign visitors and other activities enabling students to gain experience are very welcome and in support of this activity. In that sense two workshops and one symposium were organized during the three years with participation of more than 50 foreign scientists all giving lectures and interacting directly with all the researchers and students from the COE. In the last reporting period we helped train a wider range of students beyond our COE by organizing two workshops as a part of two major conferences (one in Mexico and one in USA). At the same

time our students have participated in international conferences as part of their training and in international summer schools. The activity was extended throughout the whole project period with additional scientists visiting laboratory and participating in our activities. Selected authors were invited to contribute to the third volume of papers having duty not only to present the topical research but also to contribute to the training and networking missions, that were published by the renowned international publisher (Institute of Physics UK) and through partial support of the project these articles were made free for downloading thus extending the visibility of our work presented there and providing basis for student training in the related fields around the globe.

- To improve mobility by sending our young and senior scientists to EU laboratories that have relevant expertise. Networking was improved by performing joint experiments or research in general but it can only be initiated and coordinated through exchange. This aspect of the project improved complementarity of laboratories which is an essential aspect of networking and which allowed achieving greater results with optimal investments into equipment. This is essential for experimental projects. In addition the project improved the connections within the centre between different teams.

  The limited funds for exchange available through the COE were combined with other sources to optimize activities of the COE. For example, funds were used to provide visits of scientists or our visits to the centres that have the expertise in using the equipment or taking advantage of the equipment that was purchased in the COE (NIBEC and Queens University Belfast, Ruhr University Bochum, ...).

- To improve the global visibility of our Centre and promote it into a leading experimental centre in West Balkans in fields of non-equilibrium plasma processing of electronic devices, nano-structuring of materials and monitoring and control of atmospheric pollution due to suspended particles and volatile organic compounds (VOCs). This was achieved by vigorous training of the staff,

by improved experimental facilities, by networking both in the region and in Europe and by promoting the centre through specially prepared web site, brochures and workshops and better presence at international conferences and in journals.

All aspects of improved visibility in the whole project reporting period have been documented on a number of occasions. Most importantly we have taken our role to define standards in the region and we connected our COE with other centres in the region supporting their attempts to establish their presence in the field. Two students from Bosnia and from Former Yugoslav Republic Macedonia have been taken in the program, both supported by COE to some degree. A Croatian scientist dr Eva Kovacevic (temporarily residing in France for a postdoctoral appointment) has been invited and visited laboratory giving seminars, while our collaboration with her has been proceeding over a much longer period.

- To improve the local visibility of our Centre and raise the awareness of the local industry and investors about the facilities available for the applied research. To provide an expertise for possible developments associated with modern electronic devices, nanotechnologies based on application of nonequilibrium plasmas. In the third reporting period we mainly focused on establishing connections with medical profession promoting biomedical applications while we also made contribution to the national board on nanotechnologies and new materials.

- To promote cooperative research with leading laboratories in Europe by supporting joint experiments. This is also in favour of optimal usage of the equipment and offering of joint services to both industry and funding agencies.

- In the last project period funds were used to provide visits of scientists or our visits to the centres that have the expertise in using the equipment or taking advantage of the equipment that was purchased in the COE (NIBEC and Queens University Belfast, Ruhr University Bochum, ...). We also worked with the experts from Hidden in establishing optimal operation of their system (purchased partly

through this project). Several groups have requested measurements by using our system (Czech Republic, Ruhr University, Serbia, ...) and more requests will be realized in near future.

One major proposal was prepared for EU funding by our group in the third reporting period and several including our group. Unfortunately so far there were no successful applications. We however were successful in securing a DAAD and several bilateral projects (Slovenia, France, Bulgaria, Hungary) that will serve as the basis for further preparations of proposals to EU. Also we have been involved in BSEC (Black See Economic Cooperation ) project (Bulgaria, Romania, Greece…) and ACCENT FP6 Network.

- An underlying main objective of the programme was to achieve the level of equipment, experience in preparation and organization of projects, ability to address more topical research required, visibility and general experience in order to be able to be a participant in future European Union projects. The programme will provide means to connect to and be a credible partner in future FP7 and other EU actions.

- Since XRF is nowadays the most preferred method to study cultural heritage (CH) items (to aid in the restoration, learn about original fabrication processes, determine the authenticity of the objects, investigate the negative effects of environmental pollution, etc.) we tried to take advantage of the new equipment to become a centre for protection of CH as well. Using the XRF technology, Centre supported and promoted the activities in the field of protection of cultural heritage and established new links with other similar scientific Centres in Europe.

  Proposal was made and accepted by the national ministry of science to fund these activities.

- In summary, the overall goal of the project was to become accepted as a Centre of Excellence (COE) nationally and internationally with an aid of additional

equipment, increased mobility and networking and improved dissemination. The results should facilitate integration into European projects and to be approved as the regional centre for pollution control.

## SUMMARISE THE OBJECTIVES FOR THE FINAL PERIOD, WORK PERFORMED, CONTRACTORS INVOLVED AND THE MAIN ACHIEVEMENTS IN THE PERIOD

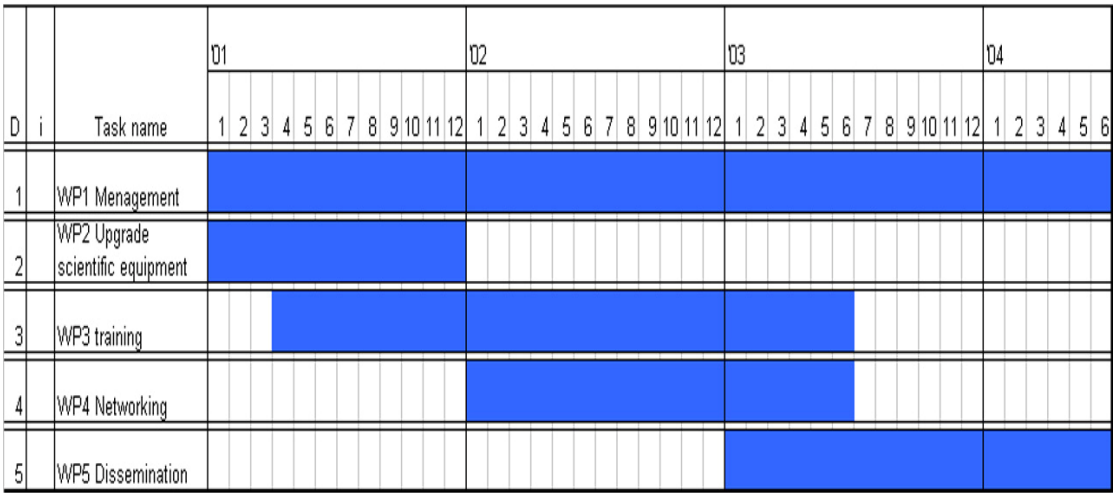
The project goals are defined through its objectives which include:

- Organization and maintaining of the Centre of Excellence, its management and its facilities;
- Recruitment, employment and training of young scientists and their involvement in research and exchange with our European collaborators;
- Initiation and continuation of networking and dissemination programs with an aim to improve the visibility of the group, its connection with other centers in Europe and beyond and the recognition of its achievements
- Continued work on improvement of the standards of research and collaboration in the region in the relevant fields of science
- Focusing the research towards achieving a maximum impact in local community, region and in general.

## WORK PLANNING AND TIMETABLE

Time development of the project was simple. Management activities were extended over the whole period of the project.

Management initiated upgrade of equipment by purchasing two experimental devices. At the same time the training commenced and after some time Networking and Dissemination activities were initiated. Training and networking lasted until the middle of the third year while dissemination extended to the end. Temporal development of the project is given in the Gant graph below.



**Workpackage list (full duration of project)**

| Work-package No[1] | Workpackage title | Lead contractor No[2] | Person-months[3] | Start month[4] | End month[5] | Deliv-erable No[6] |
|---|---|---|---|---|---|---|
| WP 1 | Management | 1 | 15 | 1 | 42 | D3, D2, D9 |
| WP 2 | Upgrade of scientific equipment | 1 | 3 | 1 | 12 | D1, D4 |
| WP 3 | Training | 1 | 78 | 4 | 30 | D6 |
| WP 4 | Networking | 1 | 10 | 12 | 30 | D7 |
| WP 5 | Dissemination | 1 | 7 | 24 | 42 | D5, D8 |
| | TOTAL | | 113 | | | |

## Deliverables list (full duration of SSA)

| Del. no. [7] | Deliverable name | WP no. | Lead particip-ant | Estimated person-months | Natures [8] | Dissemination level [9] | Delivery date [10] (proj. month) |
|---|---|---|---|---|---|---|---|
| D1 | Tender documentation | WP 2 | 1 | 1 | O | PU | M4 |
| D2 | Web site | WP 1 | 1 | 3 | O | PU | M3 |
| D3 | Project progress intermediate reports | WP 1 | 1 | 8 | R | RE | M6,M12, M18,M24 |
| D4 | Upgrade of scientific equipment and installation | WP 2 | 1 | 2 | O | PU | M12 |
| D5 | Dissemination workshop | WP5 | 1 | 3 | O | PU | M9,M35 |
| D6 | Employment of young researchers | WP 3 | 1 | 78 | O | PU | M12 |
| D7 | Electronic Newsletter | WP 4 | 1 | 10 | R | PU | M18 |
| D8 | Plasma modelling database | WP 5 | 1 | 4 | R | PU | M30 |
| D9 | Final project reports | WP 1 | 1 | 4 | R | PU | M42 |
| TOTAL | | | | 113 | | | |

**I**n the whole reporting period, Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research**,** realized the following:

- Continued operation of the steering and advisory committee and of the management;

- Purchase and completion of the upgrade of the equipment, its integration with the experimental systems and opening of new lines of research;

- Equipment installation, integration in our research programmes and application in new lines of scientific research;

- Completion of new equipment related to the monitoring of volatile organic compounds (VOCs) in open and indoor environment and starting with the application in medicine and biological research.

- Organization of two workshops and an international symposium in Serbia which support programs of training dissemination and networking, finalization of three proceedings books from the workshops and symposium carried out during the project, organization of two workshops as the official part of two major international conferences (ICPIG in Mexico and GEC in USA), which supports programs of training, dissemination and networking

- Continued improvement of chances of employment and scientific career for young students, was supported by selecting topical research and by enabling all of the engaged students full experience in scientific research including attending conferences and giving presentations, one of the students even gave an invited lecture at an international conference (satellite of ICPEAC- International symposium on electron molecule scattering and swarms- Toronto, Canada) in the third reporting period;

- Employment and training of young researchers; the initial recruitment was extended by a group of four students finalizing their BSc theses and that joined the project in near future; three of them even defended Master's theses

- Web design, maintenance and upgrading

- Development of the data base presented on the web site, special focus in this period was to complete the data base for electrons in $N_2O$, and positrons in gases. Some of

- Preparation and mailing of an electronic newsletter
- Increased visibility and efficient dissemination are shown by publication of a large number of scientific papers in international journals, presentation of papers at international conferences and their publication in proceedings of conferences or books, presentation f a large number of invited lectures, by a membership in two editorial boards, on half a dozen international scientific committees of major conferences and by a large number of citations (in excess of 400 per year).in the third reporting period
- Members of the COE have been awarded by several awards and acknowledgements.
- Organization of periodic meetings
- Preparation of periodical reports, studies, analysis, exchange of experience
- Communication activities with EU commission and other experts group;
- Initiation of networking, training and dissemination programs
- Preparation of new proposals for EU and other sources
- Cooperation with other competitive scientific centres
- Overseeing science and society issues related to the research activities conducted within the project; and
- Promotion of gender equality in the project.

**Project objectives and major achievements during the whole period**

- **1. Organization of the Centre of Excellence, its management and its facilities;**

The relevant committees for most workpackages (other than upgrading of equipment) were formed, management board and Steering advisory committee operated through regular meetings. Then the duties were given to define the network of activities and connections. Focal point for some of our workpackages was the web site that was maintained and expanded to support dissemination by adding the data base (see http://www.ipb.ac.rs/~cep/ipb-cnp/). Steps were made to achieve a visual identity of the COE.

- The core of the management were the three project leaders one in charge of the overall project and two of each of its parts, of project secretary and of people in charge of specific tasks, such as web site development, workshop organization, etc. Active collaboration was achieved between all segments of the project and the life of the COE as a whole was achieved. This was best seen in joint proposals of projects along the new lines of research such as biomedical studies of breath by proton transfer mass spectrometer and its applications in biology.

- **Recruitment, employment and training of young scientists and their involvement in research and exchange with our European collaborators;**

Continuous training of the first group of selected students was organized, exchange consisted of a visit of two students to our laboratory (and two summer exchange undergraduate students) and through sending three of our students to a summer school for postgraduates in the field of plasma physics in Bad Honeff and of sending one member with a PhD diploma to a laboratory in Belgium. Another group of 5 students

have chosen to do their BSc theses with the group and with the perspective of continuing their work within our COE taking advantage of some of the funds and programs of the COE.

### 3. Initiation of networking and dissemination programs with an aim to improve the visibility of the group, its connection with other centres in Europe and beyond and the recognition of its achievements

Networking and dissemination packages were initiated by starting the exchange, organizing workshops and visits of specialists from around the world. In particular we had joint actively pursued research with: University of Bochum, Germany, University of Ulster Belfast UK, researchers from University of Aaehus Denmark, Polytechnical University in Lisboa Portugal, Ecole Polytechnique Paris France, University of Brno Czech Republic, Bulgarian academy of science Sofia Bulgaria, Institute of Solid State Physics Hungarian Academy of science Budapest, Hungary, Joint Institute for Nuclear Research, Dubna, Russia, Department of Chemistry of the Norwegian University of Science and Technology, Trotheim, Norwey and Institute of Botany-BAS, Bulgaria.

Newsletter was sent to numerous laboratories in the region and numerous project proposals were made together with groups mainly from EU. We have also participated in sharing facilities were for the first time some of the EU groups wanted to make measurements at our system.

Two workshops and symposium were organized in August 2006, March 2007, and August 2008 and published books of proceedings with selected review articles and progress reports were published in hard copies and available on line. We also participated in organization of two specialized workshops sessions at major conferences in 2009 (ICPIG and GEC).

Database was activated presenting some of our results.

- **4. Improvement of the standards of research and collaboration in the region in the relevant fields of science**

The project was devoted to maintaining highest international standards in the field for the quality of PhD thesis, courses, presentation of results and especially in addressing the gender issues. We have successfully demonstrated that in all periods of our activity on the project.

- **5. Focusing the research towards achieving a maximum impact in local community, region and in general.**

Several aspects of making an impact were considered especially having in mind the need of the region. We have mainly worked on expanding applications of our studies in: preservation of archaeological finds, establishing biomedical applications of plasmas, application of plasmas for functionalization of textiles to improve its properties and adhesion of nanoparticles with bactericidal properties.

## MAIN PROBLEMS AND ACTIONS TAKEN

Main problems in the whole project period were:

- Lack of laboratory space and inadequate offices

The main problem in this respect is inadequate office space. Although some laboratories were upgraded during the project period more laboratory space is needed.

- Changing regulations

Most important aspect of this was the changing regulations in attaching students to our regular projects. We have resolved this problem so far but unstable conditions in realization of projects threatened our regular and our EU projects.

- Inconsistency between some of the regulations of the EU commission projects and local regulations and customs.

- Due to economic crisis our regular funding was significantly reduced and even the reduced funding was considerably delayed.

  In the third year of project there was the need to support some of the activities of the COE by the regular funding and await final payment of those funds after completion of the project. Unfortunately due to reduced income of the government our support for expenses was reduced considerably (approximately by 30%) and even those funds were delayed. Thus in the third year the funds received from the government did not suffice to cover the 10% of the COE funding and one could not devote a large percentage of these funds to programs of the COE. This was circumvented by applying for extension and focusing all the available funds to the programs of the COE. This may have led to some degree to disagreement with specific allocations by our government but we have been finally able to cover the required activities of the COE. Unfortunately the decrease and delay of regular funding coupled with the need to complete 10% of the COE activities while awaiting the remainder of the funds meant that we could not couple the COE and our regular funds in a way we did the first two years to achieve synergism and get more than merely the sum of two projects. We had, however some success in converting the initially funded students to some of the applied projects of Ministry of science and thereby increasing the number of students that could be taken in and take advantage of the COE beyond the sum of our basic government funding and the COE funding.

# SECTION 2

# WORKPACKAGE PROGRESS

The workpackage on project management will be reported in full in section 3. Here we provide the reports on deliverables associated with management such as web page establishment (Deliverable 2)

According to our plan, we predicted activities in the WP1, to last throughout the project, WP2 to be finalized in the first year, WP3, and WP4 to be completed by the middle of the third year, while the work on WP5 i.e. Dissemination to commence in the third year. In reality WP1 lasted as planned throughout the whole project, some aspects of WP2 extended beyond the first year especially since additional equipment was purchased and integration was required, WP3 and WP4 started earlier and lasted till the end of the project while WP5 started earlier.

This was all dictated by the new opportunities and changing circumstances, in most cases it led to synergism with other sources of funding leading to better overall results than planned. Taking advantage of new opportunities and even opening them was the task for the management of the project.

# WP1 – MANAGEMENT

## OBJECTIVES OF THE MANAGEMENT WORKPACKAGE

- Coordination of the overall technical, financial and administrative management
- Coordination of knowledge management
- Maintenance of the consortium agreement
- Information and communication activities, communication with EU commission
- Satisfaction of legal norms and procedures
- Responsibility for facilities required to carry out the project in its entirety-resource management
- Efficient decision making
- Horizontal and vertical integration of the project
- Adhering to time scale-time management
- Adjusting the activities to maximize the impact for the group, country and in general.

## DESCRIPTION OF WORK

### Meeting of the Management Board

Meetings of **Management Board** of Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research (IPB-CNP) were regularly organized two times a year. Members of the Board, Zoran Petrovic (chairperson-program coordinator), Gordana Malovic (co-chair) and Mirjana Tasic (co-chair) considered plans, actions, available funds and time tables. Continuous meetings were held on several occasions during the whole reporting period dealing with the extension of the project, preparation of the financial and activities report and dealing with inadequate basic funding.

**Steering-advisory committee** consisted of our EU partners:

- Prof. Dr. **R. Van Grieken**, *University of Antwerp (Campus Drie Eiken), Dept. of Chemistry (Room B.2.07), Universiteitsplein, 1, B-2610 Antwerpen, Belgium*- leading expert in microanalysis of particles suspended in the air and their impact on human health and environment in general; Velibor Novakovic from our COE has been a postdoctoral fellow with Prof Van Grieken for a year and a half

- Prof. **PD Maguire** (group leader) and Dr. **CMO Mahony**, *Plasmas & Nanofabrication Group, Nanotechnology Research Institute, University of Ulster at Jordanstown, Newtownabbey Co Antrim, BT37 0QB, Northern Ireland United Kingdom*-are renown experts in nanotube deposition in rf plasmas, their optimisation and diagnostics. Visited Belgrade and were visited by two members of the COE on two occasions.

- Prof. Dr. rer. nat. **Achim von Keudell**, *Arbeitsgruppe, Reaktive Plasmen', NB 5 / 125,Institut für Experimentalphysik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany*-is a leading expert in carbon and diamond like thin film deposition, production and control of nanoparticles in reactive plasmas. Visited our centre and participated in the workshop,

- Dr. **Zoltan Donko**, *Research Institute for Solid State Physics and Optics, Budapest, P.O. Box 49, H-1525 HUNGARY*-is a leading expert both in the world and in the region adjacent to West Balkans in plasma modeling, secondary electron yields through ion surface collisions and gas lasers. Participated in the workshop and continued collaboration on plasma modelling.

- Dr. **Timo Gans**, *Queens University Belfast,* Queen's *University Belfast 2007, University Road Belfast, BT7 1NN, Northern Ireland, UK*, a leading expert in laser spectroscopy, mass-energy analysis of plasmas and atmospheric and processing plasmas. Visited our centre on several occasions, participated in the workshop, continued to support our activation of dye laser facility

- Dr.**Vasco Guerra**, *Centro de Fisica de Plasmas, Instituto Superior Tecnico, 1049-001 Lisboa, PORTUGAL*-is a renown experet in plasma modeling, microwave plasmas, transport in air.

- Prof. Dr hab. **Grzegorz Karwasz**, *Institute of Physics, Pomeranian Pedagogical Academy, 76200 SLUPSK, Arciszewskiego 22b*-is a leading expert in atomic and molecular collision and transport databases for plasma applications.

- Dr. **Adolf Jesih** *Institut Jožef Štefan, Ljubljana Slovenija*-is a renown expert and one of leaders in the region adjacent to West Balkans in plasma polymerization, nanostructuring and growth of nanotubes. Exchange involving joint project and several visits from Belgrade. Unfortunately optimal time for hsi visit to COE could not be found.

- Dr.**Ilija Stefanovic**, *Institut für Experimentalphysik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany*-is an expert on dusty plasmas and gas discharges and breakdown. Continued exchange, numerous viisits and preparation of several joint papers and DAAD proposal and proposal for funding of the Laboratory at the Ruhr University in Bochum.

It provided guidance, recommendations and members contributed individually to the training and networking through joint projects. Members were contacted and met individually. Separate special issues concerning project were discussed with the members of the advisory committee.

**Improvement of facilities and upgrade of equipment**

Laboratories and all facilities were reconstructed and upgraded with the additional funds. The management board organized training for the new equipment and integration to the existing equipment and experimental setups. The presently purchased equipment was integrated with the equipment purchased on the basis of the funds from the other sources. All of those activities started during the first year and continued through the second and the third year of the project.

**Training of young scientists**

The management board selected five young scientists which were employed partially through the project and commenced efforts to provide funding for them to remain employed by the Institute after the finalization of this project.

The management organized participation of young scientists in conferences, in a training summer school of German Physical society, Joint Institute for Nuclear Research, Dubna, Russia, Department of Chemistry of the Norwegian University of Science and

Technology, Trotheim, Norway and organized continuous training at the Institute of Physics Belgrade.

We had also lectures by a series of foreign visitors: **Casten Makochekanwa** from ARC Centre for Antimatter-Matter Studies, The Australian National University, Canberra, Australia, **Bill Graham** from Queen's University Belfast, **Eva Kovacevic** Croatia-presently at GREMI, Universite d`Orleans, Polytech `Orleans, Orleans, France, **Robert Robson** from ARC Centre for Antimatter-Matter Studies, School of Mathematics, Physics and Information Technology, James Cook University, Townsville, Australia, **Ronald White** from ARC Centre for Antimatter-Matter Studies, School of Mathematics, Physics and Information Technology, James Cook University, Townsville, Australia, **Eiliv Steinnes** from Department of Chemistry of the Norwegian University of Science and Technology, Norway, and **Paul Maguire** from University of Ulster, Jordanstown and **Stephen J. Buckman**, Centre for Antimatter-Matter Studies, Australian National University, **Hamal Varambhia** University College London UK, **Kinga Kutasi**, Institute of Solid State Physics, Hungarian Acadmey of Science, Budapest, **Joan Marler**, University of Aarhus Denmark and many more.

Z.Lj. Petrovic held a series of lectures to postgraduate students of the Ruhr University in Bochum Germany and held a course Plasma technologies at the Faculty of Electrical Engineering University of Belgrade (in the second course he was aided by Dr M. Radmilovic).

**Other activities**

The management board initiated all supporting actions as well.

Plan was made for training, networking and dissemination. Measures were made that funding and time and human resources were appropriately assigned to ensure maximum possible success of the programs.

Management followed all sources of information on possible new projects and initiated applying to them if it was appropriated and in the best interest of the COE. The proposals will be listed later.

The board initiated preparation of the reports, intermediate report after six months and for the periodic activity and management reports.
All periodic reports were completed and at the same time transition to the operation in the second and third year (focused more on the workpackages other than upgrade of equipment) has been completed. Unfortunately delay in obtaining the rest of the funds has postponed some of the planned activities.

Dissemination, networking and training programs have been organized.

The management has considered impact of the project seriously. While the standard plan to maximize impact in education of the young scientists, in improvement of facilities for researchers living in West Balkans and in facilitating resolution of gender issues are still in focus, we have decided to broaden the scope of the project to include studies of positrons and breath analysis with biomedical applications in mind. This was made possible partly by the newly purchased equipment and partly by the available students who could work on these projects. Thus we have organized local networking with medical experts and with biologists and several proposals for joint research were prepared.

The management board also communicated with the EU commission.

**8.02.2008. Mr. Armand Beuf**, Scientific Officer of FP6 Project, visited Centre for Non Equlibrium Processes.

**Mr. Armand Beu**f, Scientific Officer of FP6 Project, visited Centre for Non Equlibrium Processes for the second time on 24.09.2009.

## CONCLUSION

1. Regular seminars and group meetings have been organized. The seminars were mainly presented by students participating in the program as a part of their training.

2. Two workshops (First and Second International workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment) with participation of more than 60 invited speakers from EU, USA and Australia were organized in August 2006, and August 2008 and published books of proceedings with selected review articles and progress reports were published in hard copies and available on line. The 5$^{th}$ EU-Japan Joint Symposium on Plasma Processing was organized in March 2007, proceedings with invited lectures was published in hard copy and available on line. We also participated in organization of two specialized workshop sessions at major conferences in 2009 (ICPIG and GEC).

3. First, second and third year reports were completed and the intermediate reports were presented as newsletters.

4. Communication with the EU commission has been maintained at the required level.

5. Reduced amount and delayed funding by the local government has been remedied by organizing a request for extension of the project and related communication with the Commission.

6. Web site has been continuously updated. Web site was set up including all the relevant data about the project. The site was extended in the third year to

include data dissemination and more modern means of communication with possible users. Inclusion of the data for the databases has continued; mainly the data for electrons following the earlier updates for positrons and negative ions.

7. Networking, training and dissemination programs have been organized

8. Based on the experiences from the present project further applications for EU funding calls have been prepared and submitted. Most were based on the networking and dissemination activities associated with this project. Several regional projects and EU funded projects are carried out with participation of some of the members of COE centre such as: ACCENT, ASSOCIATE NETWORK of EXCELENCE for *Atmospheric Composition Change* in the framework of the specific European research and technological development programme and A BSEC (Black Sea Economic Cooperation) project 'Revitalization of urban ecosystems through vascular plants: assessment of technogenic pollution impact' with the participation of the research institutions from Bulgaria, Greece, Romania, Russia, and Turkey.

9. Gender equality has been promoted by organizing the project in such a way to allow women to pursue their scientific careers without sacrificing their families This aspect of the project was monitored by the management.

10. Initiation of the newsletter and its distribution were organized by the management. Nevena Puac, Saša Dujko and Nikola Škoro were responsible for this activity.

11. Impact of our research and of the project was considered and some of the goals were modified to increase possible applications in biomedicine and introduction of modern diagnostic techniques and methods for their analysis in our region.


**Project no.026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 2 Web Site

Due date of deliverable: 1.10.2006
Actual submission Date: Continuously update throughout the project

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

# DELIVERABLE 2

## WEB SITE

### INTRODUCTION

A web page was developed as a means of communicating with our colleagues around the world and as a means of disseminating our results. This is one of the requirements of the project.

The web site was constantly upgraded as a part of the project and it was constantly expanded to accommodate the objectives of the programs. Most importantly the entry of the data for the database has begun in a serious and systematic fashion in the second year. This has continued in the third year but was slowed down by our obligation to wait for final publication of the related work before the results have been publicized on the web site.

The web page was edited and started by by Dr. Nevena Puač and Nikola Škoro and Sasa Dujko joined in the meanwhile.

While the original web presentation of groups contained some of the information its main goal was to provide introduction to the group and addresses for communications. The goals of the new web site (of the COE) go beyond that and the web site is seen as a portal for active communication and exchanges of information, as a means to carry out different activities of the COE. Tthe specific goals of the site are:

1. To provide a unified site for presenting results of the project
2. To provide means of communication with colleagues
3. To provide means of dissemination of our results

4. To increase the visibility of the Laboratory and COE

5. To provide means of distributing data and other services

6. To provide means for networking and exchanging information required for further project applications.

The design of the page incorporates the symbols that were developed already for the project and provides thus a coherent- unifying visual background. The symbols are used for all publications giving an easily recognizable trademark of the COE.

A comment: The experience with the web page so far where every participant entered her/his references while separate lists were entered for reports and proposals led to a degree of dissatisfaction and to maintain handling of the results of scientific endeavour we are preparing handling of the lists of references (for each participant, all participants, project and selected proposals) through a database of papers entered once and in a unified manner. While this activity was initiated during the project from its experience, the completion, with inclusion of all the data and implementation is expected in 6-9 months. In other words the project will continue its life with our basic and hopefully with supplemental funding.

The address of the site is:

http://mail.ipb.ac.rs/~cep/ipb-cnp/

**CONCLUSION**

1. Web site has been started for the COE as a whole, for its activities and it has been updated continuously.

2. Web site was set up including all the relevant data about the project to facilitate training and networking.

3. The site was extended in the second/third year to include data dissemination and more modern means of communication with possible users.


**Project no. 026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 3 Project progress intermediate report

Due date of deliverable: 10.01.2008
Actual submission Date: 10.01.2008

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

# DELIVERABLE 3

## PROJECT PROGRESS INTERMEDIATE REPORTS

### GENERAL

The 6 months reports consisted of the elements required for the annual report that is submitted to the EU offices. Each 6 month report was prepared as two newsletters giving details about the project during 3 months. The intermediate reports as newsletters were posted at the web site:

http://mail.ipb.ac.rs/~cep/ipb-cnp/Dokumenti/Intermediate%20activity%20report%20IPB%20CNP%20026328.pdf

Some of the elements like the list of publications are cumulative for the whole project starting from the 1st of July 2006. Management board have been meeting every 6 months from the start of the project and considered all the available documents and status of the project. Those were collected as a 6 month semi-annual report which grew later on to the present report as some of the activities went on continuously.

CENTER FOR
NON-EQUILIBRIUM
PROCESSES
INSTITUTE OF PHYSICS
BELGRADE

**Project no. 026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 9 Final project report

Due date of deliverable: 10.01.2010
Actual submission Date: 10.02.2010

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

# DELIVERABLE 9

## FINAL PROJECT REPORT

### GENERAL

Management acitivities included the writing of the present final project report. This report includes the description of all activities of the Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research in the period from 1.07.2006 up to 31.12.2009 predicted by our proposal.

# WP2 – UPGRADE OF SCIENTIFIC EQUIPMENT

WP2 - upgrade of scientific equipment started from the beginning of the project and lasted 12 months.

### OBJECTIVES OF THE UPGRADE WORKPACKAGE:

- Reinforcing the research capacities
- Decision making, tender announcement, announcement and equipment purchase
- Equipment installation and application in scientific research
- Optimal usage of the equipment

One of the major goals of the project was to provide means for reinforcement of the research capacities, which required decision making organized by the management and with the input from the advisory committee.

The decision to apply for funds required previous selecting the type of equipment, the specification of exact model, accompanying equipment cables, optional equipment etc. As similar devices could be found from different manufacturers and as they are highly specific and complex devices which may show quite different performance under different conditions, the choice was critical for the success of the mission as wrong purchase could delay the implementation of the equipment. According to the local regulations all purchase of the order of those that were requested, required forming of a tender committee and purchase through publicly announced competition so we had to comply with that. A lot of effort has been involved in setting up the tender committee and documentation, in choosing the equipment and in organizing the purchase.

According to plan and time table, the purchase of equipment was finished within the first 12 months. Purchase was organized with the agencies that gave the best offer. After the shipment, the equipment was installed, and integrated with the existing facilities.

It was the duty of the management to provide environment to facilitate the installation of the equipment and its use in the ongoing experiments. It was also the duty of the project to provide connections to other facilities in the Institute of Physics, and the other institutions in the country and in the region that would enable optimum usage and integration of the equipment with other projects, its maintenance and connection to the existing equipment.


**Project no. 026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 4 Upgrade of scientific equipment

Due date of deliverable: 1.07.2007
Actual submission Date: 1.07.2007

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

## REINFORCING THE RESEARCH CAPACITY- PURCHASE OF EQUIPMENT- PURCHASE OF ENERGY DISPERSIVE EDXRF SPECTROMETER, ITS CHARACTERISTICS AND ROLE IN THE PRESENT SETUP AND SOME APPLICATIONS

One of the objectives of the environmental research within this proposed project was to improve the level of scientific and technology research by the use of energy dispersive X-ray fluorescence technology (EDXRF).

Energy dispersive X-ray fluorescence (EDXRF) spectrometry is one of the simplest, most accurate and most economic analytical methods for the determination of the chemical composition of many types of materials. It performs non-destructive and reliable analysis from sodium to uranium, in concentrations down to ppm (parts per million) levels, requires no, or very little, sample preparation and is suitable for solid, liquid and powdered samples.
The first step was the identification of the most convenient energy-dispersive X-ray fluorescence (EDXRF) spectrometer with the characteristics related to the proposed goals. The system intended to analyze suspended PM10 and PM2.5 atmospheric particles deposited on filters have to be a compact, inexpensive, microprocessor controlled, table-top spectrometer, with a very simple sample preparation and designed for elemental analysis of a wide range of samples so it could be used for many purposes. Elements from Na to U, in a concentration range from 100% down to trace level, are to be measured in air or in helium. Because the samples do not have to be digested, a very quick analysis is possible. The risks of contamination or loss of elements have to be minimized. In addition to the main components of the aerosol, heavy metals relevant for ecology and toxicology have to be analyzed and their sources determined. This allows the sources to be determined for imission measurements and a source profile to be recorded for emission measurements.

Among the best manufacturers of EDXRF equipment such as Philips Analytical (Netherlands), SPECTRO Gmbh (Germany), NITON (US) we decided to purchase energy dispersive spectrometer (EDXRF) MiniPal4 with characteristics that satisfied our needs.

PANalytical (Netherland) is the world's leading supplier of analytical instrumentation and software for X-ray diffraction (XRD) and X-ray fluorescence spectrometry (XRF).

The proposed XRF system consisted of a sample chamber, x-ray excitation and x-ray detection subsystems and an x-ray filter wheel with filters of different composition. The detector is a Si-PIN detector of 6 mm2 (FWHM for Mn K² at 5.9 keV: 255 eV), cooled by thermoelectric means to about _18 °C. The spectrum can be accumulated in a 2048-channel analyzer. A helium system is fitted as standard in the spectrometer. Measurements are normally carried out in air, while helium is required for the determination of elements with low atomic numbers, such as Na and Mg. The usual measurement settings were used: HV, 30 kV; current, 0.3 mA; and counting time, 1000 s (for standard samples and blank filters) and 10 000 s (for aerosol samples). The automated EDXRF system is always coupled with a PC that controls the spectrometer and the data acquisition.

Tender announcement has been done on purchase of best suited equipment, Energy dispersive X-ray fluorescence MiniPal4 spectrometer was installed in the Clean room Class 100 in the Centre for Nonequilibrium processes.

**Testing of the equipment**

1. **Testing of the MiniPal4 XRF analyzer was completed according to previously defined tasks:**

1.1 *The investigation of the different filter materials*

The investigation of the different filter materials (membrane filters, i.e., surface filters made of PTFE, polycarbonate, or cellulose nitrate) that are usually used for the short-term and small air volumes sample collection was done and the best were chosen.

*1.2 Calibration*

The calibration was based on a direct correlation between the counting rate and the concentration. In order to determine the specific sensitivity for the various elements, a series of thin-film reference standards have to be used. The purchase of some reference standards is in progress. At the moment, secondary standards are being used. The measurements were performed in air and in helium medium. The resulting sensitivity coefficients as a function of the atomic number have to be determined.

*1.3 Determination of detection limits*

In general the values obtained by EDXRF spectrometers were in the range from 400 ng cm_2 (Si) to 3 ng cm_2 (heavy metals).

*1.4 Reproducibility*

To test reproducibility of the measurements, one of the calibration samples have to be measured 10 times. From repeated measurements of the standard reference samples, the relative standard deviation (RSD) will be calculated and the precision of analysis have to better than 1% for high-Z elements and about 5% for Al and Si.

*1.5 Measurements*

*1.5.1 Environmental*

MiniPal4 EDXRF spectrometer, equipped with a rhodium anode tube, 5 tube filters, a helium purge facility, a high resolution Silicon Drift Detector and a 12-position removable sample changer with sample spinner was applied to the chemical analysis of suspended particulate matter in air, now of much interest in view of global climate change and health effects. Particulate matter PM10 (D<10 micrometers) and PM2.5 (D<2.5 micrometers) were episodically monitored in the Belgrade urban air and analyzed for trace elements content.

PM10 and PM2.5 are today a key issue in contemporary air pollution research. PM10 and PM2.5 samples from the urban air of Belgrade were taken in four season's episodes, from three sites and were collected on Pure Teflon and Teflon-coated Quart filters using MiniVol air samplers (Airmetrics Co. Inc., 5 l/min flow rate) provided with PM10 and PM2.5 cutoff inlets. Mass concentrations were determined and compared to the common meteorological parameters such as temperature, humidity, wind speed and direction etc. and the correlations among them were determined. Physical characterization of atmospheric particles has been performed by optical and scanning electron microscope. The elemental composition (Al, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, and Pb) of the aerosol samples was determined by XRF spectrometer. The mass concentrations and heavy metal contents in PM10 and PM2.5 in Belgrade urban area have been compared to those from other European cities as well as to the EU Directive 99/30. Multivariate receptor modeling (PCA, PMF, UNMIX) and air back trajectories analysis were used to identify the main sources. From the statistical properties of air pollutants the level of reduction of particle matter emission sources required to meet the AQS can be estimated. These results may be useful for developing air control strategy in future years. A standard operating procedure for the XRF analysis of aerosols on filters is recommended by the US Environmental Protection Agency and was applied in our measurements.

Street dust and nearby surface soil samples from selected locations in Belgrade were analysed for elements of environmental importance with MiniPal4 EDXRF spectrometer as well. Average concentrations values of the elements indicative for traffic emission, determined in soil samples alongside roads, exceeded the concentrations in road dusts, as a result of long term accumulation.

### *1.5.2 Cultural Heritage Protection*

XRS is nowadays the most preferred method to study cultural heritage (CH) items (to aid in the restoration, learn about original fabrication processes, determine the

authenticity of the objects, investigate the negative effects of environmental pollution, etc.). Atmospheric particulate matter significantly affects the state of conservation of various cultural heritage resources. Aerosols may deposit on surfaces exposed to both outdoor and indoor (e.g. museums) environments. The particles soil these surfaces and most of them contain chemical compounds (or these compounds may be formed after deposition) that react directly or indirectly with various materials (e.g., stone, stained glass, bronze).

MiniPal 4 EDXRF spectrometer was applied for the specific purpose of compositional analysis of archaeological artifacts such as ceramics, metal and glass samples of different periods and origins in Serbia. Using the XRF technology, Centre supports and promotes the activities in the field of protection of cultural heritage and established new links with other similar scientific Centers in Europe.

*1.6 Intercomparison*

We have been invited to participate in the Proficiency Test Exercise for X-Ray Fluorescence Laboratoires „Grass Mixture" organized by the International Atomic Energy Agency, Wien, Austria and we took part. The exercise was conducted by X-Ray Fluorescence Group/Instrumentation Unit, the IAEA Laboratories, Seibersdorf, Austria between April 2009 – December 2009. The test was carried out in accordance with the rules presented in the ISO/IEC 17043:2008 entitled „Conformity assessment – General requirmenets for proficiencey testing". Natural Grass Mixture was analysed using MiniPal 4 XRF Analyser.

**Conclusion**

- Within the proposed project, energy dispersive X-ray fluorescence technology (EDXRF) equipment, MiniPal 4 bench-top XRF spectrometer was purchased and involved in existing experimental equipment to improve the level of scientific and technology research by the use

- Training of young staff on the new equipment has been completed.
- The first results related to the physical and chemical characterization of suspended particulate matter obtained with the new purchased MiniPal 4 XRF spectrometer were promising not only for environmental research but for some other applications as well.
- New field has been opened having in mind that XRF analysis is non destructive analytical method that could be used in preservation and conservation of cultural heritage by increasing the knowledge of art and archaeological objects through advanced chemical and physical analysis. Together with some other institutions from the country and abroad we have been preparing proposals with the aim to develop and apply contemporary archeometric non-destructive methods in analysis of artifacts of cultural heritage.
- Development and application of archeometric and non destructive methods in the analysis of cultural heritage 2008 - 2009: was the technological project financed by the Ministry of Science and Technological Development of the Republic of Serbia.

**REINFORCING THE RESEARCH CAPACITY- PURCHASE OF EQUIPMENT- PURCHASE OF PLASMA MONITOR, ITS CHARACTERISTICS AND ROLE IN THE PRESENT SETUP AND SOME APPLICATIONS**

At the start of the project the following experimental devices were available:

a) Experimental device for measurement of excitation, ionization and dissociation coefficients, studies of fast neutral generation in plasmas and their interaction with surfaces. The data were needed to establish the cross sections and transport coefficients for plasma etching, plasma propulsion, plasma displays, detectors of elementary particles, sputtering devices, gas lasers and light sources and for applications in atmospheric environment. The experiment has to be modified to represent a source of fast neutrals for charging damage free plasma etching. Etching by

fast ions of dielectric interconnects requires high aspect ratios for nano dimensions. In that case charge is deposited at the bottom and may generate a very large field in the transistor and cause damage. At the same time the field due to field at the bottom of vias (nanotrenches) contact holes there could be etch stop, or aspect ratio dependent etching which were shown (by us) to be due to charging. The present experiment was planned to be modified with a grid to show how fast neutrals are generated at low pressures and high electric fields due to charge transfer and how ions are removed by the grid. Plasma monitor was intended to be used to determine the distribution functions of ions and fast neutrals and analyse the efficiency of the technique of neutralization of the beam and efficiency of surface treatment. Any progress beyond 90 nm technology requires removal of charging damage and in that region pulsed two frequency plasma operation may be sufficient but to venture to real nano technologies one needs fast neutral etching.

b) Capacitively coupled plasma reactors (0.2 m3 and more than 1m3).

Those are extremely asymmetric reactors built in this way to make sure that ion energies hitting the surface are very small allowing the treatment of thermally unstable surfaces such as textile, polymers, seeds. It is of interest to extend the measurements to allow determination of the ion energy distribution and check the scaling under extreme conditions (it will probably not apply) and also the measurement is needed to optimise the performance of the reactor. In addition it is difficult to publish data in renown journals as numerous referees request very elaborate diagnostics to be available before paper is accepted. This reactor may be used for nanostructuring of surfaces and polymerization but it is not optimal for that purpose. c) plasma needle (a device with a very small size plasma and a small degree of gas heating), corona and microwave discharges for treatment of polymers, textile, nanostructuring, treatment of living matter, sterilization. These reactors are reasonably well equipped and have produced a number of good results but there is a need to expand their diagnostics tools (Langmuir probe, energy-mass analysis, laser diagnostics). These reactors cannot benefit from the plasma monitor as they operate at high pressure but it is possible to set up scaled up

models operating at low pressures and test those. d) Pulsed Townsend and glow discharge experiment It is aimed at establishing understanding of the secondary electron emission from surfaces, pseudo spark discharge that may be used as high voltage circuit breaker and dielectric barrier discharge. Application of plasma monitor in this case will be critical to understand the energy dependence of the seecondary electron yield which is the critical parameter in explaining selforganization of the Townsend discharge into constricted glow and oscillations of low current discharges. In addition this experiment is a prototype of sputtering discharges that are used for thin film deposition and under different pressure and composition of gases it is a prototype of plasma displays and many other applied discharges. Plasma monitor will have abroad range of applications here e) We are currently building a pulsed two frequency CCP and/or ICP reactor It will be the used to study deposition of nanotubes, nanostructuring of polymers and high resolution plasma etching. Knowledge of ion identity and energy is critical to explain the processes at the surfaces, plasma chemical reactions and physical sputtering. Thus plasma monitor will be essential for many applications of this system, which would otherwise have les direct explanation. For example the system may be used to establish deposition precursors for growth of nanotubes or polymerization.

According to plan we intended to purchase a vacuum system for reactive gases, new RF generator with a matching box and numerous vacuum equipment. This system has to be put together.

Available diagnostics tools in the laboratory were:

Intensified CCD camera with resolution of 2.5 ns, vacuum systems including vacuum turbomolecular stand for corrosive gases, high voltage sources, rf sources, unique voltage and current probes, monochromators of low and high resolution and diode laser with four different heads for laser absorption spectroscopy in the region from 770 nm to 850 nm. We are planning to develop Langmuir probe or to purchase one and to develop a hairpin probe. In that case perhaps the only missing diagnostics that would be of

great use are plasma monitor and laser induced fluorescence system (this system is even much more expensive than the plasma monitor and it is currently beyond our means.

Characteristics of the plasma monitor

The plasma monitor consists of ionizer, energy selector and mass analyzer in separated chamber that has independent pumping and that has an orifice through which particles from the plasma enter. Differential pumping limits the domain of pressures for plasmas to sub Torr region, though two stage pumping may be performed but with a great loss of signal. The monitor should have as wide range of masses as possible. There are two manufacturers of these systems in the world according to our experience. Hiden and Balzers both from EU. There is difference in energy analyzer and we have to check which limitations are posed by which system. The system should have ionizer or we should develop one for it, to allow it to detect fast neutrals.

## 2. TESTING OF EQP (energy mass analyzer) by HIDEN

The EQP mass/energy analyzer was purchased through the funds from this project and it was extended by an even more expensive system for sampling from the atmospheric pressure. Both systems were integrated in one special unit. As such systems are rare in the world we have done a lot of preliminary testing together with the manufacturer. While many groups have performed tests of absolute callibration of the ion fluxes we have performed tests of the actual performance of the system when connected to real applications. Thus the following problems were found:

2.1 The system is affected by external RF generators. This makes it impossible to apply the system with string 13 MHz power supplies in its vicinity. Problem is due to internal grounding and we are working together with the manufacturer to remedy that.

2.2 When studying atmospheric discharges a more favorable condition for breakdown occurs between the powered electrode and some of the electrodes inside the system. This may be corrected by controlling the voltages at the first elements inside the analyzer but that somewhat limits the range of operation.

2.3 A capacitively coupled discharge is formed between the powered electrode and the grounded surface at the entrance of the mass analyzer. This cannot be corrected by reducing the gap as this observation was made for atmospheric pressure discharges. It may be corrected in most cases, however, by inserting dielectrics and leaving no gap for gas between the powered electrodes and the mass analyzer.

2.4 Signals of both neutrals and ions from atmospheric pressure discharges in the open geometry were very weak and limited to few dominant species. We are now developing enclosures to improve sensitivity for atmospheric pressure discharges.

All of these activities were pursued with the support of Hiden the supplier of equipment. Thus we hope that our suggestions how to solve the problems will be useful for other users of the equipment.

## DESCRIPTION OF WORK

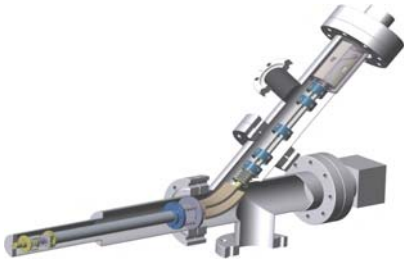
Within the first year of project, according to the plan and time table the scientific equipment upgrade was accomplished.
EQP energy mass analyzer was integrated with three stage pumping system and tested. Under this setup the applicability of the EQP device purchased under the present action has been extended to operate at high and even atmospheric pressures.
Measurements with the standard size plasma needle commenced.

**ADDITIONAL EQUIPMENT**

In the meantime, thanks to our success with this project we have secured additional funding from our government and managed to obtain additional equipment. The two sets were integrated in the past year providing a system with much more power and flexibility. Thus new avenues of research opened and so did new chances to start collaborations. The availability of mass energy analyzer operating at atmospheric pressure created interest in several laboratories to perform measurements in our laboratories thus opening new possible joint projects.

New equipment, Proton Transfer Mass Spectrometer (PTR-MS) (Ionicon Analytik, Innsbruck, Austria) was purchased and fully involved in the activities of the COE.

Today, the available scientific equipment within the Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research involve the following:



**The HIDEN EQP - The Mass/Energy Analyzer for Plasma Diagnostics & Characterization**

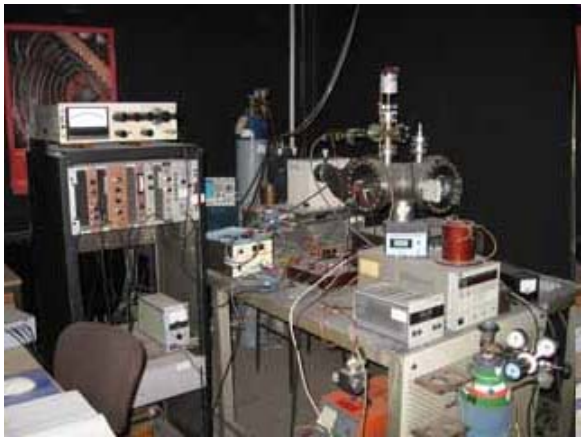
**Energy DispersiveXRF Spectrometer – MINIPAL4**

**Andor iStar ICCD detector(left) and RF CCP generator (right)**

**HIDEN Analytical HPR-60 Molecular Beam Sampling Mass Spectrometer**

**Proton Transfer Reaction Mass Spectrometer (PTR-MS)**

**Pulsed Glow Discharge Experiment**



**Swarm - Excitation Experiment**

# WP3 – TRAINING

## OBJECTIVES OF THE TRAINING WORKPACKAGE

- Studies, analysis, exchange of experience
- Organization of workshops and seminars
- Employment and training of young researchers;
- To improve chances of employment and a scientific career for young students
- Cooperation with other competitive scientific centres
- Training by manufacturer to use newly purchased equipment

### REINFORCING THE RESEARCH CAPACITY- TRAINING

The objectives of this part of the project are equally important as upgrade of equipment. The need to train students to take advantage of the existing and new equipment is essential. It provides better chances for a career in science. The training was planed to be based on our current personnel and reinforced by training missions of our partners. Finally some students got some funds to spend few months in visits to our partners. Training by manufacturer to use the newly purchased equipment was an essential part of this part of the project.

The training program lasted throughout the period of project and the students completed training and were offered permanent positions. Our goal was to have students that will eventually be employed on a semi permanent (our institutes are funded by projects so engagements are confirmed after the beginning of the next project period). Our goal was also to take advantage of the program to improve the

abilities of existing scientific staff and to educate students in other centers dealing with similar subjects of research.

Objective was to organize training in such a way to reinforce our research and technology potentials and improve the research capacities to the highest level. Vigorous training of our students and interested students in the region was organized through courses, practical work and scientific work. These courses were available to the students in the field in the region through the internet or they attended them on the basis of the available local funds. Brief, typically 2 month visits of student members of the team to institutions in EU were funded by the project in order to gain experience with the target experiment and equipment which is considered. Training missions by our partners were organized; they were invited to give series of lectures, seminars and practical guidance. Two workshops and symposium were organized in Serbia and two section workshops were organized as the official part of two major international conferences (ICPIG in Mexico and GEC in USA), which supports programs of training, dissemination and networking. Our results and also useful results of our partners and other researchers in the field were presented there. The workshop proceedings that resulted were used for dissemination of our results but were also useful in training of postgraduate students. The most important part of training was the employment of young students who were engaged for 2 years during the period of the project. This allowed them to take full employment at the Institute upon the completion of the project.

## DESCRIPTION OF WORK

Different types of training were carried during the project.

### 1. CONTINUOUS TRAINING OF THE YOUNG POSTGRADUATE AND UNDERGRADUATE STUDENTS THROUGH COURSES, SEMINARS AND SMALL PROJECTS

For this purpose, weekly seminars were organized at the Institute of Physics which consisted of talks given by senior researchers from the group, educational lectures, seminars by the students, progress reports and guest seminars by specialists from different countries.

The most useful form of student activity were the seminars at which they presented either their work, plans for further work, or selected scientific papers of interest for their project.

### List of Seminars

*December.2009.*

**Sasa Dujko** presented a talk about topics in his PhD work completed in the School of Engineering and Physical Science at James Cook University, Australia. The PhD title is 'The Multi-term Boltzmann Equation Analysis and Monte Carlo Study of Hydrodynamic and Non-Hydrodynamic Charged Particle Swarms'

**Milovan Suvakov** presented a talk about topics in his PhD work completed in Jozef Stefan Institute in Ljubljana, Slovenia. The PhD title is 'Network Models of Self-Assembled Functional Nanomaterials'.

**Marija Radmilovic Radjenovic** presented a talk about vacuum breakdown in RF cavities

*March 2009.*

**Andreja Stojic** PTR Mass Spectrometry-capabillity and applications,

**Marija Radmilovic-Radjenovic**; Determination of the drift velocity

**Sasa Lazovic**. RF disharges

*October 2008*.

**Marija Radmilovic – Radjenovic**: Atmospheric pressure discharges,

**Nikola Skoro**: Applications of microdischarges

**Sasa Lazovic**: Langmuir probes.

*May 2008*.

**Nikola Skoro**: Microdischarges-small gap gas breakdown and properties of dc discharges'

**Sasa Dujko**: Determination of low energy electron-molecule cross sections via swarm analysis.

**Olivera Sasic**: Electron scattering cross sections and transport coefficients in molecular gases and their mixtures.

*April 2008.*

**Vladimir Stojanovic**: Thermalisation of high energetic electrons in the upper atmospheric layers

**Gordana Malovic**: Mass analysis of products of atmospheric pressure discharges.

**Marija Radmilovic Radjenovic**: Mode transition in rf CCP discharges.

*March 2008.*

**Sasa Lazovic**: Diagnostic of atmospheric pressure discharge by mass-energy analyzer Hiden HPR60.

**Branislav Radjenovic**: 3D level set anisotropic etching profile evolution simulations.

**Ana Bankovic**: Transport of positrons in water.

*January 2007.*

**Sasa Dujko**: Monte Carlo research of spatial relaxation of electron swarms

**Ilija Stefanovic**: Dust in Fusion: Causations and Problems of "Tritium Inventory"

*December 2006.*

**Zoran Raspopovic**:Flux and bulk velocities in a model gas.

*November 2006.*

**Sasa Dujko**: Monte Carlo simulation technique of electron transport in magnetized plasma discharges .

**INVITED LECTURES GIVEN BY SCIENTISTS FROM ABROAD**

October 2009: **Casten Makochekanwa** from ARC Centre for Antimatter-Matter Studies, The Australian National University, Canberra, Australia visited COE and presented lecture 'Positron Interactions with Bio-Molecules"

September 2009: **Bill Graham** from Queen's University Belfast visited LGE and participated actively in experimental measurements.

August 2009 **Eva Kovacevic** Croatia- presently at GREMI, Universite d`Orleans, Polytech `Orleans, Orleans, France , "Plasma-polymerized CN nanoparticles"

February 2009: **Bill Graham** from Queen's University Belfast visited our COE and gave lecture 'Electronegative plasmas - the pluses and minuses'.

December.2008: **Robert Robson** from ARC Centre for Antimatter-Matter Studies, School of Mathematics, Physics and Information Technology, James Cook University, Townsville, Australia gave a lecture: Introductory transport theory for charged particles in gases.

**Ronald White** from ARC Centre for Antimatter-Matter Studies, School of Mathematics, Physics and Information Technology, James Cook University, Townsville, Australia presented a lecture: Towards kinetic theory in soft-condensed matter.

October 2008: **Eiliv Steinnes** from Department of Chemistry of the Norwegian University of Science and Technology visited Centre for nonequilibrium processes in October and held an invited lecture "Distribution and fate of metals supplied to Norway by long-range atmospheric transport".

September.2008: **Paul Maguire** from University of Ulster, Jordanstown, visited LGE and held lecture 'Carbon nanotubes for Field Emission and Biosensors and other applications`

March 2008: **Hemal Varambhia** from University College London gave seminar on QUANTEMOL - getting electron molecule scattering cross sections easily.

November 2007: **Joan Marler**, University of Aarhus, Denmark, "When Antimatter attacks..." - High Resolution Positron Scattering from Atoms and Molecules

**Ron White**, James Cook University of Northern Queensland, Townsville Australia, Modern kinetic theory of electron and positron swarms in neutral gases

**Stephen J. Buckman**, Centre for Antimatter-Matter Studies, Australian National University, Low Energy Lepton Interactions - Electron and Positron Driven Processes and Their Applications, Colloqium of the Institute of Physics

November 2006: **Marina Vladimirovna Frontasyeva,** Joint Institute for Nuclear Research, Dubna, Russia, visited Institute and presented lecture:"Atmospheric Deposition Of Trace Elements In Some Selected Countries Of Europe And Asia – Estimations Based On Moss Analysis"


Most of all, visitors to the laboratory were asked to participate in the writing of the monograph, a book with invited lectures from the 1st and 2nd Workshop on Nonequilibrium processes hold in August 2006 and 2008. that also contained more than 30 invited lecturers

In order to facilitate contacts with new generations of students and to broaden the visibility in the future generations we organized a public lecture of Stephen J Buckman "Antimatter, does it matter?" at the science fair (he was one of two key speakers at the fair visited by more than 30000 visitors).

Members of the COE Centre (Milovan Suvakov and Ana Bankovic) took an active role in the Science Festival that was held from 5th to 7th December 2008 and in December 2009 in Belgrade by giving an experimental presentations for curious public from 7 to 77. They were able to come and ask, look, listen, feel, smell… the science. http://www.festivalnauke.org/2008/sr/festival/archive.html

Science Festival hosted more than 30.000 visitors each year in only three days.

In addition, both Ana Bankovic and Milovan Suvakov were active in Petnica research center for young scientists (high school age).

**AWARDS AND ACKNOWLEDGMENTS**

The success of our young staff has been evident through several awards

**Milovan Suvakov**, research assistant, have won "Ljubomir Cirkovic" award for the best MSc thesis for the year 2006.

**Nikola Skoro**, research trainee, have won "Ljubomir Cirkovic" awards for the best BSc thesis for the year 2006.

**Nevena Puac**, PhD, has been awarded the prize for the best PhD thesis in the field of Materials science by the Yucomat (Serbia and Monte Negro materials science society). the award was announced at the meeting in 2007 and presented at the YUCOMAT meeting in 2008.

**Nevena Puac**, PhD, has been awarded a prize by 'Academic Radoslav K. Andjus' Fund for best young researcher science's publication in physiology and biophysics in 2006/2007.

ФОНД
«Академик Радослав К. Анђус»

*за перспективне младе истраживаче у области физиологије и биофизике*

**НАГРАДУ за 2006/7. годину**

додељује

***мр Невени Пуач***

*Председник жирија*

***Проф. др Богдан Ђуричић***

*Београд, 28.12.2007.год*

**Zoran Mijic**, research assistant, has won "Ljubomir Cirkovic" award for the best MSc thesis for the year 2007.

УНИВЕРЗИТЕТ У БЕОГРАДУ
ФИЗИЧКИ ФАКУЛТЕТ

ФОНД „Проф. др ЉУБОМИР ЋИРКОВИЋ"

Одлуком Одбора Фонда за најбољу магистарску тезу одбрањену на Физичком факултету у 2006/2007 години, награђује се

*Зоран Мијић*

На основу тога издаје се ова

**ДИПЛОМА**
О ДОДЕЉИВАЊУ НАГРАДЕ

Датум
14.12.2007.год.

Председник одбора

**Ana Bankovic**, research trainee, has won "Ljubomir Cirkovic" award for the best BSc thesis for the year 2007.

УНИВЕРЗИТЕТ У БЕОГРАДУ
ФИЗИЧКИ ФАКУЛТЕТ

ФОНД „Проф. др ЉУБОМИР ЋИРКОВИЋ"

Одлуком Одбора Фонда за најбољи дипломски рад одбрањен на Физичком факултету у 2006/2007 години, награђује се

*Ана Банковић*

На основу тога издаје се ова

**ДИПЛОМА**
О ДОДЕЉИВАЊУ НАГРАДЕ

Датум
14.12.2007.год.

Председник одбора

**Mira Anicic**, research assistant has won Award for Excellency and Best Student Talk in the Fourth International Summer School „NUCLEAR PHYSICS METHODS AND ACCELERATORS IN BIOLOGY AND MEDICINE" held in Prague, July 2007.


**Marija Radmilovic**, won the **award** of the Institute of Physics for the **scientific results for 2008**.

**Mira Anicic** was awarded for the **best poster presentation** by Conference Committee of the Fifth International Workshop on Biomonitoring of Air Pollution in Buenos Aires, Argentina, September 2009

In addition to this, several of our somewhat more senior members have given invited lectures at international conferences (D. Maric, S. Dujko, M. Radmilovic, G. Malovic, and Z. Petrovic). It is important to mention that young researcher **Ana Bankovic** gave an invited lecture with the title**:** 'Nonconservative transport of electrons and positrons in gases , at the 25th International Workshop on Low Energy Positron and Positronium Physics & 26th International Symposium on Electron-Molecule Collisions and Swarms conferences in Toronto, Canada. 29th- 4th August.

Related to the training programs we had five students working on their PhD thesis, four (including one from FYR Macedonia) were working on their master's thesis and one completed defense of the Master of Science thesis.

In addition to the five students listed under thus project one student from the region, Snježana Dupljanin Popović (Banja Luka, Bosnia), has commenced her postgraduate studies as a part of the COE training program. Five different students have started work on their BSc theses.

Prof. Dr. Zoran Petrović gave a course on Plasma technologies at the Faculty of Electrical Engineering, University of Belgrade.

Under regular courses at the Faculty of Physics of the University of Belgrade, postgraduate students had courses and examinations that provide a foundation for their work in the COE under guidance of Prof. Dr. Zoran Petrović, Dr. Gordana Malović, Dr. Marija Radmilović-Rađenović, Dr. Dragana Marić and Dr. Nevena Puač.

Prof. Dr. Zoran Petrović, Dr. Gordana Malović, Dr. Marija Radmilović-Rađenović are listed as professors for PhD studies at the faculty of Physics University of Belgrade (Z. Petrovic was also elected to the position of a full professor at that department). Dr. Ž. Nikitović is engaged for postgraduate courses together with prof. Olivera Šašić at the Faculty of Traffic engineering, and Z. Lj. Petrović was elected to the position of full professor at the faculty of Electrical Engineering , department of Physical electronics. Prof. Jasmina Jovanović is teaching at the faculty of Mechanical Engineering.

## 2. TRAINING BY EXCHANGE OF STUDENTS AND SENIOR SCIENTISTS

Due to limited funds this part of the programme could only be initiated and only limited funds were used indirectly drawn from the overheads dedicated to the project. We have thus drawn additional funds from the regular national project to support these activities.

Zoran Petrović has been invited to give a series of lectures to postgraduate students at Ruhr University in Bochum (November 2007), as a part of the series of lectures by

distinguished scientists (previous lecturers were M. Lieberman, UC at Berkeley and T. Makabe, Keio University). He has delivered 5 lectures lasting 2 hours each over the period of 11 days to postgraduate students from Ruhr University.
Zoran Petrović has visited Australia on two occasion (June-July 2007 and January-February 2008) where he gave seminars at James Cook University Townsville, Australian National University Canberra (July 2007) and Flinders University Adelaide (February 2008).
Dr. Dragana Maric gave seminars at Australian National University Canberra and Flinders University Adelaide (January 2008). Dragana Maric was also invited to give a lecture at Ruhr University Bochum Germany in June 2008.
*Velibor Novakovic*, Assistant Research Professor started his Post Doc Studies in November at the Environmental Analysis Group within MiTAC Department of Chemistry, University of Antwerp, under the supervision of Prof. Rene Van Grieken The project he is working on in Belgium is *Chemical characterization of individual fine particulate matter with respect to their health impact*.

This project aims at reducing the health risks and health costs attributable to particulate pollution. The main task would be identification of pollutants that are responsible for the adverse health effects. The component-specific toxicity of fine particulate air pollution has not been characterized sufficiently. Considering that, the research unit of lung toxicology (KULeuven) collected unique data on the association between fine particulate air pollution and mortality (total, cardiovascular and respiratory mortality) in Belgium. This overview shows that the effects of air pollution are much stronger in summer than in winter, even in the Belgian temperate climate. Until now, one can only speculate about the mechanisms underlying the much stronger association between mortality and particulates during warmer periods, even though particulate levels reach higher values in winter. This study is directly related to the current projects carried out by the host unit: "Health effects of particulate matter in relation to physical-chemical characteristics and meteorology (PARHEALTH)" in cooperation with partners from KULeuven, UGent, ULBrussels en KMI.

*Mira Aničić*, research assistant visited Norwegian University of Science and Technology in Trondheim, Norway and took advantage of 4 weeks stay (January 22 – February 16 2008) for collaborative scientific works. At the Laboratory leaded by Prof. Dr. Eiliv Steinnes, in the frame of Active Moss Biomonitoring research of the atmospheric deposition in urban area of Belgrade she analysed the moss samples by Inductive Coupled Plasma Mass Spectrometry (ICP MS) for almost 70 elements.

Group of students from the plasma part of the project (A. Banković, S. Lazović and N. Škoro) have attended the summer school (two weeks September 2007) for low temperature plasmas and attended the courses and the workshop. This was organized in Bad Honeff by German physical society and University of Ruhr in Bochum. They had a series of lectures, attended a master class and presented posters with their own work. This activity was supported by the project

Two postgraduate students from Brno University visited our laboratory in April 2008 and participated in joint measurements and also some of the training courses. Their names are Nina Radic i Tomasz Hoder and in the meantime Tomasz has obtained his PhD.

In the project lasting period several members of our COE have completed and defended theses.

***PhD theses***

**2009**

**Sasa Dujko,** James Cook University, Australia

**Milovan Suvakov**, Institut Jozef Stefan, Ljubljana, Slovenia

**2008**

**Vladimir Stojanovic**, School of Electrical Engineering, University of Belgrade, Belgrade

**2007**

**Nevena Puac,** Faculty of Physics, University of Belgrade, Belgrade

**2006**

**Velibor Novakovic**, Faculty of Physics, University of Belgrade, Belgrade

***MSc theses***

**2006**

**Zoran Mijic**, Faculty of Physics, University of Belgrade, Belgrade

**Mira Anicic**, Faculty of Chemistry, University of Belgrade, Belgrade

**Milovan Suvakov** Faculty of Physics, University of Belgrade, Belgrade

**Dejan Maletic**, Faculty of Physical Chemistry, University of Belgrade, Belgrade

**Aleksandra Nina**, School of Electrical Engineering, University of Belgrade, Belgrade

**Snjezana Dupljanin**, Faculty of Physics, University of Belgrade, Belgrade

***BSc theses***

2009

**Bojan Seslak** Faculty of Physical Chemistry, University of Belgrade, Belgrade

**Marija Vranic**, Faculty of Physics, University of Belgrade, Belgrade

2008

**Nikola Petrovic**, Faculty of Physics, University of Belgrade, Belgrade

Dejan Maletic Faculty of Physical Chemistry, University of Belgrade, Belgrade

2007

**Sasa Lazovic** Faculty of Physics, University of Belgrade, Belgrade

**Ana Bankovic** Faculty of Physics, University of Belgrade, Belgrade

2006:

**Nikola Skoro** Faculty of Physics, University of Belgrade, Belgrade

2008

**Aleksandar Bojarov** (the best BSc at Faculty of Electrical Engineering)

**Ivana Djordjevic**

*High School graduation*

2008

**Jovana Vranic** Plasma Physics - picturebook (in serbian))

### 3. Training by attending conferences, workshops and symposia

All participants in the project have attended at least one international conference including the undergraduate students working on the BSc theses.

**LIST OF THE CONFERENCES WITH THE PARTICIPATION OF THE COE RESEARCHERS**

2009

**2nd International Conference on Advanced Plasma Technologies (iCAPT-II) & International Plasma Nanoscience Symposium in Piran, Slovenia**. (1 invited lecture, 2 posters)

**62nd Gaseous Electronics Conference (GEC) in Saratoga Springs, NY, USA. 20th - 23rd Oct 2009** (5 posters, 1 invited lecture, 1 chairman of a session and a special workshop)

**Workshop on Biomonitoring of Air Pollution in Buenos Aires, Argentina 20th -24th Sep 2009.** (1 poster-best poster award)

**11th YUCOMAT in Herceg Novi, Montenegro** 31st Aug-04th Sep.2009. (4 posters- 1 chairman, 1 Member of a board, organizing committee)

**19th International Symposium on Plasma Chemistry in Bochum, Germany.** 26th – 31st July (1 poster)

**25th International Workshop on Low Energy Positron and Positronium Physics & 26th International Symposium on Electron-Molecule Collisions and Swarms conferences in Toronto, Canada**. 29th - 4th Aug (2 invited lectures)

**29th International Conference on Phenomena in Ionized Gases in Cancun, Mexico**. 12th – 17th July (1 topical lecture, 1 co-organization, 1 invited lecture, 1 poster)

**2nd Workshop on Plasma for Environmental Issues, a satellite meeting of the 36th EPS Conference on Plasma Physics, Sofia, Bulgaria.** 3rd July (l lecture)

**4th International Congress on Cold Atmospheric Pressure Plasmas: Sources and Applications in Ghent, Belgium**. 22nd-24th.jun. (1 poster)

**1st ICPC NanoNet Workshop in Prague, Czech Republic**. 1st June, (1 member of the steering committee, 1 lecture)

**XVIII Symposium of Biological Society, Vrsac, Serbia**. 27th- 29th May. (1 poster)

**40th Annual Meeting of the Division of Atomic, Molecular, and Optical Physics in Charlottesville, Virginia, USA.** 17th – 20th May. (3 posters)

**Workshop on Radio-Frequency Discharges in La Badine - Presqu'île de Giens, France**. 17th – 20th May (1 topical lecture)

**7th EU-Japan Joint Symposium on Plasma Processing in Liblice, Czech Republic**, 23rd – 26th April (1 invited lecture, 1 poster)

**Fundamentals and Applications of Microplasmas Conference in San Diego, California, USA**. 1st – 6th march (1 topical lecture)

**4th International Conference on Proton Transfer Mass Spectrometry and its Applications and a training course Hands on PTR-MS in Obergurgl, Austria**. 17th – 19th Feb. (2 posters)

**2008**

**9th European Meeting on Environmental Chemistry in Girona, Spain . 3rd – 6th December** (1 poster)

**50th Annual Meeting of the Division of Plasma Physics in Dallas, Texas**. 17th – 21st November (1 oral presentation, 1 topical lecture)

**61st Annual Gaseous Electronics Conference in Dallas, Texas**. 13th – 17th October (1 invited lecture, 2 oral presentations).

**9th Asia-Pacific Conference on Plasma Science and Technology and 21st Symposium on Plasma Science for Materials held in Huangshan, China** 8th – 11 October (active contribution)

**YUCOMAT 2008 in Herceg Novi, Montenegro 10th – 14th September** (1 lecture, 2 posters)

**XVII International Conference on Gas Discharges and their Applications in Cardiff, UK**, 7th – 12th September (1 lecture)

**Second Central European Symposium on Plasma Chemistry (CESPC) in Brno, Czech Republic** 31st – august – 4th September (1 invited lecture)

**15th International school on condensed matter physics in Sofia, Bulgaria**.31st August – 5th September

**Second International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment and SPIG 2008 in Belgrade and Novi Sad.**23rd – 29th August ( 2 invited lectures)

**19th ESCAMPIG in Granada, Spain**. 15th – 19th July (1 topical lecture, 1 oral presentation, 2 posters)

**CEPAS conference in Cluj-Napoca, Romani**a. 18th – 20th June (4 posters)

**23rd Symposium on Plasma Physics and Technology in Prague, Czech Republic**. 16th – 18th June (1 invited lecture, 4 posters)

**5th Symposium Chemistry and Environmental Protection, , Tara, Serbia,** 27th -30th June (2 posters)

**6th EU - Japan Joint Symposium on Plasma Processing**.21st – 23rd April (2 invited lectures)

**XVI International Seminar on Interaction of Neutrons with Nuclei ,Dubna, Russia**, 11th – 14th June (oral presentation)

**9th Highway and Urban Environment Symposium, Madrid, Spain. 9th** -11th June (1 poster)

**2007**

**XV International Symposium on Electron-Molecule Collisions and Swarms in Reading, UK**, 1st-4th August. (2 lectures)

**XXVIII ICPIG, Prague, Czech Republic** 18th July (1 lecture)

**Fourth International Summer School and Workshop: "Nuclear Physics Methods and Accelerators in Biology and Medicine", Prague, Czech Republic**. 8th – 19th July, (1 lecture, 1 award)

**1st WeBIOPATR workshop-Particulate matter: Research and Management** ", Belgrade, Serbia 21st- 22nd may (1 invited lecture)

**Meeting of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation***)*, Dubna, Russian Federation. 5th -9th March (1 poster)

**8th European Meeting on Environmental Chemistry (EMEC8), Inverness, Scotland**, 5th – 8th December (1 poster)

**2006**

**7th European Meeting on Environmental Chemistry (EMEC7) Brno, Czech Republic**, 6th – 9th December. (2 posters)

**6th International Conference of the Balkan Physical Union, Istanbul, Turkey (**2 posters)

**LIST OF INVITED AND TOPICAL LECTURES GIVEN BY THE COE RESEARCERS**

**61st Annual Gaseous Electronics Conference in Dallas, Texas**. 13th – 17th October

**Zoran Petrovic**: 'Micro-Discharge Scaling and Development from Centimetres to Microns: DC and RF Breakdown and Discharge, Characterization around the Paschen Minimum'

**YUCOMAT 2008 in Herceg Novi, Montenegro**. 10th – 14th September
**Nevena Puac**: 'Studies of atmospheric discharge of small dimensions used for treatment of biological samples'

**XVII International Conference on Gas Discharges and their Applications, Cardiff, UK**. 7th – 12th September
**Zoran Petrovic and Jasmina Jovanovic**: 'Electron and positron swarms: collision and transport data and kinetic phenomena'.

**Second Central European Symposium on Plasma Chemistry (CESPC) in Brno, Czech** Republic. 31st – august – 4th September
**Nevena Puac**: 'Diagnostics of the Properties of the Plasma Needle'

**2nd International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment and SPIG 2008 in Belgrade and Novi Sad**. 23rd – 29th August
**Dragana Maric**: 'Hollow cathode discharges: Volt-ampere characteristics and space-time resolved structure of the discharge'
**Zoran Petrovic**: 'Cross sections and transport properties of negative ions in rare gases'

**19th ESCAMPIG in Granada, Spain.** 15th – 19th July
**Dragana Maric** Space time development of low pressure gas breakdown
**Zoran Petrovic** Thermalization of high energy electrons in pure N2 at high altitude

2**3rd Symposium on Plasma Physics and Technology in Prague, Czech Republic**. 16th – 18th June
**Zoran Petrovic**: , "Diagnostics of the properties of the plasma needle",
**6th EU - Japan Joint Symposium on Plasma Processing.** 21st – 23rd April
**Zoran Petrovic**: 'Voltampere characteristic of low current micro discharges and transport coefficients in CFx/CF4 mixtures'
**Gordana Malovic**: 'Mass analysis of products of atmospheric pressure discharges'.

**XVI International Seminar on Interaction of Neutrons with Nuclei ,Dubna, Russia**. 11th – 14th June

**Mira Anicic:** 'Active moss biomonitoring of trace elements with Sphagnum girgensohnii moss bags in relation to atmospheric bulk deposition in Belgrade'

**2nd International Workshop on Non-equilibrium Processes in Plasmas and Environmental Science**, Belgrade and Novi Sad, Serbia, 23-26 August 2008

**Jasmina V. Jovanović** :Cross sections and transport properties of negative ions in rare gases

**The 9th Asia-Pacific Conference on Plasma Science and Technology (APCTPST) and 21st Symposium on Plasma Science for Materials (SPSM)**,, Huangshan, China 8-11 October 2008

**Z. Lj. Petrović**, Kinetic phenomena and data for cross sections for electrons, positrons and negative ions in ionized gases

**2007**

**XV Intetnational Symposium on Electron-Molecule Collision**, Reading, UK, 1st-4th August.

**Dragana Maric**: 'Space-time resolved kinetics of low-pressure breakdown'

**Sasa Dujko**: 'On developments in the theory of electron and positron swarms'

**XXVIII ICPIG, Prague, Czech Republic**. 18th July

**Marija Radmilovic-Radjenovic**: 'Modeling of the gas breakdown in microgaps and 3D profile evolution during plasma etching'

**Fourth International Summer School and Workshop: "Nuclear Physics Methods and Accelerators in Biology and Medicine"**, Prague, Czech Republic. 8th – 19th July,

**Mira Anicic**: 'Active moss biomonitoring of atmospheric trace element deposition in urban area using INAA and AAS analytical techniques'

**1st WeBIOPATR workshop-Particulate matter: Research and Management**", Belgrade, Serbia. 21st- 22nd may
**Mirjana Tasic**: 'Source Identification of Trace Elements in urban particulate matter'

**5th EU-Japan Joing Symposium on Plasma Processing**, Belgrade, Serbia 7-9 03 2007
**Z. Lj. Petrović**: Spatiotemporal Development of Low-Pressure Gas Discharges

**-Workshop:Serbia-Slovenia bilateral cooperation, 9th Annual Conference of the Yugoslav Materials Research Society**, (Yucomat Herceg Novi, Montenegro,), September 10-14. 2007
**N. Puač**,, "Studies of application and characterization of plasmas used in treatment of polymers and organic materials"

S**econd workshop and training school on low cost applications of plasma technology in industry and environment**,, Cairo, Egypt 10 – 15 November 2007
**Z. Lj. Petrović:** Transport of charged particles and fast neutrals in low pressure gases and discharges
**VI Serbian Conference On Spectral Line Shapes In Astrophysic**, Sremski Karlovci, Serbia 11-15 June 2007
**Ž. Nikitović**: Electron, ion and atom collisions leading to anomalous Doppler broadening in Hydrogen and Hydrogen rare gas mixtures

The policy that each member of the team will attend one international conference was extended to most researchers in the program including students. The students had specific tasks to make contacts, present their work, learn and also to present a review of some of the lectures that they have attended or some research that they have seen.

## 4. Employment of young researchers

We have completed the first year requirement to recruit and finally employ three young researchers (Ana Bankovic, Sasa Lazovic and Andreja Stojic). As a matter of fact two more students (Nikola Skoro, Mirjana Nesic), were employed in the past with the use of additional funds and all **five** will participate in training, exchanges and enter the project. In the third year we have engaged the following students (S Marjanovic, M.Savic, A. Bojarov and I Djordjevic as well as A Stojic to some degree). The first three and A Stojic have found positions on the ongoing funding by the government through our main fundamental or applied research projects.

Several more young students have passed through courses led by the members of the COE and are preparing for their engagement in the center. One student from the region (Bosnia) has commenced her work on the project for her Masters and PhD theses with the members of the COE and already has submitted one paper to a journal while one more is being written.

**Ana Bankovic**


**Nikola Skoro**

**Sasa Lazovic**

**Andreja Stojic**

**Mirjana Perisic**


**Dejan Maletic, Srdjan Marjanovic and Marija Savic are new PhD students**

**Conclusion of the report for the workpackage WP3**

- As a part of their training, all of the participants, including all students from the COE, attended a large number of lectures by the leading international scientists and also attended international conferences where they presented their papers and made contacts in addition to being subjected to a lot of review lectures useful for their training.

- Two workshops and symposium were organized in August 2006, March 2007, and August 2008 for the purpose of the training of young students and the dissemination of our results. Published books of proceedings with selected review articles and progress reports were published in hard copies and available on line

- Two section workshops were organized as the official part of two major international conferences (ICPIG in Mexico and GEC in USA),

- We were visited by some of the representatives of our foreign partners for the purpose of the training of participants at the project.

- A number of members of the COE participated in graduate and postgraduate studies at the University of Belgrade. Some have participated in other universities by giving special lectures to the students.

- Members of the COE and their visitors participated in the Science Fair aimed at general public.

# WP4 – NETWORKING

## OBJECTIVES OF THE NETWORKING WORKPACKAGE

- Mobilization of human resources
- Demonstrating and validating new knowledge through research and development
- Supporting collaboration and coordination, and other activities (such as conferences and studies) in the area
- Exchange of information and experience through electronic network
- Joint experiments and strategic scientific exchange
- Electronic Newsletter (Deliverable 7)

## DESCRIPTION OF WORK

### COOPERATION WITH OTHER COMPETITIVE SCIENTIFIC CENTRES AND NETWORKING

In November 2007, Velibor Novakovic started his postdoctoral appointment in Micro- and Trace Analysis Center (University of Antwerp - Department of Chemistry) under Professor Rene Van Grieken supervision. His research field was devoted to the fundamental and methodological research related to micro- and trace analysis and in applications concerning environmental, cultural heritage conservation and material science problems. Main topics covered the atmospheric deposition of nutrients and heavy metals to the North Sea, aerosols in remote areas, the damage to historical buildings and medieval glass windows by sea salt and by air pollution, aerosols in museums and important churches, the relation of aerosol concentrations and health

problems. He was also involved in projects for the development and testing of new analytical instruments or techniques, e.g. for aerosols, precious metals and cement-related products.

We have also continued very string cooperation with Keio University Yokohama Japan, Department of Electronics on plasma technologies for production of integrated circuits. This was one of the backbones for the commencement of the EU Japan symposium on plasma processing and has been a precursor for collaboration between several EU groups (Bochum, Belfast) and Keio University along similar lines.

We have become a full member of the Center for antimatter matter studies in Australia and collaboration on transport of positrons is a new line of research for both our group and several centers in Australia. In the shadow of this, novel line of research studies of cross sections for electron scattering and transport of electrons in hydrodynamic and non-hydrodynamic conditions also progress very well. A similar collaboration is considered with the Institute for nonequilibrium plasmas in Greifswald, Germany and several centers in Europe and US.

**CONFERENCES AND WORKSHOPS**

We planed and organized specialized workshops: 1st International Workshop on Non equilibrium Processes in Plasmas and Environmental Science, in August 2006 at Kopaonik, Serbia. 2$^{nd}$ International Workshop on Non equilibrium Processes in Plasmas and Environmental Science, which was almost completely funded by this project was organized jointly with an International conference SPIG 2008 in Belgrade and Novi Sad, from 23 – 26 August 2008, both associated with this project. The conference had impact on training, networking and also on dissemination of results. Workshop brought a number of new participants to the SPIG thus invigorating the SPIG conference increasing the attendance and improving the overall success of the SPIG conference. Bringing together sufficient number of specialists in the field of non-equlibrium plasmas

and their interactions with surfaces provided a critical mass of experts for the workshop to become one of the most important meetings in the field in that period.

We will try to maintain the organization of those workshops in future.

**JOINT EXPERIMENTS AND STRATEGIC SCIENTIFIC EXCHANGE**

Joint projects were initiated with groups in University of Ulster, Ruhr University Bochum Germany, Polytechnical University in Lisboa Portugal, Ecole polytechnique Paris, France, Institute for solid state physics of the Bulgarian Academy of Sciences, Institute for solid state physics in Budapest, Hungary, Joint Institute for Nuclear Research, Dubna, Institute for Botany, Sofia, Bulgaria and many more. Joint research was carried out also with scientists from the University in Aarhus Denmark, Queens University Belfast, University of Brno, Institute Jozef Stefan Ljubljana and University College London. This was done in addition to some joint projects with scientists from USA and as already mentioned Australia and Japan. In general collaboration of some form (exchange of data, future plans, etc..) has extended to a much larger number of centers.

We have developed joint experiments in microdischarges during 2006-2008 with the Nanotechnology and Integrated Biomedical Engineering center of the University of Ulster in Jordanstown, Northern Ireland (C.Mahony, P. Maguire, also with W. Graham, T. Gans). Different experimental systems were developed in two centres and some experiments have been carried out jointly. Research at University of Ulster mainly focuses on RF breakdown and micro hollow discharges and in Belgrade on parallel plate Townsend and glow discharges. One invited lecture was presented at International Microplasma conference in Tawan (Prof. Petrovic was invited but due to visa limitations could not travel and the lecture was presented by C. Mahony) and two papers were published in leading international journals. One invited lecture was presented jointly at the leading conference GEC in Dallas USA (Petrovic and Maguire).

Dragana Maric and Zoran Petrovic visited NIBEC (Nanotechnology and integrated Biomedical Engineering Centre) of the University of Ulster on two occassions in Junne and November/December 2009. They worked on the joint program of research on micro discharges and application of plasmas in nanotechnologies (the later will be presented in a chapter in a monograph due to be published by Springer in 2010). Laboratory in Belgrade was visited by Paul Maguire related to the same topic and related to preparation of the chapter on Nanotechnolgies and plasmas. Paul Maguire and Zoran Petrovic presented a joint invited lecture at GEC in October 2008.

With University of Ruhr in Bochum we have worked (Dr. I. Stefanovic and prof. J. Winter) on defining the goals and plans for a major project proposal for their laboratory where Prof. Petrovic and Dr. D. Maric were included as foreign participants. The line of research is also in direction of microdischarges. The project was accepted for funding by German institutions and Zoran Petrović and Dragana Marić are listed as external participants. It is important to note that preparations for joint EU proposals will be under way later this year. Dr. Ilija Stefanović was engaged in both centres and participated in joint program by working in both laboratories. Several of his trips between Bochum and Belgrade were supported by this project.

Ilija Stefanovic visited Laboratory in Belgrade and Dragana Maric Ruhr University in Bochum related to the joint programme led by J Winter and Z Petrovic and as a part of that German side ensured continued funding over the following 5 years with members of our COE as collaborating foreign scientists.

We have commenced work on the joint research with the group of Prof. Mirko Černak from University of Brno and Bratislava. Two of his students have stayed in Belgrade for two weeks with their apparatus and we performed preliminary measurements

A joint project with group of Prof. Tennyson at University College London has commenced on calculation of the cross sections for electron scattering by using R Matrix

approach and the QUANTEMOL code. One of the students (Hemal Varambhia) from UCL has been to Belgrade to commence joint research projects. Calculations for electron scattering on $BF_3$, $C_2H_2F_4$ and HBr have commenced.

Work on the diagnostics of a pulsed Hollow cathode spectral source with the Solid State Physics Institute of Bulgarian Academy of Sciences (Renna Djulgerova and Valentin Mihailov) continued throughout the time of the project, first publication was made in J. Phys. Conference series and a regular article will be submitted shortly, while the work will continue to provide physical basis for studies of hollow cathode discharges which are predominant form of micro discharges and have the highest potential for applications in nanotechnologies and light sources.

Compilations of data and calculations of transport properties of positrons in gases were carried out with support of colleagues from the Australian National University (S. Buckman and R. Robson), James Cook University of Townsville Australia (R. White) and University of Aarhus- Denmark (J.Marler). This is a genuinely new field of research that our group initiated during the duration of the project and is gaining popularity with several centers in UK, Spain, USA and other countries entering that field. Applications are modeling of positron diagnostics and therapy in human tissues based on fundamental directly measured collisional data that are now available.

Diagnostics and modeling of microwave plasmas were initiated with Technical University of Lisbon- Portugal, (V. Guerra) and Institute of Solid State Physics in Budapest Hungary (Kutasi). We plan to set up an experiment in due course but modeling is progressing very well.

Diagnostics of negative ions in plasmas for etching in micro electronics and nanotechnologies was done through exchange with experts from Ecole polytechnique – Paris France (J.P.Booth, P. Chabert). This line of work complements very well our studies of transport in plasmas with large percentage of radicals, our compilation of data for negative ions now residing in our data base and our plans to develop a GEC cell plasma etcher experiment in our laboratory.

Nanostructuring of polymers and textile fibers continued with Jozef Stefan Institute Slovenia- (Adolf Jesih) but very little success was achieved as polymers that were intended to be put on textile did not work well with fibres that we selected. The work however continued with two groups, one of the University of Maribor (Slovenia= Marija Gorensek- COST action) and one with a group in Nuclear Institute Vinca in Belgrade and with Faculty of Technology and Metallurgy Belgrade – department of textile Engineering (M Radetic) on development of textiles impregnated by nanoparticles of silver to produce textiles for medical application that are bactericidal.

Laboratory was visited by Prof W Graham from Queens University on two occasions and he participated in measurements of breakdown properties in water vapour.

Nevena Puac and Zeljka Nikitovic have visited the Institute Jozef Stefan in Slovenia working on the measurements by using catalytic probes and analysis of the role of radicals in fluorine containing molecular gases. Miran Mozetic from the same Laboratory has visited our COE during a conference in September 2008 while Puac, Nikitovic and Petrovic visited Slovenian group in September 2009. This is a new line of research that was initiated in the last year of the project partly as a result of the fact that Prof. Mozetic attended one of our workshops. It is a proof how such programs improve joint research, networking, mobility (both Nikitovic and Puac are on a half year postdoctoral appointment in Jozef Stefan).

COE was visited by Timo Gans and experts from Radian Dyes working on starting the dye laser purchased through funds of our Ministry of science. Kari Niemi from the Queens University is scheduled to continue the programme but his visit was postponed due to malfunctioning of the NdYAG laser which has been repaired recently.

Kinga Kutasi from the Institute of solid state Physics, Hungarian Academy of science, has visited our laboratory in September 2009 and in February 2009 working on a joint programme of modeling of gas breakdown by a hybrid code.

In the frame of Active Moss Biomonitoring research of the atmospheric deposition in urban area and industrial zones, joint experiment was initiated between Norwegian University of Science and Technology in Trondheim, Norway (under the supervision of Prof. Eiliv Steinnes) and Environmental Physics Laboratory of the IPB CNP (supervised by Dr Mirjana Tasic). Experiment was set up in Belgrade and analytical procedure is carried out by Inductive Coupled Plasma Mass Spectrometry (ICP MS) in Trondheim.
A joined research has been initiated and started in November 2008 in the frame of BSEC (Black Sea Economic Cooperation) project.

**JOINT PROJECT PROPOSALS**

As one of the key motivations and objectives of the project was to be in position to file proposals for further, specialized projects with EU bodies and we had a major activity as several proposals were prepared and submitted. We have submitted the following proposals:

The following joint project proposal was submitted and accepted:

1. A BSEC (Black Sea Economic Cooperation) project REVITALIZATION OF URBAN ECOSYSTEMS THROUGH VASCULAR PLANTS: ASSESSMENT OF TECHNOGENIC POLLUTION IMPACT, *Metaphor:* GARDEN CITY was proposed by Institute of Botany-BAS, Bulgaria, Greece, Romania, Russia, Serbia, and Turkey. The purpose of the project was to make an expert examination of accumulation of heavy metals and other toxic elements of industrial and transport emissions by various tree and bush species with the aim to find sorts capable to accumulate the maximal number of pollutants and to resist the effect of adverse environmental factors. The other purpose was to compare bioaccumulation of toxic elements in woody species in the areas of temperate-continental and subtropical Black Sea climate. The first results have been obtained; the intercomparison of the methodology and analytical techniques is in the course.

2. E14043 Nanovision with colleagues from Serbia and Slovenia. The project is being funded and we participate in it together with our colleagues at the Faculty of Technology and metallurgy.

3. ACCENT EUROPEAN NETWORK of EXCELENCE "Atmospheric Composition Change" ACCENT:2006 - 2009: EUROPEAN NETWORK of EXCELENCE ”Atmospheric Composition Change” ACCENT , the framework of the specific European research and technological development programme ”Integrating and Strengthening the European Research Area” under Priority 6 ”Sustainable development, global change and ecosystems”. Group participates as ACCENT ASSOCIATE in Joint research programme: Aerosols with theme: Health-related particles (PM10 and PM2.5) as indicator of air quality in Belgrade urban area.

4. Currently we are working on preparation of the proposal with colleagues from Gerifswald Germany and Toulouse France: GRID for the European Plasma Community) and

5. with colleagues from Spain, UK, France and Poland on COST action proposal: Positrons in Physical, Chemical and Biological Processes.

6. Laboratory for Environmental Physics participated in the Intercomparison Exercise of XRF Laboratories, " Proficiency Test for XRF Laboratories: Natural Grass Mixture was analysed using MiniPal 4 XRF  organized by IAEA Laboratories, AUSTRIA,

CENTER FOR
NON-EQUILIBRIUM
PROCESSES
INSTITUTE OF PHYSICS
BELGRADE

**Project no.026328**

**IPB-CNP**

# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 7 Electronic Newsletter

Due date of deliverable: 19.06.2008
Actual submission Date: 19.06.2009
Will be repeated every at least 2 months

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

# DELIVERABLE 7

## ELECTRONIC NEWSLETTER

### INTRODUCTION

As promised in our proposal we have established an electronic newsletter that was sent to more than 100 addresses initially and it is likely that this number will grow in future. HTLM format was chosen to provide visual material and to maintain our visual identity. The information on networking, training and dissemination activities are provided, new published papers are listed and special milestones are presented. While most of the information is presented also on our website, newsletter serves a different purpose in facilitation networking and presenting information on our activities.

Four issues have been presented:

http://mail.ipb.ac.rs/~cep/ipb-cnp/eNotes/issue4/eNotes0609.html

**HTTP://MAIL.IPB.AC.RS/~CEP/IPB-CNP/ENOTES/ISSUE1/ENOTES0608.HTML**

**HTTP://MAIL.IPB.AC.RS/~CEP/IPB-CNP/ENOTES/ISSUE2/ENOTES0808.HTML**

http://mail.ipb.ac.rs/~cep/ipb-cnp/eNotes/issue3/eNotes1208.html

The newsletter also plays a role of three monthly or six monthly intermediatte reports.

In August 2008 newsletter was prepared in support of the 2nd International Workshop on Non-equilibrium Processes in Plasmas and Environmental Science. The newsletter was designed by Nevena Puac and Sasa Dujko and prepared and supplied with information by Sasa Dujko and Nikola Skoro.

## CONCLUSION

Several major activities were undertaken and under the networking. Five proposals for international projects are being prepared with different groups around the Europe. Several regional projects and EU funded projects are carried out with participation of some of the members of our centre.

There are several ongoing studies that were extended through this period and several new scientific projects with groups around the Europe (and world) have commenced. We have opened collaboration with a number of new centres.

Most active research is our joint research with the University of Ulster in Belfast, UK, and with Ruhr University in Bochum Germany on micro discharges and their application for nanotechnologies. Experiments are performed in both laboratories with active exchange of scientists. Similar activities are being carried out on other topics including positron transport, plasma diagnostics and atomic and molecular data.

# WP5 – DISSEMINATION

## OBJECTIVES OF THE DISSEMINATION WORKPACKAGE

1. Conferences, seminars, working groups and expert groups;

2. Book

3. Trans-national technology transfer

4. Development of research and innovation strategies;

5. High level scientific achievements;

6. Database with data for plasma modeling, for modeling of plasma and ion beam surface interaction

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**Project no. 026328**

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# Reinforcing Experimental Centre for Non-equilibrium Studies with Application in Nano-technologies, Etching of Integrated Circuits and Environmental Research

## Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 5 Dissemination workshop

Due date of deliverable: 19.06.2009
Actual submission Date: 19.06.2009

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:

INSTITUTE OF PHYSICS

**ORGANIZATION OF DISSEMINATION WORKSHOP AND INTERNATIONAL CONFERENCES**

At the very beginning of the project we organized First International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment in August 2006, at Kopaonik, Serbia. The proceedings of the workshop included invited lectures from more than 30 renowned researchers and was published in hard copy and was available online as well.

**FIRST INTERNATIONAL WORKSHOP ON NONEQUILIBRIUM PROCESSES IN PLASMA PHYSICS AND STUDIES OF ENVIRONMENT**
**August 2006, Kopaonik, Serbia**

*Journal of Physics: Conference Series*. **Volume 71, 2007**

**PREFACE** 011001**First International Workshop on Nonequilibrium Processes in Plasma Physics and Studies of Environment**
*Z Lj Petrović, G Malović, M Tasić and Ž Nikitović*

**PAPERS PUBLISHED IN THE PROCEEDINGS**

012001**High Pressure Laser-Generated Shocks and Application to EOS of Carbon**
*D Batani, R Dezulian, H Stabile, M Tomasini, G Lucchini, F Canova, R Redaelli, M Koenig, A Benuzzi, H Nishimura, Y Ochi, J Ullschmied, J Skala, B Kralikova, M Pfeifer, T Mocek, A Präg, T Hall, P Milani, E Barborini and P Piseri*

012002**Anomalous Diffusion at Edge and Core of a Magnetized Cold Plasma**
*Mario J Pinheiro*

012003**Non-neutral Plasma Confinement in Toroidal Geometry**

*J P Marler and M R Stoneking*

012004**The $v = 0 \rightarrow 1$ vibrational cross-section for e–$H_2$scattering: An unresolved problem with wide implications**

*R D White, R E Robson, Michael A Morrison, B Li and K F Ness*

012005**Negative electron conductivity in gases and semiconductors**

*N A Dyatko*

012006**Electron and ion swarm data of fluorinated gases used in plasma processing**

*J de Urquijo*

012007**Modelling of breakdown behavior by PIC/MCC code with improved secondary emission models**

*M Radmilović-Radjenović, Z Lj Petrović and B Radjenović*

012008**Effects of fast neutral particles in low-pressure gas discharges**

*Z Donkó, P Hartmann and K Kutasi*

012009**On hydrogen negative ion formation and concentration measurements in hollow cathode and positive column glow discharge**

*V Gencheva, R Djulgerova, V Mihailov, T Dohnalik and Z Lju Petrovic*

012010**Nitrogen dissociation in low-pressure microwave plasmas**

*Elena Tatarova, Vasco Guerra, Júlio Henriques and Carlos M Ferreira*

012011**Non-equilibrium calculations of atmospheric processes initiated by electron impact.**

*L Campbell and M J Brunger*

012012**Diagnostics on an atmospheric pressure plasma jet**

*K Niemi, St Reuter, L Schaper, N Knake, V Schulz-von der Gathen and T Gans*

012013**Plasmas in saline solution**

*W G Graham and K R Stalder*

012014**Low energy ion implantation using non-equilibrium glow discharge**

*Svetlana Radovanov and Ludovic Godet*

012015**Non-equilibrium processes and dust formation in low pressure reactive plasmas**

*I Stefanovií, E Kovačević, J Berndt and J Winter*

012016**An assessment of air quality in Belgrade urban area: $PM_{10}$, $PM_{2.5}$and trace metals**

*M Tasic, S Rajsic, V Novakovic and Z Mijic*

012017**Environmental impact of plasma application to textiles**

*M Radetic, P Jovancic, N Puac and Z Lj Petrovic*

**EU-Japan symposium** was organized during the first year of our project. This conference was not planned in our proposal but we got offer to organize it and its organization was integrated into our project and partially supported. During the second year a book originating from the meeting was completed. First, completion of review articles was solicited from the selected participants of the conference, refereeing and editing of the articles was organized and then both electronic and hard bound versions of

the book were published by a specialized series of the largest international publisher of journals in physics, British Institute of Physics (Conference Series).

The book serves multiple purposes:

-it was a good pedagogical introduction for students into topical research issues in the field;

-presentation of the results from our group (two articles) served as a good comparison, test of the validity and quality of our results and the most efficient dissemination of our results as the intended users of our results were in the audience, at least two invited lectures at different conferences and two more at the VI EU Japan meeting followed as a result of this meeting and of presentation of our results at that meeting;

-to give our project and the COE a motivational focus and provide team work across the specialized teams giving the whole centre greater coherence and unity;

-it served a purpose of networking as several proposals of EU projects were put together on the basis of the direct interactions of different scientists during the meeting.

**5TH EU—JAPAN JOINT SYMPOSIUM ON PLASMA PROCESSING**
**7–9 March 2007, Belgrade, Serbia**

**Accepted papers received: 24 October 2007**
**Published online: 21 November 2007**

**Journal of Physics: Conference Series Volume 86, 2007**

*Jonathan Tennyson, Daniel B Brown, James J Munro, Iryna Rozum, Hemal N Varambhia and Natalia Vinci*

012002**Electron Attachment to Radicals and Unstable Molecules**
*Karola Graupner and Thomas A Field*

012003**Electron Impact Ionization/Dissociation of Molecules: Production of Energetic Radical Ions and Anions**
*S Feil, P Sulzer, A Mauracher, M Beikircher, N Wendt, A Aleem, S Denifl, F Zappa, S Matt-Leubner, A Bacher, S Matejcik, M Probst, P Scheier and T D Märk*

012004**Electron-Impact Induced Neutral Radical Fragmentation of $CH_4$**
*Casten Makochekanwa, Masamitsu Hoshino, Hiroshi Tanaka and Mineo Kimura*

012005**Progress towards the measurement of absolute elastic electron-molecular radical scattering cross sections**
*T M Maddern, L R Hargreaves, S J Buckman and M J Brunger*

012006**Cross section data for electron collisions in plasma physics**
*B P Marinković, V Pejčev, D M Filipović, D Šević, A R Milosavljević, S Milisavljević, M S Rabasović, D Pavlović and J B Maljković*

012007**Evolution of Negative Ion Resonances at Surfaces: Effect of Environment and Orientation**
*Petra Tegeder and Eugen Illenberger*

012008**Is $CF_3I$ a good gaseous dielectric? A comparative swarm study of $CF_3I$ and $SF_6$**
*J de Urquijo*

012009**Spatiotemporal Development of Low-Pressure Gas Discharges**
*D Marić, G Malović and Z Lj Petrović*

012010**Diagnostics of the plasma series resonance effect in radio-frequency discharges**
*J Schulze, T Kampschulte, D Luggenhölscher and U Czarnetzki*

012011**Ion behavior in capacitively-coupled dual-frequency discharges**
*Zoltán Donkó and Zoran Lj Petrović*

012012**Kinetic and Diagnostic Studies of Molecular Plasmas Using Laser Absorption Techniques**
*S Welzel, A Rousseau, P B Davies and J Röpcke*

012013**Reactive Oxygen Emission from Microwave Discharge Plasmas**
*S Popović, M Rašković, S P Kuo and L Vušković*

012014**Ultraviolet (UV) emissions from a unipolar submicrosecond pulsed dielectric barrier discharge (DBD) in He-Air mixtures**
*A V Pipa, M Schmidt and K Becker*

012015**Generations and applications of atmospheric pressure glow discharge by integration of microplasmas**
*O Sakai and K Tachibana*

012016**Modelling of Plasma Surface Interaction**
*Satoshi Hamaguchi, Masashi Yamashiro, Masaaki Matsukuma and Hideaki Yamada*

0120173**D Etching profile evolution simulations: Time dependence analysis of the profile charging during $SiO_2$ etching in plasma**
*Branislav Radjenović and Marija Radmilović-Radjenović*

012018**Modeling of Deep Si Etching in Two-Frequency Capacitively Coupled Plasma in $SF_6/O_2$**
*Fukutaro Hamaoka, Takashi Yagisawa, and Toshiaki Makabe*

012019**Plasma assisted growth of ultrathin nitrides on Si surfaces under ultrahigh vacuum conditions**
*Per Morgen, Ali Bahari, Kjeld Pedersen and Zheshen S Li*

012020**Reaction mechanisms and thin a-C:H film growth from low energy hydrocarbon radicals**
*E Neyts, A Bogaerts and M C M van de Sanden*

Another 6 speakers did not prepare the manuscript so the lectures included more of the worl leaders in the field like M.J. Kushner, … .

The 5th EU Japan symposium was highly regarded by our colleagues as one of the best conferences in the field in the past decade, attracting only the top researchers with program that is better or equal to the best international conferences. During this year 6th EU-Japan symposium was organized by the colleagues from Osaka University at Okinawa. We participated in organization and preparation of the programme. Z.Lj. Petrović was a cochairman of this conference presenting an invited progress report and a concluding session with a review of the whole conference. Gordana Malović presented an invited lecture at the conference.

We also organized another international workshop associated only with the project:

**The Second International Workshop on Non-equilibrium Processes in Plasmas and Environmental Science** was organized in August 2008 in Belgrade and Novi Sad.

The workshop was organized before the international conference SPIG 2008 (Symposium on Physics of Ionized Gases) at Novi Sad during the last week of August 2008. Invited speakers at the workshop and several speakers at the SPIG (Symposium on Physics of Ionized Gases) conference gave lectures on a number of new topics. This was a good opportunity for our students (and young PhDs) to learn something more and also to learn how to evaluate our results when presented to a number of leading international scientists. It provided an opportunity to our students to present theory work to international scientists and have comments on their work and open possible

collaborations. Together with SPIG we provided sufficient number of experts in the fields of non-equilibrium plasma physics and elementary processes in ionized gases that would be a very effective body to present and evaluate our results.

**The Second International Workshop on Non-equilibrium Processes in Plasmas and Environmental Science** ,

Journal of Physics: Conference Series Volume 162, 2009

**-Speakers specially invited for the workshop.**

012001 (reference to the paper in the book of proceedings published by IOP) Study of higher excited states of some polyatomic molecules relevant for plasma physics and environment B P Marinković

012005 Nonequilibrium calculations of the role of electron impact in the production of NO and its emissions L Campbell and M J Brunger

012006 Recent developments on PLASMAKIN – a software package to model the kinetics in gas discharges N R Pinhão

012008 An overview of modelling of low-pressure post-discharge systems used for plasma sterilization K Kutasi, C D Pintassilgo and J Loureiro

012009 Electric propulsion using ion-ion plasmas A Aanesland, A Meige and P Chabert

012013 The dynamics of radio-frequency driven atmospheric pressure plasma jets L Schaper, S Reuter, J Waskoenig, K Niemi, V Schulz-von der Gathen and T Gans

012015 Surface functionalization of organic materials by weakly ionized highly dissociated oxygen plasma A Vesel and M Mozetic

012016 Two-dimensional dusty plasma crystals and liquids Z Donkó, P Hartmann and G J Kalman

012017 Effects of friction on modes in collisional multicomponent plasmas J Vranjes, S Poedts, M Kono and M Y Tanaka

**- Speakers at SPIG who had given a lecture on a different topic at the workshop**

012002 Low energy positron interactions - trapping, transport and scattering J P Sullivan, S J Buckman, A Jones, P Caradonna, C Makochekanwa, D Slaughter, Z Lj Petrović, A Banković, S Dujko, J P Marler and R D White

012010 The Electrical Asymmetry Effect - A novel and simple method for separate control of ion energy and flux in capacitively coupled RF discharges U Czarnetzki, B G Heil, J Schulze, Z Donkó, T Mussenbrock and R P Brinkmann

012011 Space and phase resolved optical emission in mode transitions of radio-frequency inductively coupled plasmas D O'Connell, K Niemi, M Zaka-ul-Islam and T Gans

012014 Progress report: Direct injection of liquids into low-pressure plasmas M Goeckner, D Ogawa, I Saraf and L Overzet

**- Members of the COE presenting their work either at SPIG or at the workshop itself.**

011001 Nonequilibrium Processes in Plasmas Zoran Petrović, Dragana Marić and Gordana Malović

012004 Cross sections and transport properties of negative ions in rare gases J V Jovanović and Z Lj Petrović

012007 Hollow cathode discharges: Volt-ampere characteristics and space-time resolved structure of the discharge D Marić, N Škoro, G Malović, Z Lj Petrović, V Mihailov and R Djulgerova

012018 Source apportionment of atmospheric bulk deposition in the Belgrade urban area using Positive Matrix factorization M Tasić, Z Mijić, S Rajšić, A Stojić, M Radenković and J Joksić

**-Authors invited to contribute to the book that did not attend the workshop**

012003 Positron transport in gases M Charlton

012012 Influence of plasma and radio wave treatment on paper structure I I Filatova, V V Azharonok, V A Dlugunovich, O Tsaruk, I V Voschula, N A Fomin and N B Bazylev

012019 Determination of chemical composition of individual airborne particles by SEM/EDX and micro-Raman spectrometry: A review: E A Stefaniak, A Buczynska, V Novakovic, R Kuduk and R Van Grieken

Another 6 speakers did not prepare the manuscript so the lectures included more of the worl leaders in the field like T. Makabe,V. Godyak, M. Turner, or G. Poparic, O. Sasic, M. Cernak..

Poster was designed for the workshop, speakers were selected and contacted and a large part of organization was completed.

Book of proceedings from the Workshop was published online (http://www.iop.org/EJ/toc/1742-6596/162/1) by Institute of Physics Conference series and was also be published as a hard copy within a specialized series of the largest international publisher of journals in physics, British Institute of Physics (Conference Series).. In order to improve the visibility and dissemination of our results we have made payment to enable free downloading of the papers from the book.

3. Our centre has won organization of the **20th ESCAMPIG (European Conference on Atomic and Molecular Processes in Ionized Gases)** that will be held in July 2010 in Novi Sad. Organization has already begun. Zoran Petrovic, Gordana Malovic are co-chairs of the Local Committee and Dragana Maric is the Secretary of the Local Committee and member of the International Scientific Committee. Large part of the preparations for the conference and support for the meetings and distribution of information was covered by the COE as a part of increased visibility and standing of the group and as a part of networking plans.

Zoran Petrovic was asked and succeeded to organize 2 workshops/special sessions at major international conferences (ICPIG 2009, CANCUN Mexico, and GEC 2009) at Albany NY, USA). Both were held as a part of the official programme and both were successful.


**Project no.026328**

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# Specific Support Action

**Specific Measures in Support of International Cooperation (INCO)**
INCO-CT-2006-026328-IPB-CNP

## Deliverable 8 Plasma modeling data base

Due date of deliverable: 19.06.2008
Actual submission Date: 15.12.2008

Start date of project: 01.07.2006 Duration: 42 months

Lead Contractor:
**Institute of Physics**

**DATA BASES FOR TRANSPORT DATA FOR ELECTRONS, POSITIVE AND NEGATIVE IONS, FAST NEUITRALS AND POSITRONS**

Based on the request from the plasma device manufacturers community and especially by the modellers of the plasmas with comprehensive models integrated vertically and applied to develop new generations of plasma devices we have put together a data base for the transport properties for the negative ions which exist in plasmas used for processing of integrated circuits.

http://mail.phy.bg.ac.yu/~cep/ipb-cnp/ionsweb/index.htm

The data base has sections for electron, ion and positron scattering with different gases, while section for fast neutrals will be added once the related papers are published. The first set of data was for Cl- ions in rare gases. Only the figures are available and tabulated data may be obtained by request since possible commercial distribution may be organized under the project. In the meantime we have added almost all ions in most gases of interest for plasma processing in nanoelectronic industry.

Web site was developed in the first year with the purpose of dissemination of our results. The web is filled with information regularly and expanded. In a complex project such as ours one always finds new things that need to be represented on our site and the process will continue beyond the third year as well. Details of the work completed so far are given in Deliverable 2.

The update of the database for electrons, ions, (negative and positive), fast neutrals and positrons will continue. The main work has progressed in putting together a data base for positrons in water vapour, but presentation on the web site will have to await publication of the corresponding paper. The same is true for electron transport and cross section data for $N_2O$ where paper has been accepted and the entire set of data has already been put on the web site, while few months ago only graphs with the data were placed.

Other activities in dissemination of our results

M**EDIA PRESENTATIONS FOR GENERAL PUBLIC: PRESS** TV

- A press release was made related to the 75 years since positrons were discovered (and thereby antimatter).
- **Politika** daily, the oldest daily newspaper in Balkans published an article on the visit of SJ Buckman, JP Marler and RD White was published in December 2007, article based on the press release was published in March in Novosti the biggest selling daily journal in Serbia.
- Presentation of possible use of XRF analyser in archeology, presented by Andreja Stojic, has been broadcasted in the frame of scientific programme „KONTEKS 21" on 02.05.2008 on national TV station RTS2.
- Applications of breath gas analysis by Proton Transfer Mass Spectrometry (PTR-MS) in the medicine, presented by Zoran Petrovic was broadcasted within the scientific programme „DETAIL" on 12$^{th}$ of June 2009 on the national TV station RTS2.
- 10.11.2009.**NEWS ABOUT FIRST SERBIAN GOOGLE WAVE ROBOT DEVELOPED IN OUR LABORATORY BY S MARJANOVIC AND M SUVAKOV PUBLISHED ON THE WEB (IN SERBIAN)**
- Presentation of the work on positrons by Zoran Petrovic and Ana Bankovic was given at RTV network in November 2009.

### Review articles and invited papers at conferences

The members of the research team have published several review articles in the whole reporting period. Most importantly a chapter was prepared for the book on nanotechnologies edited by US scientists: Anatoli Korkin (University of Arizona), Predrag

Krstic (Oak Ridge National Laboratory) and Jack Wells that is in production at Springer Verlag. Total number of pages in the book will be 53 and it will be one among the total of 9 chapters.

The second important review was prepared for the special issue of Journal of Physics D , entitled: "Measurement and interpretation of swarm parameters and their application in plasma modeling" by Z Lj Petrović, S Dujko, D Marić, G Malović, Ž Nikitović, O Šašić, J Jovanović, V Stojanović and M Radmilović-Radenović (J. Phys. D: Appl. Phys. 42 (2009) 194002 ), totaling 33 pages in two column A4 size journal.

Other review articles published in the three years period are:

Positron transport: The plasma-gas interface
J. P. Marler, Z. Lj. Petrović, A. Banković, S. Dujko, M. Šuvakov, G. Malović and S. J. Buckman
*Physics of Plasmas* **16**, 057101 (2009) p7.

Plasma surface interaction in integrated circuit production and biomedical applications
Z. Petrović, M. Radmilović–Radjenović, B. Radjenović, D. Marić, N. Puač, G. Malović
Journal of Optoelectronics and Advanced Materials, **11** (2009) 1163 – 1169.

Kinetic phenomena in charged particle transport in gases, swarm parameters and cross section data
Z Lj Petrović, M Šuvakov, Ž Nikitović, S Dujko, O Šašić, J Jovanović, G Malović and V Stojanović
Plasma Sources Sci. Technol. 16 (2007) S1–S12 doi:10.1088/0963-0252/16/1/S01 TOPICAL REVIEW

Data and Modeling of Negative Ion Transport in Gases of Interest for Production of Integrated Circuits and Nanotechnologies,
Z.Lj. Petrović, Z.M. Raspopović, V.D. Stojanović, J.V. Jovanović, G. Malović, T. Makabe, J. de Urquijo,

Applied Surface Science 253 (2007) 6619–6640, doi:10.1016/j.apsusc.2007.02.005

On new developments in the physics of positron swarms
Z. Lj. Petrović, A. Banković, S Dujko, S. Marjanović, M. Šuvakov, G.Malović, J. P. Marler, S.J Buckman, R.D. White and R.E. Robson
Journal of Physics: Conference Series 199 (2010) 012016

D. Maric, N. Škoro, G. Malovic, Z. Lj. Petrovic, V. Mihailov and R. Djulgerova,
"Hollow Cathode Discharges: Volt-Ampere Characteristics and Space-Time Resolved Structure of the Discharge",
Journal of Physics: Conference Series Volume 162, 2009 012007

Jasmina V. Jovanovic and Zoran Lj. Petrovic
"Cross Sections and Transport Properties of Negative Ions in Rare Gases",
Journal of Physics: Conference Series Volume 162, 2009 012004

Z.Lj. Petrovic, •Z. Nikitovic and V.D. Stojanovic,
Modelling of Anomalous Doppler broadened Lines,Thermalization of Electrons and the role of Radicals inDischarges at high E/N
Journal of Physics: Conference Series 133 (2008) 012003

Electron and Positron swarms: Collision and Transport Data and Kinetic Phenomena
Z.Lj. Petrović, S. Dujko, A. Banković, J. Jovanović, V. Stojanović and J.P. Marler
XVII International Conference on Gas Discharges and Their Applications, GD2008, Cardiff, September Sunday, 7th until Friday 12th. Invited lecture Cardiff University pp.71-81.

Low energy positron interactions - trapping, transport and scattering
J P Sullivan, S J Buckman, A Jones, P Caradonna, C Makochekanwa, D Slaughter, Z Lj Petrović, A Banković, S Dujko, J P Marler and R D White

Journal of Physics: Conference Series Volume 162, 2009 012002

Radionuclides and Particulate Matter in Belgrade
iD.Todorovic, D.Popovic, S.Rajsic, M.Tasic,
In: Environmental Research Trends, ed. M.Cato, Nova Science Publishers, pp 271-301, 2007

Assessment of Air Quality in an Urban Area of Belgrade, Serbia
Mirjana Tasić, Slavica Rajšić, Milica Tomašević, Zoran Mijić, Mira Aničić, Velibor Novaković, Dragan M Marković, Dragan A. Marković, Lazar Lazić, Mirjana Radenković, Jasminka Joksić,
In: Environmental Technologies, New Developments, Edited by E. Burcu Ozkaraova Gungor, I-Tech Education and Publishing, Vienna, Austria, www.i-techonline.com , ISBN 978-3-902613-10-3, 2008, 209-244

*In addition one major review of nanotechnologies and palsmas has been given at the ICPC Nanonet workshop in Prague in June 2009 and it has been published on the internet as presentation.*

0, Applications of plasmas for nanoelectronics and nanotechnologies: new plasma sources, new understanding of plasma surface interactions
Zoran Petrović
ICPCNanoNet Workshop1st June Prague (published on internet)
http://www.icpcnanonet.org/images/stories/Presentations_Wshop1/zoranpetrovicprague2009_part1.pdf
http://www.icpcnanonet.org/images/stories/Presentations_Wshop1/zoranpetrovicprague2009_part2.pdf)

During the past three years a large number of publications were made in international journals as well as a large number of presentations at conferences. Most importantly there were numerous invited lectures at very highly ranking conferences including a specialized conference on Micro discharges, ICPIG (International Conference on physics of Ionized Gases). Special characteristics of the second and third years of the project are that young

scientists, especially students, have participated in conferences more than before and the trend will continue. Even the presence of younger scientists as invited speakers increased. For example Dragana Marić gave a lecture at International Symposium on Electron Molecule Scattering and Swarms and so did Saša Dujko who gave an invited lecture as a student. Plan is to maintain the same level of presence in journals and conferences and hopefully the same number of invited lectures. Full list of publications is given at the end of this report.

Z.Petrović was invited to give a series of lectures to postgraduate students as a distinguished visiting professor at the Ruhr University in Bochum. While this is also a part of the training mission it served a purpose of disseminating our achievements in different branches of plasma physics.

## LIST OF DELIVERABLES

**Table 1: Deliverables List**

List all deliverables, giving date of submission and any proposed revision to plans.

| Del. No. | Deliverable name | Workpackage no. | Date due | Actual/Forecast delivery date | Estimated indicative person-months *) | Used indicative person-months *) | Lead contractor |
|---|---|---|---|---|---|---|---|
| D2 | Web site | WP1 | M3 | M3 | 4 | 4 | 1 |
| D3 | Project progress intermediate reports | WP1 | M2 | M24 | 6 | 6 | 1 |
| D4 | Upgrade of scientific equipment and installation | WP2 | M12, | M12, | 1 | 1 | 1 |
| D5 | Dissemination workshop | WP5 | M9, M35 | M9, M35 | 4 | 4 | 1 |
| D6 | Employment young researchers | WP3 | M12 | M12 | 36 | 36 | 1 |
| D7 | Electronic Newsletter | WP4 | M18 | M20 | 10 | 10 | 1 |
| D8 | Plasma database modelling | WP5 | M18 | M30 | 4 | 4 | 1 |
| D9 | Final project reports | WP1 | M42 | M42 | 4 | 4 | 1 |

***) if available**

## LIST OF MILESTONES

### Table 2: Milestones List

List all milestones, giving date of achievement and any proposed revision to plans.

| Milestone no. | Milestone name | Workpackage no. | Date due | Actual/Forecast delivery date | Lead contractor |
|---|---|---|---|---|---|
| M1 | Coordination of the -advisory board and steering committee | WP1 | 24 | 24-42 | 1 |
| M2 | Reports every six months | WP1 | 18 | 18 | 1 |
| M3 | Auditing | WP1 | 23 | 23 | 1 |
| M4 | Preparation of new proposals for EU and other sources | WP1 | 24 | 24-42 | 1 |
| M5 | Training courses for our students and for the students in the region | WP3 | 24 | 24-42 | 1 |
| M6 | Training missions by foreign partners | WP3 | 15 | 24 | 1 |
| M7 | Training on newly purchased equipment | WP3 | 24 | 24-42 | 1 |
| M8 | Activation Electronic Newsletter and mailing list | WP4 | 24 | 24-42 | 1 |
| M9 | Organization of the workshop and editing of Proceedings | WP5 | 24 | 24-42 | 1 |

# SECTION 3

# CONSORTIUM MANAGEMENT

According to our project proposal all management activities belong to the work package 1 and this section may be regarded as the report for WP1. In this section we will list the general activities of the management. Listing and details of specific programmes were made in reports for corresponding workpackages.

## OBJECTIVES OF THE WORK PACKAGE 1

Objectives of the Work package 1 consortium management were the following:

- coordination of the over
- all technical, financial and administrative management;
- coordination of knowledge management;
- maintenance of consortium agreement;
- information and communication activities, communication with EU commission
- satisfaction of legal norms, and procedures
- responsibility for facilities required to carry out the project in its entirety –resource management
- efficient decision making
- horizontal and vertical integration of the project adhering to the time scale- time management

## Activation of the newly obtained equipment, initiation of networking, dissemination and other workpackages

In the project period the most important tasks of the management were to initiate and oversee workpackages dealing with networking, training and dissemination of results and to oversee activation and implementation of the new equipment.

One of the most important tasks was to communicate with the management of the Institute. Project leader is a member of the board of directors of Laboratories and one of the co-leaders is member of the board of the Institute while the other has just completed the term in that board and acts as deputy director of the department. So they all have experience and developed connections with the management of the Institute. The management kept constant contacts with the external members of the board of the project. The management followed the flow of funds and met often to discuss how the funds should be used in the most optimal way.

Management often communicated with somemembers of the advisory board asking for advice, especially the advice regarding the equipment.

The management board initiated and oversaw execution of all supporting actions.

Plan was made for training, networking and dissemination. Measures were made that funding and time and human resources were appropriately assigned to ensure the success of the programs. Dissemination, networking and training programs have commenced and were actively pursued.

Management pursued all possibilities of opening new activities that would be in line with the project and discussed how to integrate those activities into the project. For example possibilities to organize two international conferences opened and also to participate in organization of one more. We have taken advantage to integrate those into our training

(by including our young students or even undergraduate students), networking (by organizing a specialized round table discussion at a closing on opening new international projects) and dissemination (by opening possibilities to present and disseminate our research) workpackages.

Management followed all sources of information on possible new projects and initiated applying to them if it was appropriated and in the best interest of the COE.

Management provided facilities for a workshop and publication of a book with review articles from the COE and from partners in the program.

The board initiated preparation of the reports, intermediate report after six months and maintenance of the web site and newsletter. It was also responsible for all the communication with the EU commission.

Finally management had to organize operation of the project in the last year when funds from our local government were reduced and delayed. Extension was organized in order to justify expenses for the remaining 10% of funds

## ADDITIONAL FUNDING SECURED BY THE ACTIVITIES OF THE MANAGEMENT

The purchase of PTR-MS, Proton Transfer Reaction Mass Spectrometer, a highly sensitive volatile organic compounds detector was funded by other activities. PTR MS is based on unique soft ionization technique and allows detecting and quantifying concentrations of components in the pptv range avoiding fragmentation of molecules. Real time and on line measurement combined with a detection limit of 30 pptv makes the PTR-MS as essential instrument for scientific laboratories and research groups all over the worlds. The first measurements of VOCs, in indoor and outdoor ambient air, were conducted. The instrument has a wide applicability in various fields such as:

Environmental research, Waste Incineration, Food and flavor science, Biological research, Process monitoring, Indoor air quality, Medicine and biotechnology. This piece of instrumentation was chosen as a complementary research tool enabling us to cover a wider range of applications and to have a better access to international projects and networks. Thus it is fully in line with the activities on the project.

**Opening new lines of research based on the new equipment**

Management has pursued new networks of collaborators within the community of scientists in the fields of biology, medicine, micromachining, technologies of organic materials, nanotechnologies and environmental science to open new possible lines of research based on our new equipment.

## Funding for engagement of students that will be employed through the COE

Management of the project has secured funds from its ongoing research projects with the Ministry of Science to engage students that have recently graduated to start working on the project. Thus a larger number of students has participated in the overall activity of the COE than originally planned.

# PLANS AND STATUS BARCHART

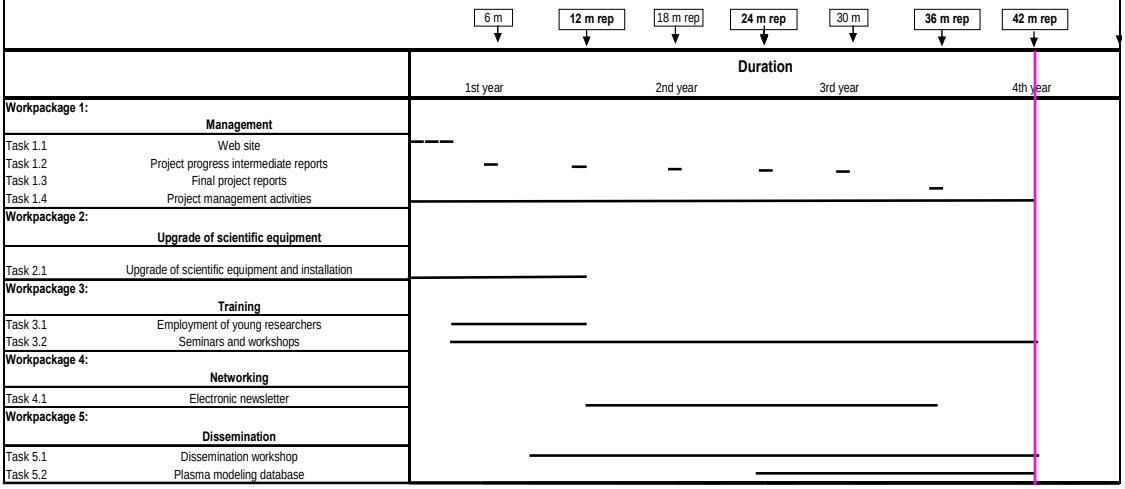
Our activities and plans for the remainder of the project are shown in the following barchart.

## Workpackages - Plan and Status Barchart

**PROJECT BARCHART and STATUS**

**Acronym:** IPB-CNP (to be frontlined to show status at project reviews)

**Contract N°** 26328 (any previous revisions to be attached if original plans are revised)




| | |
|---|---|
| **Workpackage 1:** | **Management** |
| Task 1.1 | Web site |
| Task 1.2 | Project progress intermediate reports |
| Task 1.3 | Final project reports |
| Task 1.4 | Project management activities |
| **Workpackage 2:** | **Upgrade of scientific equipment** |
| Task 2.1 | Upgrade of scientific equipment and installation |
| **Workpackage 3:** | **Training** |
| Task 3.1 | Employment of young researchers |
| Task 3.2 | Seminars and workshops |
| **Workpackage 4:** | **Networking** |
| Task 4.1 | Electronic newsletter |
| **Workpackage 5:** | **Dissemination** |
| Task 5.1 | Dissemination workshop |
| Task 5.2 | Plasma modeling database |

## CONCLUSION

The management has initiated and overseen training, networking and dissemination activities, communicated with the members of the board of the project, with management of the institute and with EU officials.

Management has followed expenditures, made plans and made sure that optimum results are achieved for the existing funds. Most importantly in all aspects of activities results were achieved that go beyond the initially planned results: additional workshops and conferences were organized, additional book of review papers was published, between 5 and 10 students participated in the activities, additional equipment was purchased from new sources and integrated in our activities. Additional sources were sought and new projects were proposed together with our colleagues some of which are members of the board of our project and some are colleagues that we met to discuss the projects proposals through activities of the COE.

In the segment of training we made sure that all students participate in international conferences as those are the best options for learning and making contacts, young researchers were promoted to give invited lectures.

# SECTION 4

## OTHER ISSUES

1. **ETHICAL ISSUES**

In this project we do not have any ethical issues apart from maintaining standard ethical practices for scientific research and for higher education.

**1. GENDER ISSUES**

In this project we adhere to the standard practices of equal opportunity employment and in addition we have made special measures to improve the status of female scientists.

1. That this was a policy adopted well before the beginning of the project is obvious from the fact that two out of three co-chairpersons are female and women participate at all levels of decision making.

2. Number of female members of the team is 11 with two female associate members. Number of male participants is 9 with no external associate participants.

3. Policies of the Institute of Physics towards racial and gender issues are in accordance with world standards and may be seen at:

http://www.ipb.bg.ac.rs/article/?id=26

as:

Institute of Physics is an equal opportunity employer. It is committed to the following principles:

- To promote equal treatment of its personnel regardless of their gender, ethnic origin, physical handicap, sexual orientation or religion.
- To ensure fair treatment in all recruitment and promotion actions.

- To provide a professional environment free of discrimination or harassment and enable all personnel to work in an atmosphere of safety, dignity and mutual respect.

- To promote policies and practices that encourage equality of opportunity in all respects.

We have prepared a set of policies in order to facilitate scientific careers of women that have families. The measures have the goal to compensate for lost opportunities for furthering career during pregnancy and due to inability to visit other laboratories or spend sabbaticals away from the home town due to the need to take care of the children.

Equal opportunities were provided to all members of the COE with adherence to the policies that were detailed above. As it turned out some of the female members took a better advantage of the opportunities than male judging by the fact that two former students at the time the project started are now general secretary and member of international scientific committee of the leading international conference in her field, while the other is principal organizer of a workshop on plasma medicine. As mentioned in our application the project allowing brief visits to foreign laboratories with stable position in the home institute allowed many women to pursue scientific carreers better.

# ANNEX

# PLAN FOR USING AND DISSEMINATING THE KNOWLEDGE[1]

## SECTION 1

### EXPLOITABLE KNOWLEDGE AND ITS USE

We have generated a wide range of data that may be exploitable after further research. Since, however, the primary goal of the project is to improve the visibility of the laboratory and its chances for further integration into the projects of the EU commission we have focused on improving our scientific ranking rather than pursuing possible applications. Nevertheless there are the several lines of research that may lead to application given the funds and manpower.

In that situation the best strategy is to provide the data and research of interest to those doing the applications so that we have both possibilities, publications in scientific journals and at the same time connections to the industry and interested users. Our ultimate goal is to make an agreement with a manufacturer of plasma equipment for integrated circuit production and carry out research for them under special contracts.

Overview table:

| Exploitable Knowledge (description) | Exploitable product(s) or measure(s) | Sector(s) of application | Timetable for commercial use | Patents or other IPR protection | Owner & Other Partner(s) involved |
|---|---|---|---|---|---|
| *1. Database for transport of negative ions in plasmas* | *Plasma modeling for device development* | *Plasma etching device production* | *2009* | *Data will be distributed through our web site from 2007 with some limitations, some of the data published in a journal* | *Z.Lj.Petrovic, J.Jovanovic, Z.Raspopovic, V.Stojanovic, G.Malovic* |
| 2. Plasma needle with external grounding o ring | Plasma source, plasma treatment procedure | Medicine, nano-technologies, research | 2010 | Patents planned for later specific developments | N.Puac, G.Malovic, S. Lazovic, A.Djordjevic, Z.Petrovic |
| 3. Physical and chemical characterization of suspended particles | Comprehensive monitoring station | Environmental protection | 2009 | This is a monitoring station with the need to obtain accreditation and be applied as a part of the regional system for monitoring | M.Tasic, S.Rajsic, V.Novakovic, |
| 4. The effect of secondary electron yields on performance of two frequency | Knowledge on optimal plasma technology | Information technologies, plasma processing of integrated | Improvement of the existing technology | Scientific publications, as patents would require building of a functional | Z.Lj.Petrovic, Marija Radmilovic, Dragana Maric, Zeljka Nikitovic, |

| Exploitable Knowledge (description) | Exploitable product(s) or measure(s) | Sector(s) of application | Timetable for commercial use | Patents or other IPR protection | Owner & Other Partner(s) involved |
|---|---|---|---|---|---|
| etching plasmas | | circuits, nanotechnologies | | plasma etcher which is beyond our means | N.Skoro |
| 5. Volatile Organic compounds (VOCs) in indoor and outdoor environment and application in medical and biological research | | Environmental protection, Medicine, Bilogy | Improvement of the existing methodology<br><br>2010 | Scientific publications, New methodology | M.Tasic, A.Stojic, S.Rajsic, Z.Petrovic, G.Malovic, N.Puac, Z.Nikitovic |

## 1. DATA BASE FOR TRANSPORT DATA FOR NEGATIVE IONS

Based on the request from the plasma device manufacturers community and especially by the modelers of the plasmas with comprehensive models integrated vertically and applied to develop new generations of plasma devices we have put together a data base for the transport properties for the negative ions which exist in plasmas used for processing of integrated circuits.

Data base is available online from 2008 and will have some limitations for use as it will be free for academia but will require a small fee for commercial applications.

## 2. PLASMA NEEDLE

It's an rf supplied atmospheric glow discharge operating in a mixture of helium or argon with air. It is similar in its operation to atmospheric pressure glow plasma jet developed by G. Selwyn only it is much smaller and control is maintained so that plasma does not heat the gas beyond 40 degrees C so that the plasma may be applied to the living tissue.

It was first developed by E. Stoffels in Eindhoven and applied to induce apoptosis and tissue separation and to treat dental cavities without drilling. Efforts are made to use it in treatment of cancer, cosmetic surgery and heart and vascular system surgery. We have shown its performance in inducing growth of plants and in direct treatment of plant cells.

We have developed the system with good measurement of the power deposition by using derivative probes and with an external grounding o ring to stabilize the discharge.

Plasma needle may be used for treatment in medicine, for low damage surgery and in treatment of materials. It may also be applied in research both in physics and in medicine.

Device has a wide possible range of applications, possible socio economic impact and we have made some preliminary measures to get possible applications developed in collaboration with scientific groups in medicine and materials science.

System for better control of the power was applied in order to .control gas temperature and avoid necrosis induced by heat. Direct measurement of such small powers is unique and is certainly marketable for a range of rf powered atmospheric pressure plasma sources.

### 3. PHYSICAL AND CHEMICAL CHARACTERIZATION OF SUSPENDED PARTICLES

Sampling of PM10 and PM2.5 suspended particles in Belgrade urban area were continued. Mass concentration measurements and trace element analysis were performed. After statistical data processing (multivariate receptor modeling) and consideration of meteorological parameters influence, the analysis of air back trajectories for high PM concentrations was done. The so-called Eta model used for simulation and air back trajectory calculation is a regional weather prediction primitive equation model for synoptic and meso-scale processes. In this study model with 3.2 km horizontal resolution and 32 layers in the vertical was used. The boundary conditions were updated every 6 hours obtained from European centre for Medium-Range Weather Forecast (ECMWF). The model has been used for research in entire Serbia region and boundary regions of the other countries in the neighborhood.

The newly purchased system for x ray spectroscopy completes our station of monitoring of air pollution and makes it possible to seek accreditation to be the regional centre for pollution monitoring. EDXRF spectrometry was applied for

the specific purpose of compositional analysis of archaeological artifacts such as ceramics, metal and glass samples of different periods and origins in Serbia. Using the XRF technology, Centre supports and promotes the activities in the field of protection of cultural heritage and established new links with other similar scientific Centers in Europe.

Our system for sampling from the atmosphere has been protected locally and this new device will become auxiliary detection technique for the system.

Proton Transfer Reaction Mass Spectrometry (PTR-MS) (Ionicon, Innsbruck, Austria) allows on-line real-time concentration measurements of volatile organic compounds (VOCs) in the air with a high sensitivity (10–100 pptv) and a fast time response (1–10 s) in 30 pptV to ppmV range. The air to be analyzed is continuously pumped through a drift tube reactor and a fraction of the VOCs is ionized in proton transfer reactions with hydronium ions (H3O+) if their proton affinities are higher than H2O. The advantage of using proton transfer is that it is a soft ionization method that generally does not lead to fragmentation of the product molecular quasi what simplifies the mass spectra. The method requires no sample preparation.The device is constantly applied in atmospheric research of ambient air at urban and semi urban areas in Belgrade since the summer 2007. It was confirmed that the concentrations of many VOCs are higher in urban then in semi urban area. Diurnal variations, shown below, and correlations between VOCs, meteorological parameters, NOx, SO2 and ozone were found. Indoor air quality is observing constantly.
The device was applied in biological research of accumulation of nepetalactone in the atmosphere of the glass jars in shoots of *Nepeta rtanjensis* grown *in vitro*. The obtained results varied with the carbohydrate type present in the culture medium. Furthermore, it was found that the variability in nepetalactone accumulation was significantly different between different genotypes. An effort was made to apply PTR-MS in breath analyses to provide noninvasive diagnostics

of diabetes. The application of PTR-MS in biology and medicine is in the course, and first results are published in the conference proceedings.

## 4. APPLICATION OF SECONDARY YIELDS IN PLASMA MODELING

The role of secondary yields in gas discharges has been neglected when it comes to plasma sources for production of integrated circuits. The need to go to nanostructures and etch high aspect ratio contact holes made it necessary to reduce charging of the insulators during the etching and to apply pulsed two frequency systems to control the energy of ions independently of the plasma source. Our group was one of the first to point this out. Further modeling is required to elucidate the role of secondary electrons in such plasma sources and then to optimize the performance of the plasma device. Our group was also the first to describe properly how secondary yields affect dc discharges so by combining these two results it will be possible to give an insight on the performance of pulsed rf discharges.

We do not plan commercialization of this knowledge but we plan integration into international projects and collaborations and possibly collaboration directly with device manufacturers. During the third year of the project one of the new students for the Masters course (Marija Savic) has started a project to develop a general tool based on Monte Carlo technique for transport of electrons, ions, fact neutrals, metastables and photons to model secondary electron yields in a series of more complex gases of technical importance. These data will be essential in numerous applications and may be subject of commercial distribution.

# SECTION 2

## DISSEMINATION OF KNOWLEDGE

Our work has been widely presented in a number of scientific and general TV shows over the period of 5 years. Daily newspapers have recorded some of our activities on a number of occasions.

Two workshops on nonequilibrium processes in plasmas and environmental science and one EU Japan symposium on plasma processing were organized in our home country. Two workshops were organized Completion of review articles was solicited from the selected participants of the conference and other renowned scientists including some of the members of our COE. Refereeing and editing of the articles was organized and then both electronic and hard bound versions of the book were published by a specialized series of the largest international publisher of journals in physics, UK Institute of Physics (Conference Series).

The book serves multiple purposes:

-it is a good pedagogical introduction for students into topical research issues in the field;

-presentation of the results from our group served as a good comparison, test of the validity and quality of our results and the most efficient dissemination of our results as the intended users of our results were in the audience;

-to give our project and the COE a motivational focus and provide team work across the specialized teams giving the whole centre greater coherence and unity;

-it served a purpose of networking as several proposals of EU projects were put together on the basis of the direct interactions of different scientists during the meeting.

**Dissemination**

| Dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible /involved |
|---|---|---|---|---|---|
| 12 2007 | Daily newspaper article Politika daily article on the visit of SJ Buckman, JP Marler and RD White | General | Serbia, West Balkan region | One million | Z.Lj. Petrović |
| 03 2008 | Press release (75 years since the discovery of positrons) | general | Serbia, West Balkan Countries, all | Through B92 web publication press release available to all | Z.Lj. Petrović |
| 04 2008 | Article based on the press release in Novosti the biggest selling daily journal in Serbia | General public | Serbia, West Balkan | One million | Z.Lj. Petrović |
| 04 2008 | 15 minute main feature in a show on science at TV Vojvodina 1 | General Public | Serbia | Two Million | Z.Lj. Petrović |
| 05 2008 | 10 minute segment of a TV show on science Kontekst 21 of the national TV channel RTS 2 | General | Serbia | Two million | Andreja Stojić |
| 06 2009 | 10 minute segment of a TV show on science of the national TV channel RTS 2 | General | Serbia | Two million | Z.Lj. Petrović M. Tasić |
| 2007-2008 | WEB site upgrading | All | All | All interested | N. Puač, N.Škoro |

| | | | | | |
|---|---|---|---|---|---|
| **01/10/2007** | **News letter Direct e-mailing** | **Scientists in the region** | **Serbia, Croatia, Bosnia, Boulgaria, Romania, Hungary, Greece, German, UK, USA, …** | **60** | **S.Dujko N. Škoro** |
| **11/2007** | **Postgraduate course at Ruhr University in Bochum** | **Scientists at Ruhr University Bochum** | **Germany** | **50** | **Z.Lj.Petrović** |

Some of the activities are given in the table above.

During the past three years a large number of publications were made in international journals as well as a large number of presentations at conferences. Numerous invited lectures were presented at very highly ranking conferences including a specialized conference on Micro plasmas, ICPIG (International Conference on physics of Ionized Gases). Also it is important to note that we have been invited to the first conference on Application of plasmas in nanotechnologies, to write a 50 page chapter for a book providing foundation of nanotechnologies, to a steering committee of FP7 project preparing a database of activities in nanotechnologies and nano science.

A special characteristics of the of the project is that young scientists, especially students, have participated in conferences more than before and the trend continued in the third year. Even the presence of younger scientists as invited speakers increased. Two of the PhD students were invited to give invited lectures at major International conferences (**Sasa Dujko and Ana Bankovic**) in the previous period and **Sasa Dujko** gave an invited Lecture at a major US conference GEC right after obtaining a PhD thesis..Plan is to maintain the same level of presence in journals and conferences and hopefully the same number of invited lectures. Full list of publications is given in at the end of this report.

Web site was developed already in the first year with the purpose of dissemination of our results. The web is filled with information regularly and expanded,its progress is only limited by publication of the related papers. In a complex project such as ours one always finds new things that need to be represented on our site and the process will continue in the third year as well. Details are given in Deliverable 2.

All our conferences/workshops were well organized, with designed logos. Poster was also designed for the workshops, and use of similar symbols gave a sense of continuity while providing a visual identity to all meetings.

. Workshops were successful and each involved around 20 speakers from the renowned laboratories from many countries (UK, France, Germany, …).

One of the speakers at the second workshop in Serbia, Uwe Czarnetzky from Ruhr University in Bochum has won prize for applications of plasmas for the 2010 EPS conference and one of the papers cited for the award was the paper from the workshop proceedings. Member of the committee, steering committee of this project and participant of both workshops has won IUPAP young scientist award in July 2009.

Books of proceedings from the Workshop were published online by Institute of Physics Conference series and also as a hard copy. In order to improve the visibility and dissemination of our results we have made payment to enable free downloading of the papers from the all books.

Our centre has won organization of the 20th ESCAMPIG (European Conference on Atomic and Molecular Processes in Ionized Gases). Organization has already begun and preparations for the conference are the main activity of the group.

# SECTION 3

## PUBLISHABLE RESULTS

A general database has been developed for the transport properties and collision cross sections for charged and non-thermal neutral particles in ionized gases. It will consist of several separate data bases: electron-molecule scattering and transport, positrons in gases, negative ions in gases etc. Each of these subsets represents a separate entity with critically evaluated comprehensive data that may be used in plasma modeling and in modeling of novel technologies like representing deposited radiation and energy in human tissue and optimization of positron emission tomography.

### 1. DATA BASE FOR TRANSPORT DATA FOR NEGATIVE IONS

***Z.LJ.PETROVIC, J.JOVANOVIC, Z.RASPOPOVIC, V.STOJANOVIC, G.MALOVIC***

***DATA WILL BE DISTRIBUTED THROUGH OUR WEB SITE FROM 2007 AND 2008 WITH SOME LIMITATIONS, SOME OF THE DATA WERE PUBLISHED IN SCIENTIFIC PAPERS***

Based on the request from the plasma device manufacturers community and especially by the modelers of the plasmas with comprehensive models integrated vertically and applied to develop new generations of plasma devices we have put together a data base for the transport properties for the negative ions which exist in plasmas used for processing of integrated circuits.

Data base was available online during 2008 albeit with some limitations for use. Only Figures were available and tabulated data were sent to those who requested them. Data were free for academia but will require a small fee for commercial applications. The data base is still being developed and new entries were made for Cl- ions in rare gases (He, Ne, Ar, Kr, Xe) and F- ions in Ar, Xe and Kr.

This data base will be of interest to plasma modeling community and manufacturers of plasma devices. Until the end of 2008 all available entries for halogen ions were completed and new calculations were entered.

Furthermore

Contact person Zoran Lj. Petrovic zoran@ipb.bg.ac.yu.

## 2. DATA BASE FOR COLLISIONAL CROSS SECTIONS TRANSPORT DATA FOR ELECTRONS IN REACTIVE GASES

***Z.LJ.PETROVIC, O. ŠAŠIĆ, S. DUJKO, Ž. NIKITOVIĆ, V.STOJANOVIC, G.MALOVIC***

***DATA WILL BE DISTRIBUTED THROUGH OUR WEB SITE FROM 2008 WITH SOME LIMITATIONS, SOME OF THE DATA WERE PUBLISHED IN OUR SCIENTIFIC PAPERS***

Electron Transport and Collision Data for $BF_3$, $CF_4$ and HBr were posted on our web site as a part of the data base. All of those gases are critical for applications in production of integrated circuits and apart from $CF_4$ data for those gases were almost completely lacking. However, in all cases some new developments were made such as the effect of ExB fields and time resolved data. The database is still being developed and some improvements in presentation and final entries of the data are still being made.

The data sets for mixtures of $CF_4$ and $BF_3$ with relevant $CF_x$ and $F_x$ radicals have been prepared and will be posted as the results are published in the literature.

The data set for $N_2O$ has been prepared including a number of transport coefficients and the revised set of cross sections. The tables had to be posted in full based on the request of the editor of the journal where the data have been published.

## 3. DATA BASE FOR COLLISIONAL CROSS SECTIONS TRANSPORT DATA FOR POSITRONS IN GASES

***Z.LJ.PETROVIC, J.MARLER, S. DUJKO, A.BANKOVIĆ, G.MALOVIC***

***DATA WILL BE DISTRIBUTED THROUGH OUR WEB SITE FROM 2008 WITH SOME LIMITATIONS, SOME OF THE DATA WERE PUBLISHED IN OUR SCIENTIFIC PAPERS***

Positron transport and collision cross section data for Ar $N_2$ and $H_2$ were posted on our web. Those data were developed with an aim of modeling collisional positron traps for low energy (subexcitation energy) positrons and deposition of positrons, focusing and optimization of computer aided tomography as applied for medical diagnostics and in materials science.

The work is under way to extend this to water vapour; a set is complete but will be posted only when the corresponding paper has been published. The same is true for the collection of the positronium cross sections and so far we have acquired data from the literature for He, Ar and $H_2O$.

## FULL LIST OF PUBLICATIONS FOR THE 42 MONTHS OF ACTIVITY

In addition to the activities presented or planned we have also presented our results through standard channels of scientific publication, papers in journals and presentations at conferences. Here is a list of all publications.

### Books

1. Plasma Electronics: Applications in Microelectronic Device Fabrication
T. Makabe Z. Petrović
Taylor and Francis, CRC Press, New York (2006).

### Papers in journals

1. Measurements of voltage–current characteristics of a plasma needle and its effect on plant cells
N Puač, Z Lj Petrović, G Malović, A Đorđević, S Živković, Z Giba and D Grubišić
J. Phys. D: Appl. Phys. 39 (2006) 3514–3519 doi:10.1088/0022-3727/39/16/S09

2. Investigation of modified thin SnO2 layers treated by rapid thermal annealing by means of hollow cathode spectroscopy and AFM technique
R Djulgerova, L Popova, G Beshkov, Z Lju Petrović, Z Rakočević, V Mihailov, V Gencheva and T Dohnalik
J. Phys. D: Appl. Phys. 39 (2006) 3267–3271 doi:10.1088/0022-3727/39/15/008

3. Secondary electron emission of carbonaceous dust particles
I. Stefanović, J. Berndt, D. Marić, V. Šamara, M, Radmilović-Radjenović, Z. Lj. Petrović, E. Kovačević, and J. Winter
Phys. Rev. E 74, 026406 (2006).

4. The study of Control Parameters for some Divalent Metal Cations Sorption by Recycled Wool-based Nonwoven Material
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