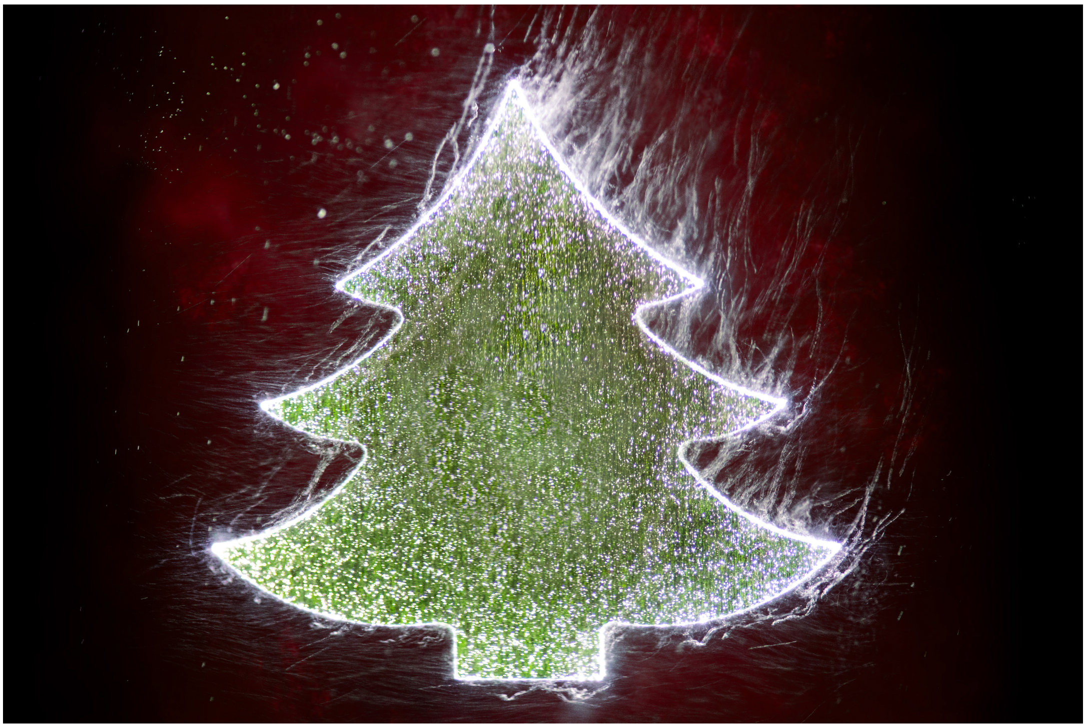
SFB-TR 87

SFB 1316

NEWSLETTER

EDITION 6



Foreword

STRONG FOCUS ON SCIENCE FOR FUTURE APPLICATIONS

The last year was full of exciting events such as the start of the new atmospheric pressure plasma collaborative research center, SFB 1316, as well as the evaluation and approval of the third phase of the collaborative research center SFB-TR 87. Both research centers cover now the whole breadth of plasma science ranging from low to atmospheric pressure plasmas. This generates a very fruitful and stimulating atmosphere among this large group of plasma scientists focusing on new experiments and new insights. Many regular meetings are organized that guarantee the exchange between the members and guests of the research consortia. Especially the training events for scientific methods and for transferable skills are shared in between the consortia and are open for all PhDs interested in plasma science. For example, an educational excursion to London for ten PhD students is planned at the beginning of 2019 to strengthen their English skills.

The intention of the newsletter is to communicate recent research results, to introduce new members of the collaborative research centers, and to disseminate the activities of the research centers to the scientific community and to our industrial partners. By browsing this newsletter, you may appreciate some of the research highlights and the progress of plasma science.

We, the team of the project public relations, originally planned to design a newsletter with a similar page count as the previous newsletter. However, due to the overwhelming response of the researchers, we had to decide to extend the newsletter this time to be able to include all articles. We are very thankful for all contributions. Our requests regarding the lengths and quality of the articles were answered promptly - many thanks for that.

The team of the public relations of the SFB-TR 87 and SFB 1316 hope that you will enjoy reading the newsletter. Furthermore, we wish you a merry Christmas and a happy new year 2019!

Dr. Marina Prenzel, public relations SFB-TR 87 & SFB 1316

Farewell

DR.-ING. STEPHAN WULFINGHOFF

Since August 2018, the former member Dr.-Ing. Stephan Wulfinghoff changes to the Institute for Material Science at the Christian-Albrechts Universität Kiel as a full professor for Computational Materials Science.

Beforehand, he worked as engineer in chief (2014-2018) at the Institute of Applied Mechanics (Prof. Dr.-Ing. Reese) at the Faculty of Civil Engineering at the RWTH Aachen and as junior research group leader (2015-2018) at the Aachen Institute for Advanced Study in Computational Engineering Science (AICES).

Within the SFB-TR 87 his research focus was the modelling of the nanoscale interface behaviour. Therefore, the separation of nanostructures within the interface was described by a cohesive zone model and the influence of different coating parameters on the failure behaviour was investigated. He will intensify the research of multiphysics simulations, modelling of functional materials and thin layers in his new position.

We wish him all the best for his future career and seeing forward for future collaborations!

Strong cooperation in investigating the scalability of plasma and coating properties

Today, low-pressure plasma enhanced chemical vapour deposition (PECVD) has established itself as economic coating process even for mass products, as demonstrated by numerous examples such as the internal coating of PE pipes, PP syringes or PET bottles, PP jam cups, or coffee capsules. Not only the process but also the plant technology is flexible. Bottles, cups, or coffee capsules as well as foil or even bulk materials can be coated with plasmas. The plasma reactor systems must always be designed specifically for the application, whereby the design of the system is often based on experience and qualitative considerations. In a strong cooperation of projects B1, B2, B3, B4, C8, and C2 of the SFB-TR 87, the use of a neutral gas flow simulation for reactor design development was therefore investigated using the example of the reactor's gas injection system for large-area PECVD coating at IKV (approx. 35 cm × 35 cm). A freely available simulation software for complex flow problems (OpenFOAM) was specifically selected as the software in order to make the results of the work accessible for simple and fast industrial application. The simulations were carried out in project C8, where the distribution of the process gases in the reactor was simulated for a variety of gas distribution systems and gas flows. The simulation is a probabilistic (Monte Carlo) simulation to solve the Boltzmann equation for finite Knudsen flows (modelling of diluted gas flows). Figure 1 shows three representative scenarios of the gas distribution in the reactor. A cross-section through the reactor cover can be seen. The spatially resolved particle density as a function of the gas inlet is shown in colour according to the legend.

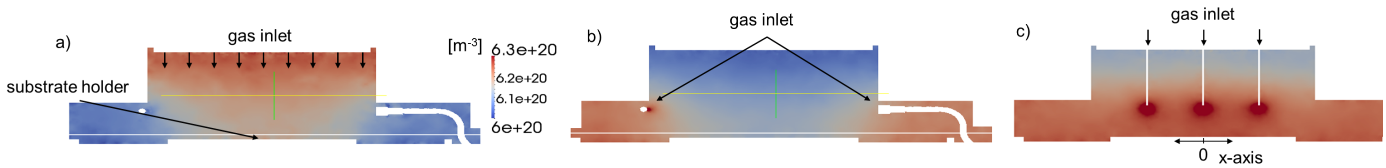


Figure 1: *Neutral gas simulation (particle density) of a) HMDSO introduced via a ring shower, b) oxygen introduced via an index plate and c) HMDSO introduced via lance matrix.*

Figure 1 a) shows the simulated distribution of the monomer gas HMDSO when introduced via a rectangular ring shower, which represents the initial state of the reactor. As the picture shows, there is an inhomogeneous distribution of HMDSO in front of the substrate holder. In the middle, the particle density is 10% lower than at the edge. In contrast to the monomer gases, the auxiliary gases were also introduced into the reactor chamber via an index plate in the reactor cover prior to these investigations. In order to compare the two gas introduction concepts, the distribution of the auxiliary gases (in this case oxygen) was also simulated. As can be seen in Figure 1 b), this gas distribution concept results in lower particle densities at the edge areas in relation to the centre of the substrate holder, whereby the difference is much smaller at 4%. These results show that these gas distribution concepts lead to inhomogeneities in the gas particle density distribution in the reactor. Since the simulation of the gas distribution of the auxiliary gases via an index plate already showed a considerably more homogeneous gas distribution in relation to the ring shower, this principle was chosen as the starting point for the development of the new design. The spatial movements and the velocity curve of the particles in the simulation suggested that a homogenization of the gas distribution could be achieved by reducing the distance between the gas inlet and the index plate. This was implemented by a gas distribution system with index plate and gas lance matrix and the gas distribution was simulated (Figure 1 c). In particular, mixed gas flows from HMDSO and O_2 were taken into account, as these are used to produce SiO_x barrier coatings. With a lance length of 8 cm (distance of the outlet to the substrate approx. 5 cm) the highest possible homogeneity could be achieved: Figures 2 a) - b) compare the particle densities in front of the substrate at given gas flows, when HMDSO is introduced via the ring shower (Reference) and lance matrix (New Design). Accordingly, for the new design, a significant reduction in the difference in particle densities between the center and edge regions of the substrate holder is calculated in relation to the ring shower.

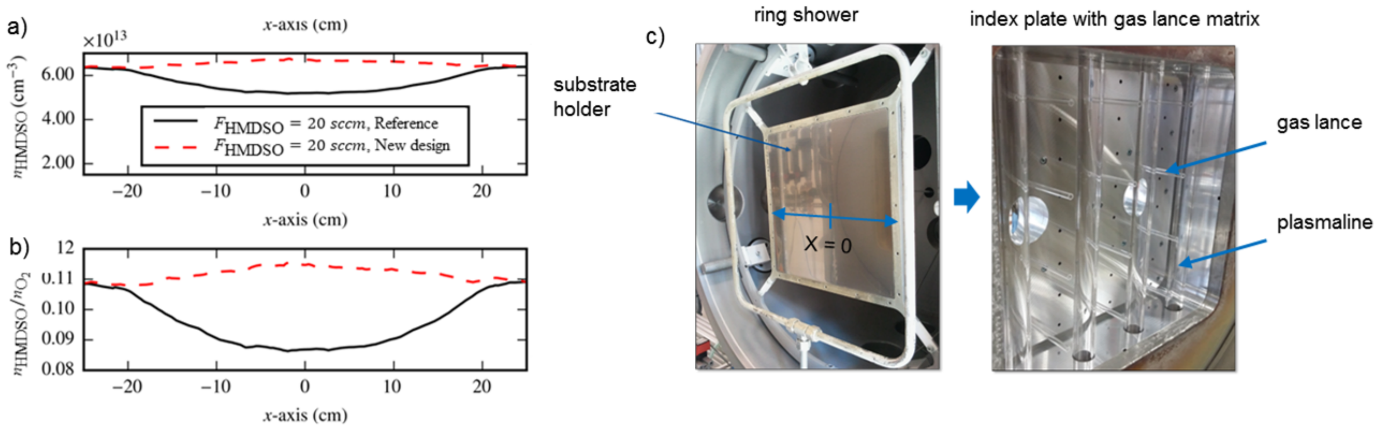


Figure 2: *Simulated particle densities in front of the substrate holder for a) HMDSO, b) the ratio of n_{HMDSO}/n_{O_2}. c) Ring shower and gas distribution system with index plate and gas lances.*

Figure 2 b) shows the corresponding comparison of the particle density ratios n_{HMDSO}/n_{O_2}. For the ring shower there is a difference between the minimum and maximum value of (n_{HMDSO}/n_{O_2})max - (n_{HMDSO}/n_{O_2})min = 0.025. For the gas lance system this value is reduced to (n_{HMDSO}/n_{O_2})max - (n_{HMDSO}/n_{O_2})min = 0.005. Thus, an improvement of the homogeneity by a factor of 5 is calculated for the new system. The gas distribution system was therefore modified in project B1 according to these investigations (Figure 2 c) and the simulation results were validated by cooperative investigations of the electron density using PAP (B2) and MRP (B4), layer stress (C2), layer thickness measurements (B3), and determination of the water vapour transmission rate and layer chemistry (B1).

The improvement of the homogeneity of coating properties over the $1225\,cm^2$ large area of the substrate holder is particularly significant regarding the layer thickness distribution. Initially the experimentally determined layer thickness increased radially from the middle of the substrate holder towards the edge, whereby the maximum deviation of the layer thickness corresponded to approx. 35%. After the modification, the maximum deviation is just about 3%. The distribution of the measured values of the water vapour transmission rate shows similar results. Before the modification, these also increased by approx. 35% from the centre of the substrate holder to the edge areas. Afterwards, this gradient towards the centre can no longer be seen. The electron densities were measured with PAP and validated with MRP. Different measuring points were approached from the center to the edge of the substrate holder. The measurements resulted in a 3.5 times higher electron density for the gas lance system in the center of the substrate holder. This increase in electron density could be attributed to the higher gas supply in front of the substrate holder by the new gas distribution system. For layer stress and -chemistry, no significant changes can be observed.

The achieved improvements of the homogeneity of the coating properties show, that despite many simplifications, a simulation of the neutral gas distribution with open source software can be a suitable tool for supporting reactor and process development.

Jaritz Montgomery, project T4 of the SFB-TR 87

Conference and Activity Review

Three PhD student from SFB 1316 consortium join Gordon Research Conference

This years Gordon Research Conference on "Fundamental Insights into Plasma Processing" was held at the Bryant University in Smithfield, Rhode Island from the 5^{th} to the 10^{th} of August. The additional Gordon Research Seminar for PhD students, Post-Docs and young scientists started at the 4^{th} of August. The PhD students Sebastian Dzikowski, Katharina Grosse, and Theresa Urbanietz from experimental physics II, RUB, working in the SFB 1316 participated in both the seminar and the conference with poster presentations. Additionally, Theresa Urbanietz was selected to give a students talk at the Gordon Research Seminar. During the Gordon Research Conference, Prof. Dr. Uwe Czarnetzki from the experimental physics V department gave a talk about challenges in diagnostics with the title "Plasma Diagnostics: What Can We Know? What Ought We Do? For What May We Hope?".

The atmosphere of this conference was very friendly and the discussions between students, post-docs and professors during the poster sessions were both fruitful and motivating. The students had the opportunity during each lunch to sit and eat with different experts (paper editors, scientists in academia and industry...) to discuss their career in a casual environment. The overall program of the Gordon Research Seminar and the Gordon Research Conference was perfectly put together and the chances for students to discuss their work with advanced researchers in their field created a very unique atmosphere for which the Gordon Research Conferences are famous.

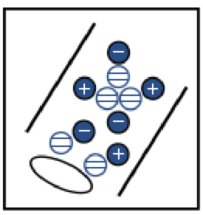
Conference announcement

Plasmatechnologietagung PT19 in Cottbus

The organization of the upcoming PT 19 is at the Brandenburgische Technische Universität Cottbus-Senftenberg (BTU). The heads of organization are the SFB members, Prof. Dr.-Ing. Thomas Mussenbrock and Dr.-Ing. Jan Trieschmann from the Electronynamics and Physical Electronics Group. The objective of this conference format is the exchange between scientists from Germany about recent developments in the field of plasma technology. Beside scientific representatitives, also industrial partners are invited to join the conference. The conference will take place between **17^{th} June and 19^{th} June, 2019** at the campus of the BTU.

More information about the conference can be found on the website `https://sites.google.com/view/pt19/startseite` and contact is possible via PLASMATECHNOLOGIETAGUNG@GMAIL.COM

Frontiers workshop in 2019 in Bad Honnef, enlarged with a simulation workshop



Another conference, which is organized by members from the SFB 1316, is the upcoming 13^{th} Frontiers in Low-Temperature Plasma Diagnostics (FLTPD), **from 12^{th} May until 16^{th} May, 2019** in Bad Honnef. The very well established conference format takes place every two years since 1993. In the next year, the conference topics are going to be enlarged with the 1^{st} Frontiers in Low-Temperature Plasma (FLTPS). The organization of the overall conference is realized by Prof. Dr. Uwe Czarnetzki, Dr. Marina Prenzel, and Susanne Hentrich from Ruhr-University Bochum. The simulation workshop is organized by Prof. Dr. Nader Sadeghi from Aix Marseille Universite.

The homepage of the conference is `http://frontiers2019.rub.de`. The organization committee can be contacted via FRONTIERS2019@RUB.DE.

Influence of the target power density on the chemical composition of composite-/compound-targets synthesized thin layers.

The intention of project T1 is to develop a fundamental comprehension of the influence of the composite-/ compound-target power density on the local and integrated chemical composition for magnetron sputtered thin layers. It is known from literature that the difference in layer composition between DC magnetron sputtered (DCMS) layers and the used composite-/compound-targets is usually over 10% [1,2]. This depends among other things on the substrate bias voltage, the substrate temperature, the pressure distance product and the difference in mass of the target's components. Recently, it was demonstrated for a Cr-Al-C composite-target (see Figure 3) that an increase in the target power density of around two orders of magnitude (from 2.3 W/cm^2 to 373 W/cm^2) provides a more than two times bigger difference between target and layer composition [3]. Thus it appears that, besides the known parameters, the target power density has a significant influence on the layer composition as well.

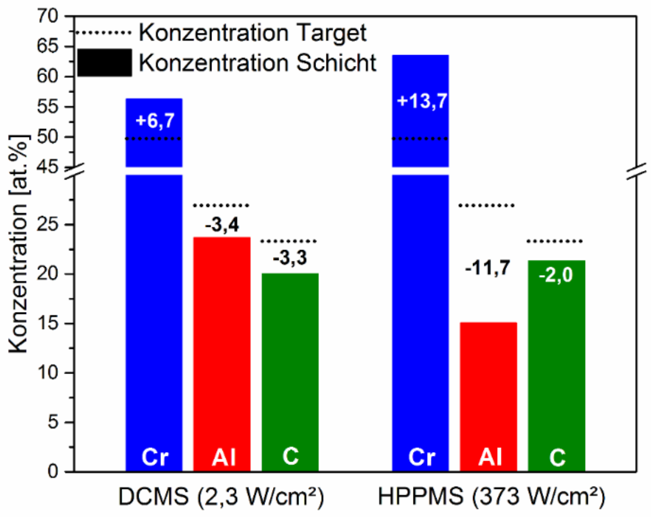


Figure 3: *Difference in target composition (dotted line) and layer composition (bar height) for DCMS (2.3 W/cm^2) and HPPMS (373 W/cm^2) deposited from a Cr-Al-C composite-target.*

Together with Plansee Composite Materials GmbH, the influence of the target power density, substrate bias voltage, substratte and target temperature and rotation as well as elemental mass difference of target constituents on the layer composition are investigated systematically by depositions from Cr-Al-C composite (M_{Cr} / M_C = 4.3), Zr_2AlC (M_{Zr} / M_C = 7.6) and Hf_2AlC (M_{Hf} / M_C = 14.9) compound-targets. These results enable the identification tof deposition parameter-dependend target composition via combinatorial layer synthesis [4] for the synthesis of stoichiometric M_2AlC (M = Cr, Zr, Hf) layers. Furthermore, this establishes a basic understanding of the physical and chemical mechanisms at the target, during gas phase transport as well as during condensation at the substrate in dependence of the above mentioned factors. Thus, the target composition can be tailored to achieve stoichiometric depostions of thin M_2AlC (M = Cr, Zr, Hf) layers.

[1] S. Mráz, J. Emmerlich, F. Weyand, J. M. Schneider, Angle-resolved evolution of the composition of Cr-Al-C thin films deposited by sputtering of a compound target, Journal of Physics D: Applied Physics 46, 135501 (2013)

[2] J. Neidhardt, S. Mráz, J. M. Schneider, E. Strub, W. Bohne, B. Liedke, W. Möller, C. Mitterer, Experiment and simulation of the compositional evolution of Ti–B thin films deposited by sputtering of a compound target, Journal of Applied Physics 104 063304 (2008)

[3] H. Rueß, M. to Baben, S. Mráz, L. Shang, P. Polcik, S. Kolozsvári, M. Hans, D. Primetzhofer, J. M. Schneider, HPPMS deposition from composite targets: Effect of two orders of magnitude target power den-sity changes on the composition of sputtered Cr-Al-C thin films, Vacuum 145 285 (2017)

[4] T. Gebhardt, D. Music, T. Takahashi, J. M. Schneider, Combinatorial thin film materials science: From alloy discovery and optimization to alloy design, Thin Solid Films 520, 5491-5499 (2012)

Holger Rueß, project T1 of the SFB-TR 87

Tributes

Masao Horiba Prize for Dr. Tsankov

The Masao Horiba Prize has been awarded annually for 15 years to scientists and technical experts to honor world-leading ideas and innovations in diagnostic methods. The specific topic is selected each year from the areas promoted/represented by the HORIBA Group. The topic of this year's award was "Advanced analytical measurement technologies for the semiconductor manufacturing process". Semiconductor technologies form the foundation of today's society. In order to drive forward the constant development, many companies in the industry need new innovations - not only in the production of materials but also in the control and observation of production processes, e. g. by new diagnostic methods.

A jury of internationally established scientists and representatives of the HORIBA Group selected the prize winners. Among them Dr. Tsanko Vaskov Tsankov from the Chair of Plasma and Atomic Physics, Faculty of Physics and Astronomy, Ruhr-University Bochum, was especially distinguished for his work "Non-invasive plasma characterization using the ion velocity distribution function". In this work Dr. Tsankov has developed a plasma diagnostic method that allows the non-invasive determination of plasma parameters. The prize was awarded at an official ceremony in Kyoto University on October, 17th 2018 (the founding day of HORIBA Group).

Poster Prize at the 8th International Workshop on Plasma Spectroscopy in Oxford

The 8th International Workshop on Plasma Spectroscopy was held from the 23th until 26th of September, 2018 at the Worcester College in Oxford, United Kingdom. Dr. Volker Schulz-von der Gathen, Patrick Preissing, and Katharina Grosse from experimental physics II, Ruhr-University Bochum, contributed with two talks as well as three poster presentations to the excellent scientific program covering active and in particular high-resolution passive spectroscopic methods. One of two poster prizes was won by Patrick Preissing (project B2 within the SFB 1316) which was announced during the conference dinner. Moreover, the excursion to Blenheim Palace was a highlight of the conference.

Research seminar

Synthesis-Structure-Property Relations for CVD and PVD Coatings

On October 9th, a seminar with Dr. Nina Schalk from the University of Leoben took place at the Chair of Materials Chemistry, RWTH Aachen. Dr. Schalk heads the Christian-Doppler Laboratory for modern coated cutting tools and gave in her lecture "Synthesis-Structure-Property Relations for CVD and PVD Coatings"; an insight into the work on the material systems TiN-TiB_2 (CVD) and Ti-Al-O-N (PVD). Regardless of material system and synthesis method, graded multilayer layers with a concentration gradient were investigated. Cross section characterization techniques such as transmission electron microscopy, nanobeam diffraction at the synchrotron and nanoindentation mapping were used to enable a comprehensive understanding. The concept of graded multilayer layers presented here is characterized by high efficiency, as several samples can be investigated in a single layer compound. Furthermore, the characterization methods used are very interesting for the layer systems deposited within the SFB-TR 87.

About Novel Research Activities

Observation of the generation of multiple electron beams during a single sheath expansion phase in capacitive RF plasmas

Low temperature capacitively coupled radio frequency discharges are of high relevance for industrial applications such as plasma etching or sputtering. In these discharges, the electron heating mode strongly affects process-relevant plasma parameters, e.g. the electron and ion energy distribution functions or the plasma density. Therefore, a complete fundamental understanding of the heating mechanisms and the energetic electron dynamics is of high relevance. In the recently accepted manuscript[1], a capacitively coupled radio-frequency discharge is operated at its limit of comparably low plasma density. Phase Resolved Optical Emission Spectroscopy provides insights into the electron dynamics on a nanosecond time scale. At low applied voltage amplitudes, it is observed that more than one electron beam is generated within a single phase of sheath expansion at a given electrode under these conditions. Figure 4 shows this phenomenon for a neon discharge operated at 1.07 Pa at a gap distance between the driven and grounded electrode of 50 mm and a voltage amplitude of 150 V at a frequency of 13.56 MHz.

The generation of more than one electron beam can be explained by the low plasma density under the used conditions, which leads to a low local electron plasma frequency. When electrons are accelerated by the electric field in the expanding sheath, they propagate towards the discharge center and leave behind a positive space charge. Consequently, cold bulk electrons move towards the sheath edge to compensate this space charge. This does not happen instantaneously but on the timescale of the local electron plasma frequency due to the electron inertia. When the local electron plasma frequency is low enough, the bulk electrons react with a significant delay. Once they react to the space charge, the bulk electrons are accelerated towards the space charge. In the moment they reach the expanding sheath edge, these electrons are accelerated by the electric field again and a second beam occurs.

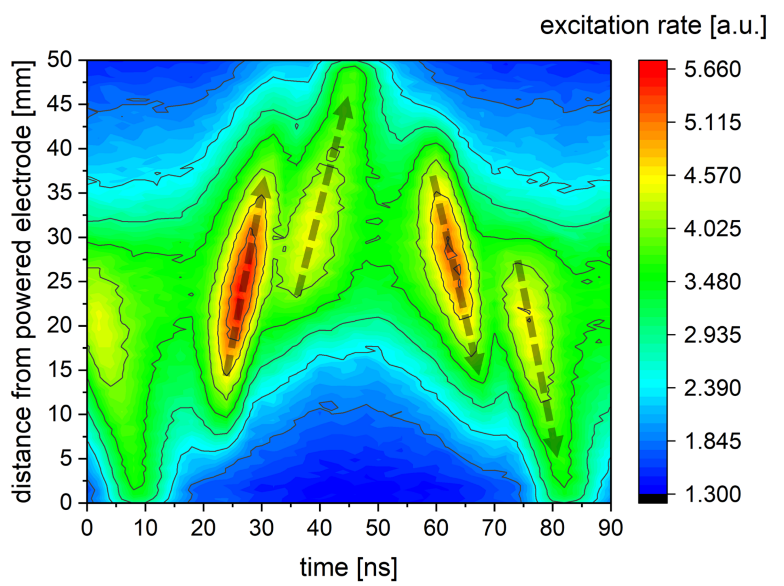


Figure 4: *Spatio-temporal plot of the excitation rate from the ground state into the Ne2p$_1$-state inferred from the measured emission data for an applied voltage amplitude of 150 V. The arrows mark the electron beams generated during the sheath expansion phase (Ne, 1.07 Pa, d= 50 mm).*

When the voltage amplitude is increased, these beams merge in time to a single electron beam. This effect has been predicted by Particle in Cell/Monte-Carlo collision (PIC/MCC) simulations before [Wilczek et al. (2015) *Plasma Sources Sci. Technol.* **24** 024002; Wilczek et al. (2016) *Phys. Plasmas* **23** 063514] and contradicts existing models that assume the generation of a single beam per sheath expansion phase by stochastic heating. In this study, results from a systematic experimental study of the effect are presented, which support the theoretically predicted phenomenon.

Birk Berger, project A4 SFB 1316

[1] DOI: 10.1088/1361-6595/aaefc7

New researcher with link to the SFB 1316 started at RUB

Interview with Jun.-Prof. Dr. Andrew Gibson

Since October 2018, Jun.-Prof. Dr. Andrew Gibson strengthens the team at the institute for electrical engineering at Ruhr-University Bochum. His expertise is the research of plasmas on biological systems.

Andrew, what was the focus of your research in York?

During my time in York I had quite a broad range of research interests, but my focus was on applications of plasma technology. My main research topic directly before I joined RUB was on the development of low-temperature plasmas for prostate cancer therapy, and how simulations could be used to better understand and optimize plasmas for this application. This involved using plasma simulations to design a plasma source suitable for clinical application for prostate cancer therapy, as well as systems biology simulations to study how plasma-delivered reactive species interact in cellular environments. Over the years, I have also worked on experiments and simulations to study low-pressure plasmas used in more traditional surface processing applications. In all of this work, a key theme has been building a solid understanding of the physics and chemistry of these plasmas and using this understanding for knowledge-based optimization of applications.

So, what is the goal of your present research at the Ruhr-University Bochum?

At RUB, I aim to use the experience I have built in interdisciplinary work, with engineers, physicists, chemists and biologists, to delve deeper into the mechanisms of plasma interactions with biological systems. Knowledge of these mechanisms has the potential to underpin a wide variety of important future biomedical applications, from cancer therapy to bacterial sterilization. It is my belief that interdisciplinary collaborations, combining experiments and simulations, have great potential to lead to new insights into this area, and this is where I aim to focus my research. I also believe that the research environment of RUB, with world-leading research groups, not only in plasma science, but in biology, chemistry and medicine, is ideal for this interdisciplinary research, which, for me, is incredibly interesting and rewarding.

Is there any link to the projects within the collaborative research center SFB 1316?

In my opinion, the physics and chemistry of atmospheric pressure plasmas are crucial starting points in understanding and optimizing their use in biomedical applications. Interactions with liquids and solids, strongly incorporated into SFB 1316, form critical parts of these systems, and as a result I can find many links between my work and the collaborative research center. For example, the fundamental physics and chemistry of transient plasmas are still not fully understood, and as such, the scientific knowledge that will be gained in these areas in the SFB can be directly incorporated into my own work to benefit understanding of plasmas in the context of biomedical applications. Similarly, plasma control strategies, such as those outlined in the collaborative research center, will be important for future applications in biomedicine, and as such, projects in this area offer a clear link to my own work. Lastly, I am actively involved in the modelling of plasma gas- and liquid-phase chemistry, which is directly linked to the experimental and modelling work being carried out in a number of projects, and therefore I hope that there will be many opportunities to collaborate with PIs across a variety of aspects of SFB 1316.

What do you like about Germany and what do you miss about Great Britain?

Germany has much better beer but I still miss the pubs in the UK!

Interview by Dr. Marina Prenzel, public relations SFB-TR 87 & SFB 1316

Insight into recent research

Modular zero-dimensional platform Z

A modular zero-dimensional plasma modelling tool "Z" (Zero-dimensional plasma modelling platform) is developed in a MATLAB environment, planned by project A9 in the SFB 1316 consortium. The modular structure is composed of a set of fundamental functions allowing an input file structure of a considered plasma chemical kinetics set to be easily converted into a set of coupled ordinary differential equations and integrated. A comma separated input file formalism is preferred providing simple handling of a table generation in a TeX format or conversion of existing chemical kinetics in already available simulation tools, such as Plasimo, via the help of additional scripting platforms i.e. python, bash, awk, and sed. The code makes use of already implemented ordinary differential equation solvers in the MATLAB toolboxes with a preference of the Livermore Solvers.

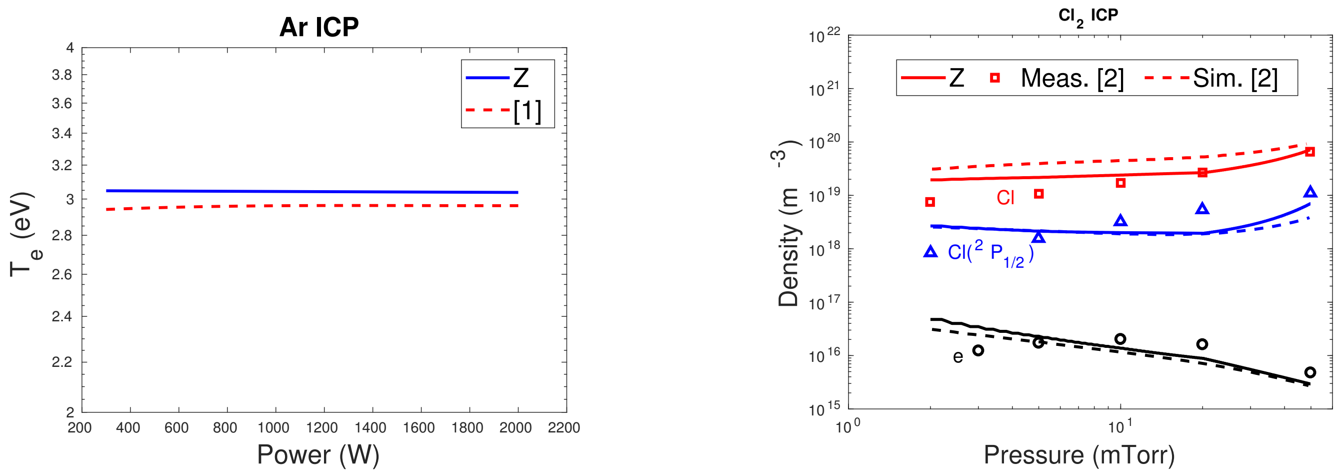


Figure 5: *Electron temperature calculated and measured for an Ar ICP discharge between 200 W and 2,000 W in the left graph. Further, the plasma density for Cl (red), Cl($^2P_{1/2}$) (blue) as well as e^- (black) is shown on the right site. Measurements are marked as empty dots, the modelling tool is shown as continuous line, simulations with the presented code are printed with dashed lines.*

The modular code platform is already validated by a benchmark against available zero-dimensional studies in the low-temperature plasma literature and further validation test cases are under progress. Initial preferences for the test cases are relatively simpler zero-dimensional formalism at low-pressure radio-frequency discharges. The Z calculations in argon already shows an agreement with the simulation results of Gudmundsson [1].

Electronegative cases of Cl_2 and O_2 models [2,3] implemented in the Plasimo framework are currently under construction and the benchmark in the former case is already promising. Figure 5 shows the electron temperature (left) for an Ar ICP discharge. On the right site of the figure, the density for Cl (red), Cl($^2P_{1/2}$) (blue) as well as e^- (black) are pictured. It can be seen that the deviation between measurements and the calculated curves are very small.

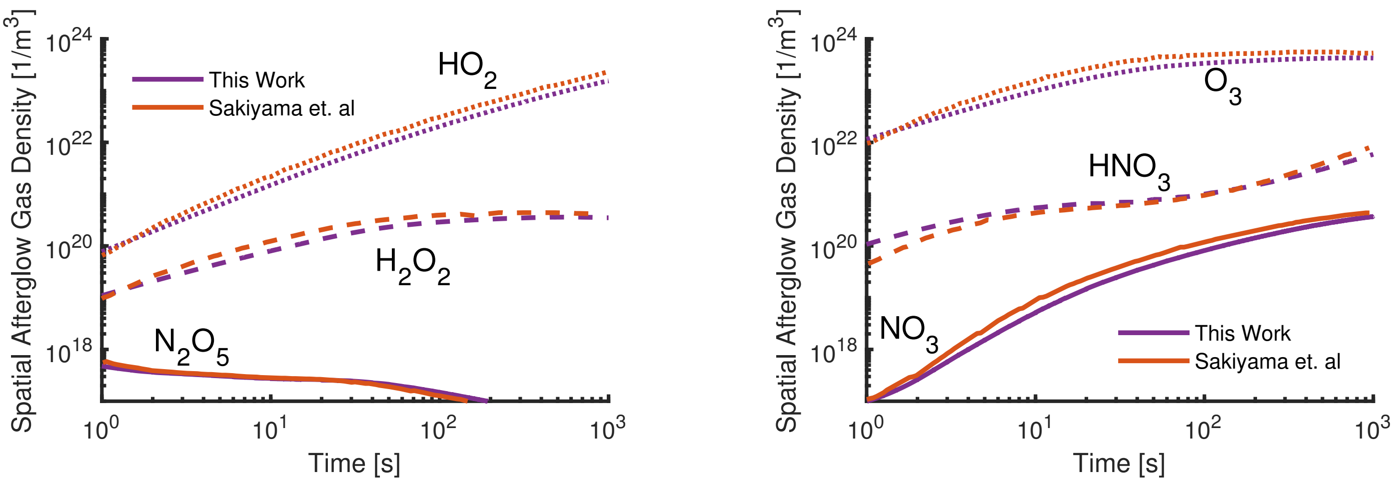


Figure 6: *Comparison of the gas density in the afterglow by Sakiyama et. al (red) and the modular zero-dimensional platfrom Z (violet). The density up to 1000 s is shown for HO_2, H_2O_2, and $N-2O_5$ in the left graph. Moreover, the density distribution for O_3, HNO_3, and NO_3 is shown in the right graph..*

More complex zero-dimensional formalism for the target group of plasma sources i.e. dielectric barrier discharges is already initiated. Multiple co-interacting zero-dimensional models via time slicing of dielectric barrier discharge and the effluent in air is also compared against the simulations, originally conducted by Sakiyama [4] and both the simulations concur on the densities and their temporal evolution. Following the test cases include the benchmark against measurements e.g. plasma jet and further progress is to be reported. Here, the direct comparison of both models for different gas components, such as HO_2, H_2O_2, N_2O_5, O_3, HNO_3, and NO_3 are shown in Figure 6.

Tabulated data of Bolsig+ has been considered in the implementation of the electron kinetics under the two-term approximation of the Boltzmann equation. However, this implementation does not respect the particular plasma composition in a self-consistent manner and the Boltzmann solver LOKi developed by Lisbon IST team is decided to be adapted for a more realistic calculation of the electron energy distribution function instead. Large molecules such as CO_2 or large electric fields are associated with significant deviation from the two-term expansion and a multi-term expansion is to be used in estimating the deviation.

Existing chemical kinetics in A9 are requested by Liam Pitchford to be included in LxCat database under a reserved name. The team is open for suggestions for the database name with current candidates of “P” or “ProPlasma” representing Process Plasmas.

[1] Gudmundsson et. al PSST **16** 399 (2007)

[2] Kemaneci et. al PSST **23** 045002 (2014)

[3] Kemaneci et. al PSST **25** 025025 (2016)

[4] Sakiyama et. al JPhysD:ApplPhys **45** 42520 (2012)

Katharina Nösges, public relations SFB-TR 87

New faces

New PhD students within the SFB-TR 87

Rahel Buschhaus studied physics at the Ruhr-University Bochum. During her Master thesis she already worked in the SFB-TR 87 by doing ellipsometry and porosimetry measurements of polymer and silicon oxide layers (projects C7 and B2). Since July 2018 she is working on project C7, which investigates the surface processes during reactive HPPMS plasma and plasma polymer interaction. Elementary processes on surfaces (polymers and HPPMS targets) in contact with a plasma are mimicked by sending quantified beams of ions, atoms and molecules to a target in an ultra-high-vacuum reactor. One aspect is the evaluation of elementary processes of ions and UV photons with barriers and membranes on polymers. However, the main aspect lays on surface processes of energetic metal ions on HPPMS target materials (e.g. Al, Cr, Ti, Cu and their oxides). Hereby, ion-induced secondary electron emission, self-sputtering rates and film growth processes will be investigated.

M. Sc. **Christoph Schulze** studied mechanical engineering at the RWTH Aachen University. He already worked in subproject C6 of the SFB-TR 87 in the context of his Bachelor and Master thesis. In subproject C6, the correlation between plasma and coating properties on the substrate side is investigated on an industrial scale. An important aspect of the third funding phase of the SFB-TR 87 is the examination of the transferability of the results of the Cr-Al-O-N coating system to the Ti-Al-O-N and V-Al-O-N coating systems. Furthermore, the continuity of artificial neuronal networks, the construction of which was started in the second funding phase, will be tested and investigated in depth.

Mathews George started his PhD in December 2018 at the institute for experimental physics II at Ruhr-University Bochum. He is going to work in project A5 of the SFB-TR 87. His focus will be on two-photon absorption laser-induced fluorescence (TALIF) and mass spectrometry measurements on HPPMS discharges. Working together with Dr. Wolfgang Breilmann and Julian Held, investigations on processes close to the target are brought into focus.

Mathews George gained two Master degrees in physics in Aix-Marseille, France. His first Master is on astro physics, where he investigated the magnetic recombination in the earth-magnetosphere. Further, his second Master degree is in plasma physics, simulating instabilities in HPPMS plasmas.

New PhD students within the SFB 1316

Patrick Preissing studied physics at the Ruhr-University Bochum. He already worked on his master thesis in the SFB-TR 87, project A5. His focus was on the Argon metastable density in HiPIMS plasmas via tunable diode laser absorption spectroscopy. Since April 2018, he is working on project B2 of the SFB 1316, dealing with laser-plasma-surface interaction. The aim is to obtain information about the complex interaction between the reactive species created in a RF driven plasma jet and the induced surface structures by laser irradiation. Therefore, passive and active optical methods will be applied to investigate the plasma kinetics and distribution of reactive species, while ex-situ surface sensitive diagnostics will give information about the surface structures.

Maximilian Klich joins project A8 of the SFB 1316, *A 1.5 dimensional transient transport reaction model of plasma jets*. He is employed as a PhD student at the institute for theoretical electrical engineering at Ruhr-University Bochum since October 2018. He is a participant of the TopIng program of the faculty of electrical engineering. As being part of this program, his master studies in electrical engineering with a major in plasma technology are still ongoing. His work within the SFB 1316 will focus on computational modeling and simulation of atmospheric plasma jets.

Christoph Stewig studied medical physics at the Martin-Luther-University Halle/Saale. He wrote his master thesis within the scope of the study WELDOX-II at the IPA Bochum, in the field of neuroimaging. Since June 2018, he is working on project A3 of the SFB 1316. This project deals with the excitation transfer between molecules in a non-equilibrium atmospheric pressure plasma and its impact on plasma chemistry. Hence, the energy and conversion efficiency of this reactions are changed as a function of the plasma properties. Due to the existence of metastable noble gas molecules within the plasma, penning ionization may also play a vital role for the understanding of the observed conversion rates. Thus far, the measurements are performed in an RF-driven helium plasma jet, utilizing Fourier transformed infrared absorption (FTIR). To estimate the impact of penning ionization on the observed conversion rates, measurements in a helium-argon plasma are going to be the next steps of investigation.

Graduate

Dr.-Ing. Felix Mitschker

Recently the SFB-TR 87 member **Dr.-Ing. Felix Mitschker** finished his PhD with summa cum laude. After his Bachelor and Master Thesis in the physics faculty at Ruhr-University Bochum, he changed project B4 within the SFB-TR 87 at the institute for Institute for Electrical Engineering and Plasma Technology. The PhD thesis focused on the influence of quantitative plasma parameters in pulsed microwave and radio frequency plasmas on the properties of gas barrier films on plastics. It was found that an increased incorporation of energy by ion bombardment, as well as an increased number of oxygen atoms impinging during film growth independently enhance the cross-linking and the barrier performance of silicon oxide coatings on plastics. Furthermore, a novel approach was introduced, combining two different deposition techniques: plasma enhanced atomic layer deposition and plasma enhanced chemical vapour deposition. Thereby, defects in resulting multilayer coatings were significantly reduced. Overall, the PhD thesis benefited from the broad variety of sophisticated collaborations within the SFB-TR 87.

Conference report

Gaseous Electronics Conference

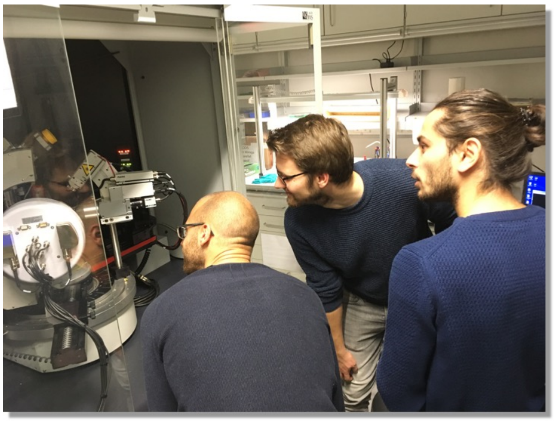
From the 4^{th} until the 9^{th} November 2018, the 71^{st} Annual Gaseous Electronics Conference (GEC) took place at the Oregon Convention Center in Portland. The GEC is a conference of the Division of Atomic, Molecular, and Optical Physics. Scientist from all over the world met to exchange scientific information in the field of gaseous electronics. Three groups from Bochum (theoretical electrical engineering of Prof. Dr. Ralf Peter Brinkmann, electrical engineering and plasma technology of Prof. Dr.-Ing. Peter Awakowicz and group of experimental physics V of Prof. Dr. Uwe Czarnetzki) as well as one group from Cottbus (theoretical electrical engineering of Prof. Dr.-Ing. Thomas Mussenbrock) joined the traditional meeting with poster presentations and oral contributions.

Especially the outstanding talk "Spatio-temporal analysis of the electron power absorption in electropositive capacitive RF plasmas based on moments of the Boltzmann equation" held by Dr. Julian Schulze (PI in the SFB 1316 as well as in the SFB-TR 87) was a highlight of the scientific program. Besides the scientific part, the institute for electrical engineering and plasma technology arranged an unofficial dinner RUB members and fellows. Furthermore, the group from Bochum and from different plasma groups all over the world shared a house close to the conference site. This flat-sharing community supported the scientific exchange, especially among the students.

Working group activities SFB-TR 87

Hands-on Workshop - Synthesis & Characterization of Hard Coatings

Which variants of the characterization of hard material coatings exist and which findings can be gained diagnostically? These and other questions were discussed by the participants of the hands-on workshop



"Synthesis and Characterization of Hard Coatings" of the working group IANiS on October 22nd in Aachen. In the laboratories of the Chair of Materials Chemistry at RWTH Aachen University, the PhD students of the SFB-TR 87 had the opportunity to exchange their previous knowledge of reactive gas phase deposition using HPPMS during the deposition of a $Ti_{1-x}Al_xN$ gradient layer as well as to gain detailed practical experience in various surface diagnostics such as energy-dispersive X-ray spectroscopy (EDX), X-ray diffraction (XRD) and nanoindentation. Finally, composition-induced differences in the measurement results of the synthesized samples were discussed and classified. Thus, the hands-on workshop has made another important contribution to the interdisciplinary exchange of young researchers in the SFB-TR 87. The participants particularly praised the independent performance of the various characterizations.

Upcoming Dates 2019

March 10th - 15th 2019
3rd Annual Meeting of DPG and DPG Spring Meeting of the Atomic, Molecular, Plasma Physics and Quantum Optics Section (SAMOP)
Rostock, Germany

April 23rd - 26th 2019
46th IOP Plasma Physics Conference
Loughborough, UK

6 Mayth - 10th 2019
C3. European Conference on Plasma Diagnostics
Lisbon, Portugal

May 6th - 10th 2019
Joint ICTP-IAEA School on Atomic and Molecular Spectroscopy in Plasmas
Trieste, Italy

May 13th - 16th 2019
13th Frontiers in Low-Temperature Plasma Diagnostics & 1st Frontiers in Low-Temperature Plasma Simulations (FTLPD-XIII & FTLPS-I)
Bad Honnef, Germany

May 19th - 24th 2019
International Conference on Metallurgical Coatings and Thin Films (ICMCTF)
San Diego, USA

May 19th - 24th 2019
10th International Particle Accelerator Conference (IPAC19)
Melbourne, Australia

June 23rd - 28th 2019
IEEE Pulsed Power and Plasma Science Conference (PPPS) and 47. International Conference on Plasma Science (ICOPS)
Orlando, USA

July 8th - 12th 2019
46th European Physical Society Conference on Plasma Physics (EPS)
Milan, Italy

July 17th - 19th 2019
19. Fachtagung für Plasmatechnologie (PT19)
Cottbus, Germany

Impressum

Öffentlichkeitsarbeit SFB-TR 87 & SFB 1316
Ruhr-Universität Bochum, Universitätsstr. 150
NB 5/126, 44780 Bochum

info@sfbtr87.de
sfb1316@rub.de