Final Program

STW Perspectief Program

Building on Transient Plasmas (BTP)

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1. Executive Summary

Plasmas are partially ionized gases. Plasmas exist in nature, but they can also be produced by man, and serve for a widespread range of applications: from semiconductor processing to environmental applications. In many applications, transient plasmas can perform much better in processing precision and energy efficiency than continuous plasmas, or they even can offer unique new features. The current lack of fundamental understanding of these transient phenomena, however, limits reproducibility and process control, which in turn prevents wide scale implementation. This program will provide the scientific background needed by the industrial partners to reliably apply transient discharges in their products and production processes. This includes high efficiency lighting by discharge lamps, the generation of EUV photons, creation of beams of electrons, ions and photons, processing of surfaces, biomedical applications, and treatment of flue gases.

To improve the performance of these plasmas, we will continue to set new international standards in plasma diagnostics, pulsed power technology and comprehensive modeling; and we will continuously test the results of different methods on one another. The results will be developed in close contact with the needs of the industrial partners, and they will be presented in an easily accessible manner for the users.

In the course of the program, we will produce a <u>design toolkit</u>: a comprehensive set of experimental descriptions, scaling laws, design rules, pulsed power technology, and validated models of transient plasmas. The industrial end-users will use this toolkit to implement new technologies and to improve their existing technology.

One of the main, and lasting, results of the program is a national platform, which unites all relevant industrial parties. In this platform, which is a meeting place and plays a mediator role, industrial parties will mutually exchange technical as well as non-technical information (commercial, regulations, markets), and will also be able to meet the academic parties.

2. Setting

<u>History</u>

The plasma medium is often denoted as the fourth state of matter. The ancient Greeks introduced the first three states of matter: solid, liquid, and gas. These consist predominantly of electrically neutral atoms and molecules. In plasmas, part of the atoms and molecules are ionized: this determines their characteristically different behavior. The word “plasma” was introduced by Irving Langmuir in 1928. Plasmas can occur in nature, but they can also be produced “on command”. Examples of plasmas in nature are lightning, the aurora, and stars. Lightning is the most prominent example of a transient plasma in nature, creating different plasma states during its short duration that all are very far from equilibrium.

Plasmas have played a major role in the development of modern day physics. Since Michael Faraday, at the beginning of the 19^{th} century, plasmas were used as a means of dissociating and ionizing matter, thus creating the opportunities for the discovery of the internal structure of atoms and molecules.

The start of the 19^{th} century also marked the first application of plasmas: arc lamps were introduced by Humphry Davy. Lighting remained the main application of plasmas for more than a century. The plasma lamps only penetrated the market after the introduction of electricity networks, around the turn of the 20^{th} century. From the middle of the 20^{th} century, the application range of plasmas expanded drastically, and nowadays only a few high tech products are around in which plasmas were *not* used in the production process. At the same time, the plasma physics discipline in Eindhoven was founded by two famous plasma physicists: Gilles Holst at Philips Research Laboratories and Hendrik Dorgelo at the TU/e. In the late fifties, it was discovered that plasmas are excellently suited as a medium in which nuclear fusion reactions generate power which can be harvested. The tokamak concept was introduced by Andrej Sacharov as one of the platforms for controlled nuclear fusion.

Applications: the present

At present, plasmas have gained a vital role in many industrial processes. In most cases, continuous plasmas are used.

Plasmas are used for a wide variety of lamps: from fluorescent tubes and compact fluorescent lamps to High Intensity Discharge (HID) lamps. If one observes the earth at night time, more than 99 % of the visible light is produced by HID lamps.

Plasma etching processes are vital for modern day micro-electronics. When the structures in a silicon wafer are etched with a plasma, the side walls can remain straight, while liquid etching creates curved sidewalls. The introduction of plasma etching processes has actually enabled the industry to live up to the predictions of Moore’s law.

Plasma deposition machines are vital for the production of architectural, coated, glass. Parts of machines which need a high hardness or wear resistance are routinely coated with materials like titanium nitride in a plasma machine. Solar cells, especially the ones on flexible substrates, can only be produced by plasma processes.

Transient plasmas

For some applications, transient plasmas are gaining importance. These plasmas have a distinct time dependence, which determines their properties. Transient plasmas can be created by pulsing the applied voltage (e.g. in a corona discharge). It is also possible to specifically shape the onset (starting, ignition) of a continuous plasma in order to influence the continuous state.

In general, the transient nature of the plasma offers many advantages. The gas can remain cool while active species like electrons can reach very high energies that are very far from any equilibrium distribution. These energetic electrons can very efficiently trigger the formation of chemically active radicals, ions and molecules, while power consumption, e.g. through useless gas heating can be minimized.

There are a few areas where transient plasmas already have a sound position. One example is the electrostatic dust precipitator, which is essentially based on corona discharges, and which is now installed in many chimneys of electrical power stations. A second example is the corona wire which is present in all laser printers, and which charges the paper electrostatically. A third example can be found in the textile industry, where transient plasmas are used to process the surface of textiles in order to improve the adhesion of prints.

In other areas, industry is considering applying transient plasmas for totally new applications, but an industrial base is still largely non-existent. Examples of this category are:

- removal of VOC's (volatile organic compounds), NO_x and SO_x from flue gases
- dry and cold sterilization and disinfection
- transient plasma based medical treatments (e.g. stimulated wound healing)
- pre-treatment of biomass and fossil fuels to enhance their complete and clean combustion
- mercury free discharge lamps
- reliable EUV lithography
- new plasma cleaning concepts for the semiconductor industry
- plasma based XUV lasers

At this very time, transient plasmas are on the verge of large scale application with an extremely broad technological scope. The reason that the application up to now is still limited lies in the fact that quite a few technological breakthroughs have to be realized: bottlenecks have to be overcome. This BTP program aims at enabling these required technological breakthroughs with an approach of combining high-level academic research with advanced industrial development activities, thus laying the base for a myriad of new products and technologies.

3. Goals, ambitions, and industrial relevance

In many applications transient plasmas can deliver much better performances than continuous plasmas. The current lack of fundamental understanding of these transient phenomena, however, limits reproducibility and process control, which in turn prevents wide scale implementation. This program will provide the scientific background needed by the industrial partners to reliably apply transient plasmas in their products and production processes. Furthermore, this program will be instrumental in creating a platform where industry and academia can meet and exchange information on transient plasmas regularly. This platform, in which *all* relevant industrial and academic parties in The Netherlands are united, and which does not exist anywhere else in the world, will bring Dutch industry to the forefront of the technology. It will be continued after the program expires.

3.1. Enable breakthroughs in plasma technology

Up to now, transient plasma technology is applied on a modest scale. However, the application range and the market penetration are still limited. To a large extent, this is caused by the limited scientific understanding of the phenomena which occur in reactive plasmas far from equilibrium. We have reached the point where the trial-and-error approach no longer suffices to advance the technology. Questions to be answered are:

- How do transient phenomena enhance the performance of plasma technology?
- How can these phenomena be altered at will?
- How can we measure, understand, model, manipulate and control transient plasmas in order to optimize existing technologies and enable new technologies?

To address these questions, we have to continue to elucidate the elementary physical and chemical processes underlying these phenomena. We already have an international standing in new measurement techniques to excite and probe these transient processes and in new physically and chemically accurate methods for modeling transient phenomena in plasmas. On the one hand, the existing knowledge has to be translated to practical guidelines for steering and controlling industrial plasma processes. On the other hand, existing methods have to be extended and cross-checked against each other, and new methods have to be developed for future use.

As this is most promising for industry, the focus of this program is on Transient Plasmas: plasmas which have an essential temporally developing aspect. Examples of transient plasmas are: corona discharges, dielectric barrier discharges, lightning and sprites, atmospheric pressure glow discharges, continuous plasmas in the ignition phase, laser produced plasmas, time modulated plasmas, magnetically contracted pinches, and pulsed and high frequency plasmas. These concepts and similar ones that have already been proposed should be brought to widespread application via the results of this program. On the other hand, proposals for other types of transient plasmas are also invited for investigation in the program.

An important element in the successful application of transient plasmas is the ability to yield the desired beneficial effects without heating the gas. They are far from thermodynamic equilibrium, which enables the delivery of active species with efficiencies that cannot be equaled by continuous plasmas. Therefore, an important part of the activities in this program will be devoted to the non-equilibrium aspects.

If a high frequency plasma is started in, for example, a lamp, details in the ignition process can have consequences for the continuous operation later on. The shape of the discharge (for example whether it is contracted or diffuse) depends on the exact sequence during startup. There is a history effect: transient phenomena influence continuous operation. These and other temporal effects, which determine the efficiency of the continuous discharge developing at a later stage, play an important role in the program.

The transient plasmas will be investigated in a coherent multi-disciplinary approach jointly by universities, knowledge institutes and industry integrating fundamental and applied research. Development of the transient plasma technology will be based on new and quantitative understanding of the various transient phenomena, providing explanations and control at a much more fundamental level than traditional engineering approaches. When the program is completed, the participating companies can finish the development of new plasma technologies, which will be based on control of transient phenomena, with improved efficiency and performance.

3.2. Industrial initiatives and targeted results

Transient plasmas are applied (and can find new applications) in many technological areas. In the following we will address four technology areas, name the industries which are active in that area, and present some targeted results which this program is aiming at.

- ***Environment****:* In The Netherlands, the interest of SME's for transient plasma technology is rapidly increasing. To a large extent, these activities center around environmental technology: the application of transient plasmas (mostly corona discharges) for the removal of poisonous, environmentally hazardous, or foul smelling components in exhaust gases and waste water.
  - *Active industries:* Oranjewoud, Circlair, 4QAir, Verhoeve Groep, Airotec. All these companies are starting up activities in the area of flue gas and air cleaning.
  - *Targeted results*: Improved performance of corona reactors and dielectric barrier discharges which are used for the treatment of flue gases and the generation of ozone. The industrial partners in this program will be able to launch new products and build up and broaden their market share.
- ***Light and radiation****:* Plasmas are able to generate light and radiation at the desired wavelengths in an efficient way. In many cases, transient phenomena play an important role in the efficiency of the final industrial process.
  - *Active industries:* Philips Lighting (ignition of plasma lamps), ASML (pulsed pinches for EUV radiation), NCLR (pulsed plasmas for laser operation), Dutch Scientific, i.e., Demaco Holland BV, Dutch Space, Heeze Mechanics, Hitech Power Protection, INCAA Computers, Imtech Vonk BV, Schelde Exotech BV, TNO (EU XFEL initiative), DSM (transient plasmas for controlled photo-chemistry) and FEI (transient plasmas for ultra-bright beams of electrons and ions).
  - *Targeted results:*
    - Better understanding of the starting of HID lamps. Under some conditions, these lamps ignite very well, under other conditions not at all. Understanding the underlying physical principles is vital to overcome the industrial complications. Proper ignition of the lamps is also a key issue in the

everlasting efforts to increase the energy efficiency, which may lead to direct, substantial, energy savings.
    - New concepts for mercury free lamps.
    - New plasma sources for the generation of EUV radiation for next generation lithography machines. Magnetically pinched plasmas in Sn vapour are explored for this technology. The extreme conditions during the transient phase of these plasmas result in several industrial problems like the generation of (lots of) Sn vapour and other kinds of debris which contaminate the machine. Laser produced plasmas are considered at this moment.
    - High Harmonic Generation based EUV sources for spatial and temporal control of EUV and XUV free-electron lasers (FELs: e.g. Fermi@Elletra, Trieste, Italy).
    - Better control of the transition between the filamentary and the uniform discharge mode in atmospheric pressure plasma processing or for high-beam quality excimer lasers.
    - New plasma sources in waveguides and transient plasma sources of electrons and ions.
- ***Surface processing**:* Another application area is the processing of surfaces using transient plasmas.
  - *Active industries*: Bradford Engineering (sterilization of medical instruments using transient plasmas), Vision Dynamics (polymer processing), Fuji (processing for plastic electronics), Philips (application of transient plasmas for biomedical applications), Catharinaziekenhuis Eindhoven (application of time modulated plasmas for skin treatment), Brandwondenstichting (plasma treatment of burns), Draka Comteq (transient phenomena in plasmas used for optical fiber production), SolMates and TSST (pulsed laser deposition), TNO Defense and Safety (textile processing, decontamination and disinfection).
  - *Targeted results*:
    - new processes for skin treatment based on a matrix addressable plasma tool, which uses the transient behavior of the radicals produced by the plasma in an intelligent way.
    - new industrial processes for the treatment of medical tools, protective clothing, textiles, plastic electronics, and glass, based on transient plasma technology.
- ***Lightning**:* Lightning is a powerful natural phenomenon, which causes a lot of damage, in particular, for all the microelectronic components that become increasingly important in our daily life. Lightning is a very clear example of a transient plasma; its early stages consist of corona discharges. High power sparks fall in the same category.
  - *Active industries:*
    - Van der Heiden Group (Lightning protection systems), KEMA (sparks), NS (sparks), and KNMI (lightning and other atmospheric plasmas).
  - *Targeted results*:
    - X-ray sources based on laboratory produced lightning strikes.
    - Improvements in lightning protection.

- new, much more reliable, switches, feedthroughs, and isolators for high voltage applications.

3.3 National and international position

National profile

Academic institutes in the The Netherlands for which the study of transient plasmas is "core business" are limited in number: Eindhoven University of Technology (faculties of Applied Physics and Electrical Engineering), Twente University (Applied Physics), and the Center for Mathematics and Informatics Amsterdam CWI (MAS 3). In addition to these groups, other teams will participate in the program and focus more on the application aspects. Examples are the Free University Amsterdam and the Faculties of Biomedical Engineering of the TU/e and the UT (medical applications), Faculty of Chemistry of the TU/e (micro-plasmas for chemical processing), FOM Institute for Plasma Physics "Rijnhuizen" (EUV optics), Delft University of Technology (EUV technology and semiconductor processing), Utrecht University (surface processing), and Groningen University (medical applications).

International position

The interest in transient plasmas is not restricted to The Netherlands. There are many active teams all around the world. Important players in Europe are the teams in Bochum and Wuppertal (Germany), Greifswald (Germany), Palaiseau/Paris (France), Toulouse (France), Bari (Italy), Belfast (UK). In the USA we can think of the teams in Norfolk, Toledo, Philadelphia, Berkeley, and others. In Russia the teams of ISAN and IVTAN in the Moscow region are very active.

However, a coordinated effort to bridge the gap between fundamental understanding and new applications and covering a wide range of industries is missing. The present program addresses the need for such coordinated effort.

Within this program, we will continue to generate generic knowledge on transient plasmas and with joint efforts we will translate this knowledge to practical implementation for the different industrial partners. This is done in a combination of models and the combined use of measurement techniques which are the keys to create new possibilities to understand, model, measure and apply transient processes in plasmas. The joint research focus on transient plasmas will therefore lead to a much more coherent and stronger knowledge position of Dutch plasma technology sector. This goal can only be reached via the STW Perspectief programma, and hardly via the existing STW Open Technologie Programma because in the latter each subproject is evaluated independently, without reference to the contribution to a common wider goal.

One of the more important assets of this program is the creation of a platform on transient plasma technology. This platform, in which *all* relevant industrial and academic parties in The Netherlands are united, will bring Dutch industry to the forefront of the technology, will enhance the market share of Dutch industry, and will bring Dutch academia to the international scientific pole position. It is a meeting point where not only scientific and technological, but also other industrially relevant information will be exchanged (commercial, marketing, regulations, etc). This platform will be a lasting effect of this program.

Relation with public policy and funding programs

There are several other national programs with which collaborations could be set up. Those programs generally focus fully on the application aspects, but synergy opportunites exist with the plasma physics research we are conducting in this program. We think of the following list:

- SenterNovem: EOS. Energy and environmentally related research.
- NWO program “Nieuwe instrumenten voor de gezondheidszorg”
- NNI, Netherlands Nano Initiative. Joint proposals will be initiated in the area of EUV technology.
- ESA, NIVR and NLR: new initiatives for re-entry protection
- NIVR: sterilization for space technology
- Other STW Perspectief programs (TFN, CCC, IS_2C, SOS). Ideas exist for joint project proposals between IS_2C and BTP.

4. Research topics and selection criteria

In many applications there are strong indications that transient plasmas can deliver much better performances than continuous plasmas, or even offer unique new opportunities. The current lack of fundamental understanding of these transient phenomena, however, limits reproducibility and process control, which in turn prevents wide scale implementation. This program will provide for the first time a wide-scale and comprehensive scientific background needed by the industrial partners to reliably apply transient plasmas in their products and production processes.

Within the program, we will produce a ***design toolkit*** in an interdisciplinary collaboration: a comprehensive set of experimental descriptions and validated models of transient plasmas, including know-how on reactor and pulsed power technology, which will allow the industrial end-users to implement new technologies and to improve their existing technology. Components of the toolkit will be:

- Mobile plasma diagnostics. The academic partners will develop a set of mobile plasma diagnostics, which can travel from partner to partner, industrial or academic. These mobile diagnostics are calibrated against advanced, newly developed, dedicated, often laser based, diagnostics at some of the academic partners.
- Comprehensive descriptions of the various plasma regimes and geometries as they are applied by the industrial partners, comprised of temporally and spatially resolved maps of plasma parameters like electron density and temperature, and chemical composition.

- Predictions of the behavior of transient plasmas when parameters like gas composition, pressure, pulse duration and current are changed. The models will be validated against the experiments. Numerical models that can be run on normal PCs will be made available to the industrial partners with a good user interface, and they will be maintained properly by the authors. Some transient plasmas require modeling from the molecular up to the macroscopic scale, using both supercomputing and model reduction; these results will be made available in quantitative result descriptions and physics based fit formula.
- Reliable pulsed power technology which will be suitable for industrial application. This implies that the power supplies and coupling electronics are reliable, efficient, and have adequate lifetime.
- Design rules and scaling laws for plasma reactors (geometry, power, chemistry, laser intensity). These are rules that predict the process efficiency and performance, based on inputs like the specific geometry, electrode configuration, power supply, gas composition and flow configuration. The scaling laws describe how the design rules in first order depend on plasma parameter changes. These design rules and scaling laws are not generated in an empirical way, but are derived from the scientific descriptions and models.

The toolkit is the combined result of all projects and all participating disciplines in the program, and its initiation and development is the most important responsibility of the program board during the duration of program. The program board will ensure that the results of all projects are collected and, if appropriate, generalized. The program board will also decide who will have access to the toolkit after the program has expired, and will maintain the toolkit during and after the program.

The National Platform on Transient Plasma Technology also plays a role in shaping the design toolkit. Participants in the platform can request the program board to implement certain components in the toolkit. If that component has generic value, is of benefit to more parties than just the requesting party, and does not jeopardize the projects in the program and STW knowledge policy in any way, the program board will grant the request. Requests for access to the toolkit by industrial parties who are not integral partners in any of BTP's projects are to be done through the platform. The platform will then consult with the program board, and a joint decision will be taken.

Of course, the industrial partners do not have to wait until the end of the program before they can use the results. Already in the first years, we expect to be able to deliver parts of the toolkit. Scaling laws, pulsed power technology and plasma reactor design rules, for example, will become available 1-2 years after the start of a particular project. The existing collective expertise of the participating academic groups will enable this.

The reactor geometries and discharge regimes to be studied in a particular project will be chosen in coordination between industry and academia. This will ensure that the results of the projects (parts of the design toolkit) will be of immediate relevance to the industrial partners. Since in each project modelers, experimentalists and industry work together intensively, progressive insight can be accommodated adequately, and can effectively be translated to industrially relevant information.

Within BTP, the following technological areas will be stimulated with descending priority:

- Treatment of gases
- Photons: lighting, laser and EUV technology
- Treatment of surfaces
- Lightning

The main criteria for assessment whether a specific project application falls within this program is the following:

- The project is based on a transient plasma or on transient phenomena in plasmas
- The transient nature yields, if adequately controlled, benefits with respect to stationary plasmas
- The project is based on a collaboration between two academic groups and at least one industry.
- The project contains experimental characterizations, but also theory and modeling activities. Projects with exclusively theory and modeling, without connection to experimental work, are not acceptable.
- The project has good potential to generate a contribution to the design toolkit.

The following categories of plasma technology are <u>not</u> eligible for funding under this program:

- Continuous plasmas with no transient phenomena
- Transient plasmas or transient effects which are not relevant for the application
- The transient thermonuclear plasmas in fusion technology

5. Scientific challenges

In this program, we will address the scientific issues which are specifically related to time dependent initial behavior of the plasma in a state very far from equilibrium. Ionization fronts with their very high electron energies, EMC issues, pressure waves, transient gas temperature increases, and relaxation phenomena will be investigated. These are all very challenging scientific topics, but at the same time they double as technological problem areas where improvement has to be made.

The state of the art is illustrated on the following example: X-ray emission from lightning strokes was recently observed and could be reproduced in lab experiments in Eindhoven; the source is very strong. The general surprise of plasma scientists about these observations shows how much we still need to learn about transient plasmas and which unexpected new potentials they can offer beyond already known mechanisms.

To this end, several scientific innovations will have to be pursued:

- Temporally and spatially resolved diagnostics of the electron energy distribution, the electron density, the chemical composition of the plasma, and the electrical field strength. Time resolutions have to be pushed below the nanosecond level while at the same time spatial resolutions have to be pushed substantially below the mm range.
- High harmonic generation and lasing at XUV and soft x-ray wavelengths from laser-irradiated plasmas, including laser-induced transient plasmas for pulsed deposition processes.
- Temporally and spatially resolved modeling of the microscopic non-equilibrium phenomena in the plasma. Techniques to be developed and used where required: Three-dimensional modeling of the discharge evolution, multiscale modeling joining particle models and fluid approximations in an efficient manner, adaptive grids and further model reduction allowing to understand macroscopic properties starting from molecular scales.
- Mapping of the chemical activity: which radicals and/or ions play a dominant role, where are they produced and how, where and when do they do their work? Characterization of the "deliverables" of the plasma: the fluxes of photons, electrons, radicals and molecules.
- Electromagnetic compatibility issues resulting from the plasma and the driving electronics, Modeling the interaction between the plasma and the driving power supply.

The abovementioned new diagnostics and models will bring the program partners to the international top position. Sub-nanosecond active diagnostics with the targeted spatial resolution are pursued nowhere else in the world. The combination of the mentioned new numerical and theoretical techniques is not to be found in any existing modeling platform.

These scientific challenges are pertinent to several, completely different and uncorrelated, applications. However, this is where the advantage of a program approach becomes evident. If the answer to a challenge is found for one application, others will benefit. One example: if a new, sub-nanosecond time resolution plasma diagnostic is developed within a project with ASML, Rijnhuizen and UT as partner on EUV lithography technology, the same diagnostic will also be available to a project on corona-discharge treatment of flue gases with Oranjewoud, Circlair, 4Q-Air, TUE and CWI as partners. Another example: a numerical code developed to describe the propagation of lightning strikes can also be used to describe the starting of certain types of discharge lamps.

Because of the large scope of the required technological and scientific skills, these research actions cannot be pursued by one single group. As illustrated above, a program approach which combines the efforts of computational scientists, experimental physicists, and electrical engineers is the only way to realize the ambitions.

For each project running under this program, it is vital that numerical/theoretical analysis is combined with experimental characterization, all on the same geometry. Only in that way a comprehensive description of the relevant processes can be obtained.

6. Coherence, knowledge transfer and utilization

It is vital for all participants in the various project that run under this program to meet each other on a regular basis in order to exchange scientific know-how, but also to foster new application perspectives. The following actions will be taken:

- The NNV spring symposium on Plasma Physics, which is organized annually in Lunteren in the month of March, will be extended with one day. Part of that extra day is only open to the participants in the program, part of it will be open to the general public. All program personnel will present posters. The program leader and the program advisory committee will meet with all project leaders. As much as possible, the half-yearly progress meetings of the utilization committee associated with each individual project will be held on this day in Lunteren as well. The program board will maintain and extend the design toolkit during these meetings.
- A similar action will be taken with the annual WELT-PP (Workshop on the exploration of Low-Temperature Plasma Physics) meeting in Rolduc, which is organized in the month of November. That meeting has a more international character, with regular participation by the groups in Bochum, Düsseldorf, Wuppertal, Antwerpen, and Belfast.
- Visibility will be fostered by stimulating participation of program partners in the annual FOM-days in Veldhoven. Together with the research school CPS and the Plasma Physics section of the NNV, we will open negotiations with FOM in order to get to a plasma physics session, where also the output of this BTP Perspectief program can be exposed.
- Courses will be organized on the topic of the program. These courses will be set up in collaboration with the NEVAC and possibly with commercial training firms (e.g. RCT&P). In those courses, the works force to be employed at program partners will get adequate training in this technology.
- Active collaboration will be sought after with the Higher Professional Education (HBO). HBO schools can participate in the SIA-RAAK. The aim is to initiate parallel projects: a SIA-RAAK action can be connected to and jointly coordinated with a projecet within BTP.
- Attract SME’s to the program. Several SME’s are already foreseen to take part in individual projects. However, in the last 5 years the interest of SME’s for plasma technology for all kinds of applications has exploded. Contact will be established with MKB Nederland.
- All projects will also have their own utilization committee. Per project, this untilization committee will be instrumental in channeling the transfer of knowledge and expertise from academic parties to industry.

National Platform on Transient Plasma Technology

In 2008, the program leader organized a Breakfast Session on Plasma Technology at the TU/e, and also a SuperTU/esday on the same theme. For both occasions, the address list of the 3TU Innovation Lab was used in the advertizing campaign, and the result was that at both events around 40 representatives of industries, mostly SME's, showed up. A substantial part of these companies are using or are intending to use transient plasma technology. This community is a good base for a National Platform on Transient Plasma Technology, which has as its main goal the stimulation of contacts and knowledge transfer between the various industries. It will serve as a meeting point and as a central mediator. Industrial parties can exchange information, of both technical and non-technical (commercial, regulations, markets) nature. The platform has the potential to foster the aforementioned "explosion of applications", also to parties which are currently not even in view. The academic parties will also take part in the meetings of the platform. The initiation of the platform will be taken up by the program board in collaboration with the 3TU Innovation Lab. Syntens and possibly FME and MKB-Nederland will also be involved.

Knowledge transfer

Within each individual project, the scientific and technological information generated by the academic parties is transferred to the industries in that project in accordance with STW knowledge policy rules. The utilization committee is instrumental in that, but also bilateral contacts, extra technical meetings, joint patent applications, etc.

On the level of the program as a whole, there are two vital aspects which boost the transfer of knowledge between individual projects : the design toolkit and the National Platform on Transient Plasma Technology.

The design toolkit, as described in section 4, is like a living organism. Industrial partners can ask for specific items to be included, and academic partners then will focus their research accordingly. The program board will supervise this process in all individual projects, and will make sure that the results of the scientific measurements and models are translated to items which are of more use to the industries (design rules, scaling laws and pulsed power technology). The program board will also ensure that there is no "double work": identical research actions in two or more of the projects in the program have to be avoided. All industrial project partners will have access to the design toolkit. Twice per year, during the program meetings in Lunteren and Rolduc, the program board will maintain and extend the design toolkit.

The National Platform on Transient Plasma Technology will be instrumental in stimulating the transfer of knowledge between industries participating in different projects within BTP, but also (if appropriate) to external parties.

Kick-off symposium

The program as a whole will have a widely advertised symposium as kick-off event, which will be planned immediately after the projects that will be granted have been selected. During that symposium, to which all of the academic and industrial teams working on this subject in The Netherlands (and in the nearby plasma-technological “hot regions” of Bochum/Essen/Wuppertal/Jülich and Antwerpen/Gent/Mol/Leuven) will be invited, the scope of the program and the infrastructure and expertise of all partners will be presented. This will foster the international collaboration. This symposium will also be the kick-off of the abovementioned Platform.

Knowledge transfer officer
Setting up the kick-off symposium, the half-yearly technical program meetings in Lunteren and Rolduc, creating procedures and infrastructure for the design toolkit, and initiating the National Platform on Transient Plasma Technology are all the responsibility of the program board. This is a formidable task, which will require a lot of time. Therefore, in the first one to two years of the program the board will be assisted by a Knowledge Transfer Officer. This is a scientist, funded at postdoc level, who has as its sole responsibility to initiate the abovementioned program assets. Once the structures are up and running, the position can either be terminated or reduced in fte share. The Knowledge Transfer Officer will be stationed at TU/e, in the vicinity of the program leader, and he will be on the payroll of TU/e. His salary will be partially funded by the contributions of the industrial partners, partially covered by TU/e.

The knowledge transfer logistics come with expenses. The two symposia (kick off and final) cost 7 k€ each, the 10 program meetings 5 k€ each, the 6 meetings of the National Platform 1 k€ each, a total of 70 k€.

7. Organization of the program and budget

Budget
For this call a budget of 4.6 M€ is available which must be matched by the contributions of potential technology users (companies/institutes) to a total of at least 6.1 M€. The maximum of project costs that can be requested from STW is € 750.000 per project. A contribution of potential “users” of at least 25% of the total project budget is compulsory and adds up to the requested amount.
The users do not have to co-finance up-front in the program but may contribute in-kind (materials, equipment, facilities etc.) and/or financially in the project wherein they will participate.
To realize the ambitions and cohesion of the program a budget of 70 k€ for conferences, workshops and events will be reserved on program level. This funding will be made available by the STW board upon advice of the program committee.

Who can apply
Scientists employed by Dutch universities or institutes recognized by NWO are eligible to submit a (pre-)proposal (see OTP-guidelines of STW for eligibility criteria). Since BTP is a multidisciplinary program, projects which involve two or more research groups with different backgrounds (e.g. mechanical engineering/chemical engineering, applied

mathematics/physics) are preferred. In the project description it should be made clear what the added value of the multidisciplinary approach is for the project.

Proposals and selection

The selection of proposals will be done in two steps: a call for pre-proposals and an invitation to the applicants of pre-proposals to submit full proposals. The pre-proposals will be evaluated by the program committee. The STW board will decide on the funding of the full proposals.

Funding

Project grants will cover:

- personnel costs (including OIO’s, postdocs, technical assistants and programmers)
- material costs (including national travel costs)
- international travel costs
- costs for equipment

The institution(s) of the applicant(s) ensure(s) the required infrastructure, the supervision and the fitting into the research program of the research institute. STW may verify this with the dean or the executive board of the institute.

The expertise required for the research must be available at the requesting institute(s), so that external consultants will not be necessary. When foreign universities and institutes that cannot apply for STW-funding (e.g. TNO) are involved in the program, these parties take care of their own funding.

How to submit?

In order to minimize the time needed for writing and evaluating the proposals, it is compulsory to submit a preliminary proposal. All pre-proposals must be written in accordance with the formal guidelines that can be found in the call for pre-proposals. Only pre-proposals written in English and in accordance with the guidelines will be accepted for evaluation. **Pre-proposals should be sent by email to STW (info@stw.nl).** Pre-proposals should be submitted to STW **before Monday 2 March 2009, 24.00 hrs**. Pre-proposals submitted after this deadline will **not** be accepted.

Pre-proposals

Pre-proposals should contain a short description (3 A4) of the proposed research, utilization paragraph and estimated budget. The proposal should make clear which potential users will contribute to the project. Support letters are optional for the pre-proposals but can be included (letters of intent are accepted).

The pre-proposals will be ranked by the the program board on the basis of how well they fit within the scope of the program. The members of the program board will first assess the pre-proposals individually before dicussing them plenarily in the board. The program board will advise the applicants 1) to submit a full proposal or 2) to adjust the proposal so that it would fit better into the program or 3) not to enter the subsequent selection procedure.

Full proposals

Full proposals must consist of a detailed description of the expected results, planning of the research and a utilization paragraph. The utilization paragraph should include the important industrial challenges that will be solved, the time frame to implementation and the expected bottle-necks during the implementation. Companies and institutes, which will potentially contribute, should be involved bottom-up during the preparation of the proposal.

A full proposal will be evaluated only if it is preceded by a pre-proposal.

The scientific quality and the utilization perspective of the full proposals will be evaluated individually by peer review. An independent jury of about eight (inter)national experts of universities and industry (applicants will be excluded) will rank the full proposals. Each jury member will give 3 marks for each proposal: one for scientific quality, one for utilization potential and one for the strategic fit within the program. The marks will be averaged with equal weight to one final score for the proposal which determines the ranking. In addition to the ranking by the jury the program committee will formulate an advice on the cohesion between the project proposals and their relevance for the program. The decision of the STW board will be based on the ranking by the jury and the advice of the program committee.

The guidelines for full proposals are based on the “Open Technology Program (OTP)” with as main difference that the potential technology users (companies/institutes) should contribute for at least 25% of the total project costs. The proposals should therefore be accompanied by a ‘letter of participation’ in which the contribution has been made explicit and in which details are given on what, when and how these contributions will be made available. For more details see “richtlijnen voor het open technologieprogramma" (www.stw.nl).

Assesment and selection criteria

Upon receiving a pre-proposal STW will decide on its admission (eligibility criteria). The program committee will assess the strategic fit within the research program and its topics. Each individual program committee member will give a mark for the strategic fit for each proposal. Then, in a plenary session the program committee will discuss all pre-proposals and formulate an advice to the applicants. This advice can be: 1) to submit a full proposal or 2) to adjust the proposal so that it would better fit into the program or 3) not to enter the subsequent selection procedure.

The program committee will evaluate the fit of the pre-proposals within the framework of the program and will use the following considerations:

- How well do the goals of the project fit within the ambitions of the program. Do the expected results meet the industrial needs in the long term (2013-2017)?
- To what extent does the proposal fit within the research topics of the program?
- Does the program strengthen the Transient Plasma expertise in The Netherlands in general and of the participants in the project in particular?

- To which extent is the project proposal multidisciplinary? What are the positive effects from the interdisciplinary cooperation? How is interaction in between researchers and between university and industry organized?
- Do the proposals overlap each other and if so, what are the consequences for the funding?

Full proposals will be evaluated by peer review on scientific quality and utilization potential.

Scientific quality:

- Originality and innovative character of the proposal
- Contribution to the aims of the Perspectief program
- Expected impact on the scientific community
- Research method
- Time schedule
- Budget
- Infrastructure

Utilization:

- Potential economic impact
- Past performance in utilization by the applicants
- Contribution to the development of applied knowledge and aims of the program
- Impact on utilization if the project is carried out successfully
- Different steps needed (time path) to utilize the results
- Chance on patents and/or know how agreements
- Participation of users

The jury will be asked to assess the proposals on these aspects and also on the strategic fit within the program.

Time schedule

Call for pre-proposals open	Mon 26 January 2009
Deadline pre-proposals	**Mon 2 March 2009, 24.00 hrs.**
Notification to applicants pre-proposal of the positive/negative advice to submit full proposal	Tue 17 March 2009
Deadline full proposals	Mon 18 May 2009, 24.00 hrs.
Start review by experts	Mon 25 May 2009
Protocol sent to applicants	Fri 28 Aug 2009

Deadline comments applicants	Fri 11 Sept 2009
Proposals sent to jury	Mon 21 Sept 2009
Ranking by jury ready	Mon 12 Oct 2009
Advice Program Committee to STW board ready	Fri 23 Oct 2009
Decision by STW board on funding + notification to applicants	Fri 6 Nov 2009

Program Board

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