International Low Temperature Plasma Community

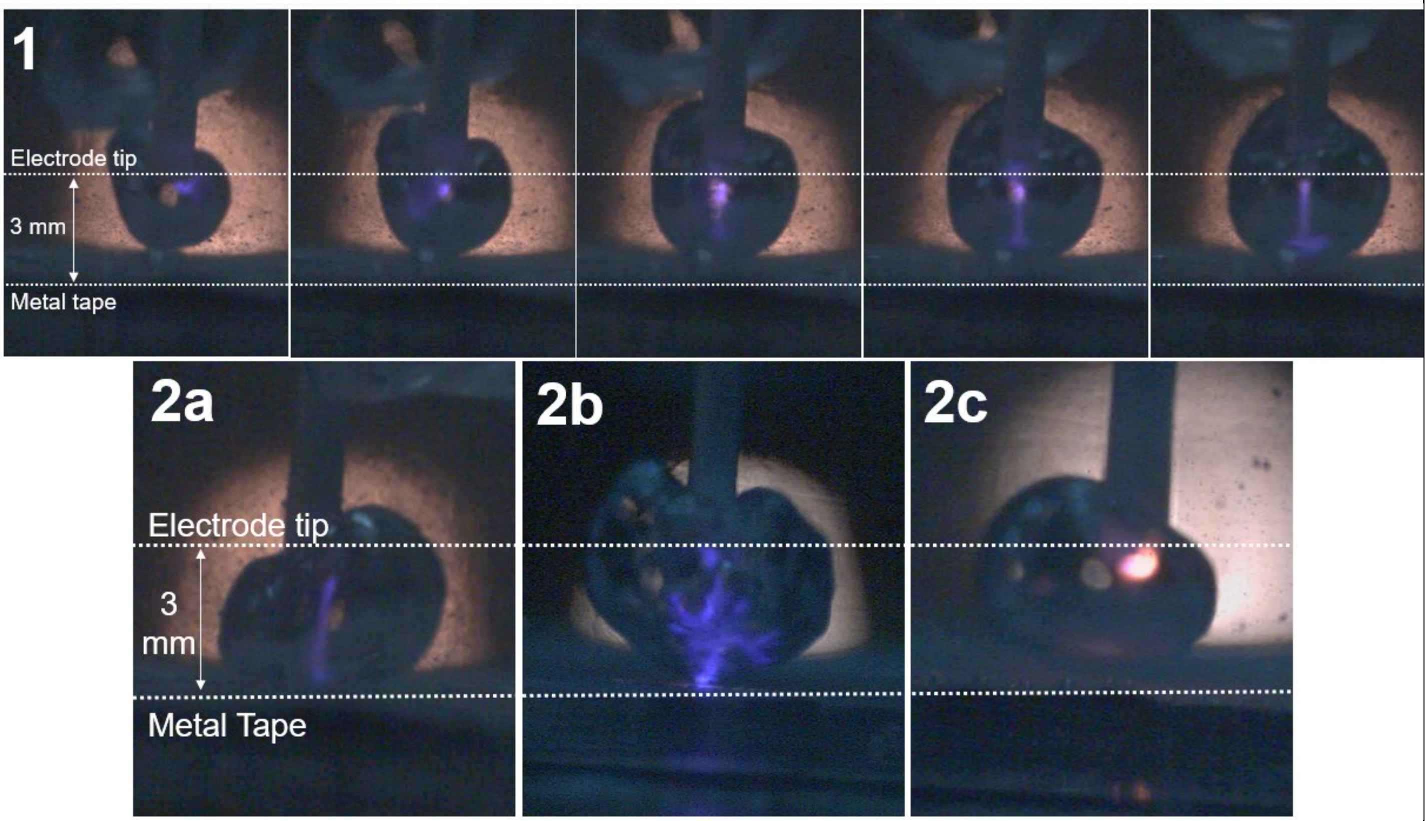
https://mipse.umich.edu/iltpc.php, iltpc-central@umich.edu

Newsletter 36

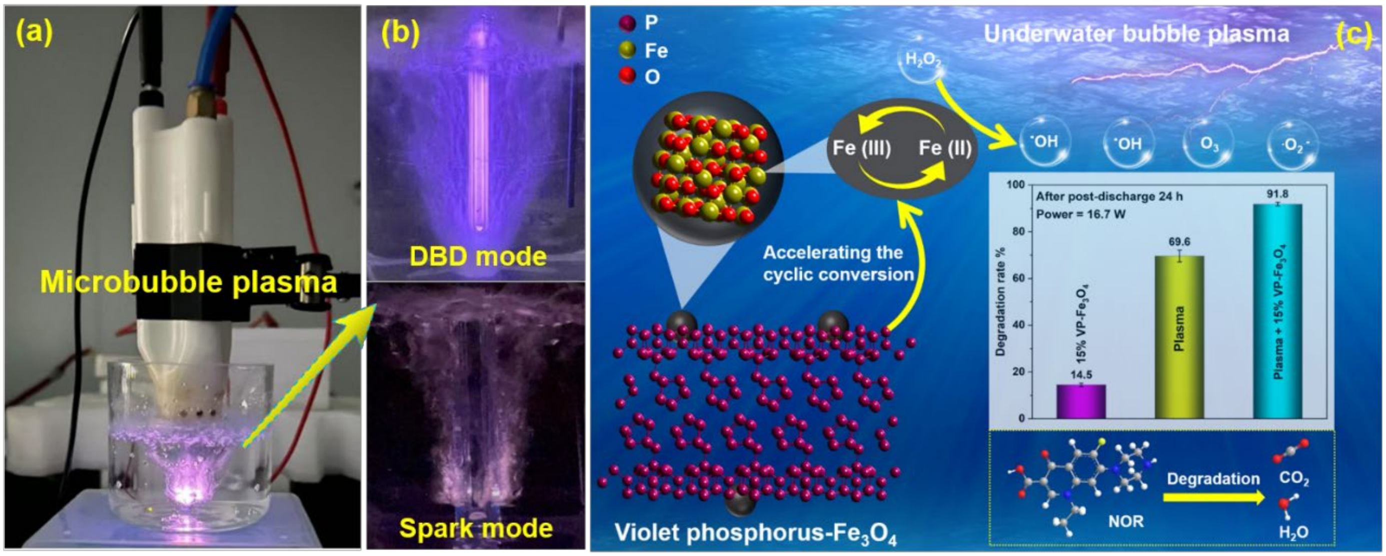
17 November 2023

Images to Excite and Inspire!

Please send your images (with a short description) to iltpc-central@umich.edu. The recommended image format is TIF, JPG, or PNG. The minimum file width is 800 px.



Plasma generation in liquid for catalyst-free ammonia synthesis: Dc-driven atmospheric pressure plasmas can easily produce a good amount of ammonia by supplying nitrogen into the water. The plasma, acting as the anode in the electrolytic reaction, was generated inside bubbles using a dielectric-tube-covered electrode, where the plasma stretched out from the electrode tip and moved towards the aluminum tape electrode (1). In this system, the liquid is viewed as the cathode of the reaction. Different liquid conductivities affect the size and shape of the plasma discharge. Low conductivity water such as tap water (2a) and distilled water (2b) produced a long, bright, and purple glow-to-spark-like plasma discharge, while a NaCl solution (2c) which has a high conductivity generated a yellow-orange corona-like plasma discharge near the electrode tip. As the size of the plasma increases, its area in contact with the water also increases resulting in a higher ammonia production rate, with tap water, distilled water, and NaCl solution producing 0.36 μmol/min, 0.71 μmol/min, and 0.26 μmol/min, respectively. The expansion of the bubbles from the generated plasma suggests the synthesis of ammonia occurs at the plasma-water interface. Results from the experiment are available from: Mary Ramoy et al., "Catalyst-free synthesis of ammonia using dc-driven atmospheric-pressure plasma in contact with water", J. Phys. D: Appl. Phys. **57,** 01LT01(2024). **Dr. Naoki Shirai,** Hokkaido University, Japan, nshirai@qe.eng.hokudai.ac.jp.



Violet phosphorus-Fe_3O_4 as a novel photocatalysis-self-Fenton system coupled with underwater bubble plasma to efficiently remove norfloxacin in water: Many persistent organic pollutants like the antibiotic norfloxacin, are able to pass through conventional wastewater treatment systems and flow unimpeded into local streams and rivers. Green and enhanced treatment technologies for wastewater are necessary to limit the uncontrollable spread of antibiotic pollution. A novel 3D multi-microhole helium plasma jet device was developed which can produce an underwater bubble plasma (UBP) with higher concentrations of reactive oxygen and nitrogen species, which is of great significance for water activation in emerging applications. An efficient photocatalysis-self-Fenton system based on violet phosphorus (VP)-Fe_3O_4 was constructed to achieve significant degradation performance. The VP-Fe_3O_4 coupled with UBP has also been found to have a higher synergistic degradation ability, which is due to its excellent reducibility and the electron donating ability of VP, boosting the cycle of Fe(II)/Fe(III) in Fenton reactions. The VP-Fe_3O_4 can also consume O_3 generated by UBP, with the enhanced in-situ H_2O_2 production. The efficient utilization of H_2O_2 via the Fenton reaction improves the generation of •OH. This research provides a promising strategy for environmental remediation via the incorporation of photocatalysis-self-Fenton system and UBP. Not only is the suggested approach pivotal to the treatment of the target antibiotic, but it also represents a potential solution for many persistent organic pollutants currently present in wastewater effluent. **Dr. Zhijie Liu**, Xi'an Jiaotong University, Shaanxi, China, liuzhijie2010@163.com. (Source: Chem. Eng. J. **452** (2023) 139481. http://dx.doi.org/10.1016/j.cej.2022.139481)

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Call for Contributions

Please submit content for the next issue of the Newsletter. Please send your contributions to iltpc-central@umich.edu by **December 15, 2023.** Please send contributions as MS-Word files if possible – and **avoid sending contributions as PDF files**.

In particular, please send **Research Highlights and Breakthroughs** using this ***template:*** https://mipse.umich.edu/iltpc/highlight_template_v05.docx. The highlight consists of an image and up to 200 words of text; please also send your image as a separate file (the recommended image format is JPG or PNG; the minimum file width is 800 px). The topic can be anything you want - a recently published work, a new unpublished result, a proposed new area of research, company successes, anything LTP-related. Please see the *Research Highlights and Breakthroughs* for examples.

LTP Perspectives: Policy, Opportunities, Challenges

Challenges in the Decarbonization of Aviation That Can Benefit from LTP (and Good Old-Fashioned Gas Discharge Physics)

Air transportation is responsible for emitting over 2% of all man-made carbon dioxide. Yet, its climate impact is greater due to contributions from nitrogen oxides, the warming effects of contrails, and the sector's continuous growth. In the face of this, the aviation industry has an aspirational goal to reach net zero carbon by 2050. The path to decarbonization, within a sector reliant on combustion and hydrocarbon fuels, presents significant challenges. This is especially evident in long-distance aviation, where full electrification is not a feasible solution. To the readers of the ILTPC Newsletter, here are three challenges where our expertise may play a role in reaching aviation's sustainability goals, while helping maintain affordable airfares.

First is the role that plasma, and plasma catalysis, may play in the development of *economically competitive methods for producing sustainable fuels.* Given the significantly lower energy density of even the most advanced batteries compared to hydrocarbon fuels, airlines currently have no alternative but to use sustainable aviation fuels (SAF). The main obstacle to their widespread adoption remains their cost. Given the potential for distributed processing resources and feedstock versatility, it is worth exploring whether plasma reactors can help with the economics of the problem.

Next, is the role that plasma-assisted combustion can have in endowing the *engines with the flexibility to reliably, efficiently, and cleanly burn SAF, as well as hydrogen and its carriers.* In particular, the integration of hydrogen into commercial aviation propulsion is very attractive given its high specific energy (per unit mass), and its dual use in hybrid-electric propulsion concepts – hydrogen can be combusted in gas-turbine engines, as well as used in fuel cells. However, the use of all these fuels in combustion will require new technologies for ignition, flame-stabilization, and low emissions (especially NO_x), potentially enabled by LTPs.

Finally, although less cutting edge than LTP technology (but equally, if not more, complex, and fascinating), there is an opportunity for research on *lightning attachment to a new generation of aircraft* that look like flying wings, have ultra-slender wings, and incorporate other unusual features. These geometry modifications are motivated by a need to reduce fuel-burn, and sometimes to accommodate the larger fuel tanks needed for hydrogen, but they are also challenging the industry standards for design and certification. For these new vehicles, standards that rely on in-service experience, historical data, and simple analytical rules, do not suffice. An approach that incorporates knowledge of the discharge physics, at the attachment-point-scale, into the aircraft-scale problem, presents a more versatile and robust method to adequately protect aircraft against lightning and static discharges. The LTP community is well positioned to tackle outstanding questions about the physics of lightning attachment, which can facilitate this transition.

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Leaders of the LTP Community: Career Profiles

Professor John P. Verboncoeur – Pioneer of Computational Plasma Physics and an Extraordinary Leader

As a pioneer in particle simulation of plasmas, Professor John Verboncoeur's work helped to define the field of computational plasma physics. John Verboncoeur is Professor of Electrical & Computer Engineering and Computational Mathematics, Science, and Engineering at Michigan State University (MSU), where he also currently serves as Senior Associate Dean for Research and Graduate Studies in the College of Engineering. He received a Ph.D. (1992) in nuclear engineering from the University of California at Berkeley (UCB). After a postdoc at Lawrence Livermore National Lab and UCB, he was appointed Associate Research Engineer and then Nuclear Engineering faculty at UCB.

Dr. Verboncoeur has made foundational contributions in theoretical and computational plasma physics. He is best known for being the principal author of several families of particle-in-cell Monte Carlo (PIC-MC) bounded-plasma codes, including XPDP1 and XOOPIC, which enabled realistic simulations of bounded plasmas in general, and whole plasma devices in particular. One particular important pioneering aspect of bounded plasma models is moving beyond perfect electrical conductor (PEC) to include complex impedance boundaries and circuits. In LTPs, this allows the modeling of non-ideal driving circuits, including matching circuits, and it also allows generalization to circuit networks. Used by thousands worldwide, these codes have revolutionized plasma modeling in both the basic and commercial plasma modeling areas, as well as providing an accessible teaching tool. Several generations of computational plasma physicists have been educated using his code suite, including both students and professionals through his university courses and over 20 international workshops on using PIC codes that he participated. Because of the significant emphasis in understanding both the numerics and the physics of the models, including the stability, convergence, and other quantifiable metrics, this combination made his code results the gold standard in the plasma PIC simulation community – indeed many approximate methods and competing PIC codes are benchmarked against them. His codes have been used for a broad range of applications spanning low temperature plasmas for lighting, thrusters and materials processing to hot plasmas for fusion, from ultra-cold plasmas to particle accelerators, from beams to pulsed power, from intense kinetic nonequilibrium plasmas to high power microwaves.

In plasma applications, Verboncoeur personally contributed to LTPs for materials processing, lighting, and displays, to high temperature fusion, from beams for lithography to heavy ion fusion and accelerators, from devices such as thermionic energy converters to microwave sources. His influential work includes beam and emission physics, multipactor discharge, plasma breakdown phenomena, and plasma-surface interactions in general. He became an IEEE Fellow in 2013, received the IEEE NPSS Shea Distinguished Member Award in 2018, the IEEE Plasma Sciences and Applications Committee Award in 2019, and IEEE NPSS Charles K. Birdsall Award in 2022.

Not overshadowed by his profound achievement in scholarship, Dr. Verboncoeur is also a pillar in the plasma science community and is known for his supportive professional community leadership. Beyond MSU, Dr. Verboncoeur has served as various leadership roles in national and international professional societies and advisory committees for science agencies and government labs. He is Past President of the IEEE Nuclear and Plasma Sciences Society, an IEEE Director, Acting Vice President of IEEE Publications Services and Products Board (PSPB), and serves on the Board of Directors for the American Center for Mobility national proving ground. He is Associate Editor of Physics of Plasmas, and serves on the DOE Fusion Energy Sciences Advisory Committee as well as the recent Sandia National Laboratories Grand Challenge LDRD External Advisory Board. Starting in 2016, he chaired the IEEE SmartAg initiative (Smart

Agrofood systems: technology applied to the food supply chain). He is the 2023 IEEE Vice-President of Technical Activities Board (TAB).

Besides plasma science and fulfilling his professional leadership roles, he has also managed to take time and led a number of successful startups, including computerized fitness equipment, digital health systems, distributed publication software including the consumer credit report for a big-three credit bureau, and a role in the US Postal Service mail forwarding system.

Dr. Verboncoeur is a kind person who is always enthusiastic about helping others in need. As both a scientist and a leader, he continues to inspire the next generation for the LTP community and beyond.

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Tribute

Dr. Eva Stoffels – Pioneer in Plasma Medicine

On July 20th, 2023, Dr. Eva Stoffels passed away, at the age of 54.

Eva was one of the earliest pioneers of the research area of Plasma Medicine. She started working in that field around 2002, as one of the very few in the world at that time. She recognized in an early stage that the exposure of living cells and tissues to plasmas had all kinds of effects which had the potential to fight diseases and infections: the area of plasma medicine was born. It took a few years, but then a large part of our low temperature plasma science community followed in her footsteps.

Originally from Warsaw, Poland, she graduated at Eindhoven University of Technology (TU/e) for her MSc (1991) and her PhD (1994). After her PhD, she was appointed Fellow of the Royal Dutch Academy of Science. After that, she spent two years in Kyoto, Japan. During that time, she developed a unique technique of “electron attachment mass spectrometry” for electro-negative species in plasma processing. In 2002 she became Assistant Professor in the department of Biomedical Engineering of the TU/e.

In 2007, the first edition of the ICPM, the International Conference on Plasma Medicine, was held in Corpus Christi, TX, USA. Eva was one of the founders. The picture below shows her together with Drexel friends at this crucial Plasma Medicine event.

Translated from her funeral card, which was received from her husband Winfred:

> As a young teenager Eva already performed research in her first passion, chemistry, at the University of Warsaw. In her heart she always remained a chemist. During an international chemistry contest, she met her future husband, Winfred Stoffels, for whom she came to the Netherlands in 1990. After her study at Eindhoven University of Technology, Eva worked in Kyoto, Japan, for two years. The country settled into her heart, she spoke Japanese fluently and frequently returned.
> Eva became an internationally recognized authority in the biomedical plasma science. As a frequently invited speaker, she traveled across the world.
>
> Nevertheless, in 2008, she made the choice to focus on her main passion: animals, and after obtaining a degree in veterinary medicine, she opened a veterinary practice in Retie, Belgium.

In 2021 Eva heard she was terminally ill. Despite the complications, she continued working in her practice, took care of her own guinea pigs, sheep, rabbits and chinchillas, researched guinea pig diseases, and transmitted her knowledge to other vets.

We remember Eva as a hyper-intelligent and dedicated woman, sometimes impatient and direct, but always full of love and passion.

1st International Conference on Plasma Medicine, Corpus Christi, Texas, USA. (left to right) Halim Ayan, Alex Fridman, Eva Stoffels, Greg Fridman, Danil Dobrynin

On behalf of the Board of Directors of the International Society for Plasma Medicine, and the International Conference on Plasma Medicine:

Prof. Gerrit Kroesen, Eindhoven University of Technology, the Netherlands (president ISPM)
Prof. Alexander Fridman, Drexel University, USA (Organizer first ICPM)
Prof. Kunihide Tachibana, Emeritus Professor, Kyoto University, Japan
g.m.w.kroesen@tue.nl, fridman@drexel.edu

General Interest Announcements

- **3rd US Low Temperature Plasma Summer School, Ann Arbor, USA – Save the Dates – June 24-28, 2024**

  The 3rd US Low Temperature Plasma Summer School (USLTPSS) will tentatively be held at the University of Michigan, Ann Arbor, USA on June 24-28, 2024. The USLTPSS is primary intended for graduate students, post-doctoral researchers and early career investigators, and provides a broad introductory overview of the science and technology of low temperature plasmas. The format of the USLTPSS will follow that of the 2nd rendition (https://mipse.umich.edu/summer_school_2023.php), offering lectures, poster-sessions, networking and mentoring opportunities, hands-on demonstrations and tutorials. The application portal and website will open in late January 2024. Questions prior to the opening of the portal can be directed to mipse-central@umich.edu.

- **DOE Collaborative Research Facilities Webinar, November 29, 2023 at 3:00 PM EST**

  The US Department of Energy (DOE) supports *Collaborative Research Facilities* (CRFs) which are available to the international community. The CRFs provide plasma sources, diagnostics and computations to enable investigations that support and expand upon what individual researchers can accomplish at their home institutions. There are three CRFs for low temperature plasmas:

Princeton Collaborative Research Facility (PCRF)	https://pcrf.princeton.edu/
Sandia Plasma Research Facility (PRF)	https://www.sandia.gov/prf/
Magnetized Plasma Research Laboratory (MPRL)	https://mprl.auburn.edu/

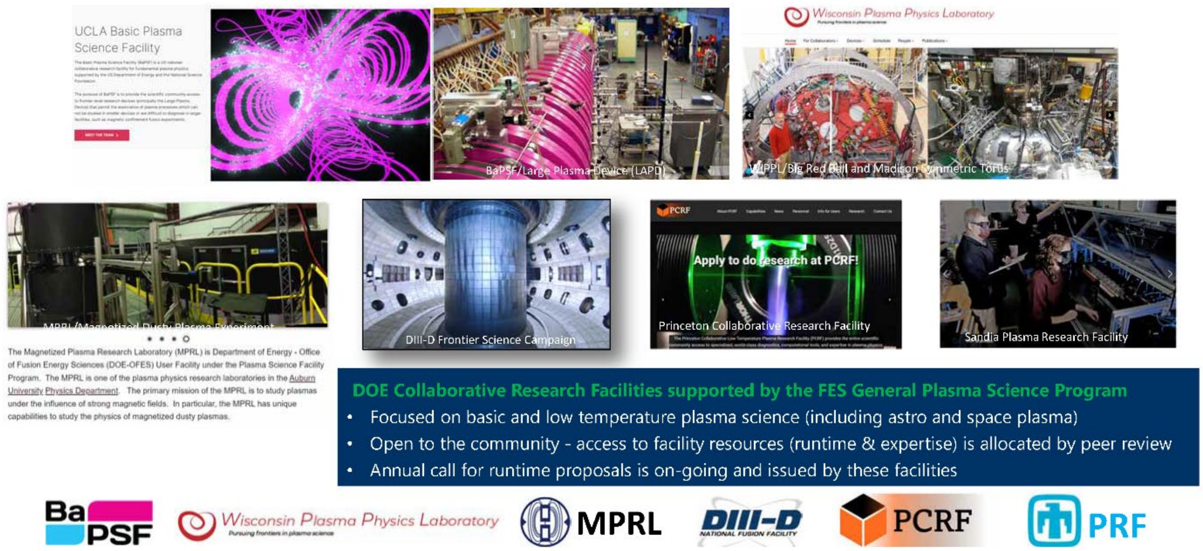
A Webinar will be held to describe the opportunities available at all of the DOE CRFs and the process to submit a proposal to use the facilities. The DOE Webinar is scheduled for **November 29, 2023 at 3:00 PM EST**. Please register in advance for this webinar:

https://pppl.zoom.us/webinar/register/WN_gL1q7nuCQa6KW1w8wvcB7g

Webinar: DOE Collaborative Research Facilities in Plasma Science

November 29, 2023 at 3:00 PM EST

Interested in learning how to carry out research on some of these facilities? Please register in advance for this webinar:
https://pppl.zoom.us/webinar/register/WN_gL1q7nuCQa6KW1w8wvcB7g

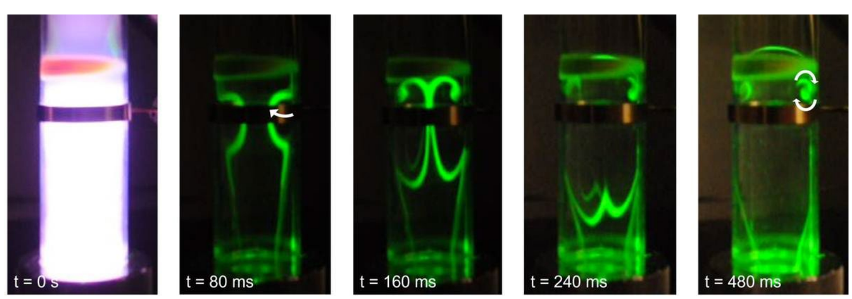


Directors of the CRFs:
Prof. Troy Carter, Basic Plasma Science Facility (BaPSF/LAPD), University of California – Los Angeles
Prof. Cary Forest, Wisconsin Plasma Physics Lab. (WiPPL/BRB/MST), Univ. of Wisconsin Madison
Prof. Ed Thomas, Magnetized Plasma Research Laboratory (MPRL/MDPX), Auburn University
Dr. Richard Buttery, DIII-D Frontier Science Campaign, General Atomics
Dr. Yevgeny Raitses, Princeton Collaborative Research Facility (PCRF), Princeton Plasma Physics Lab.
Dr. Shane Sickafoose, Sandia Plasma Research Facility (PRF), Sandia National Laboratory
Dr. Nirmol Podder, U.S. Department of Energy (DOE)

Meetings and Online Seminars

- **2024 U.S. Dusty Plasma Workshop, University of Minnesota, Minneapolis, USA – Save the Dates – May 19-22, 2024**

Please save the dates for the 2024 U.S. Dusty Plasma Workshop, the 16th workshop in this series. The workshop will be hosted by the University of Minnesota (Minneapolis, USA) on May 19-22, 2024. The workshop will take place on the Minneapolis campus on the banks of the Mississippi river and close to downtown Minneapolis..



We invite you to join us for an exciting meeting covering all aspects of dusty plasmas, including:

- Basic physics of dusty plasma
- Experimental studies of dusty plasmas
- Theoretical and computational studies of dusty plasmas
- Astrophysical and atmospheric dusty plasmas
- Microgravity dusty plasma experiments

- Magnetized dusty plasmas
- Industrial and research applications of dusty plasmas
- and more

The abstract deadline is **March 1, 2024** and early registration deadline is March 20, 2024. For more information, please visit the workshop homepage at https://dpw2024.umn.edu.

Contact:
Prof. Uwe Kortshagen
University of Minnesota, USA
korts001@umn.edu

- **5th International Conference on Data-Driven Plasma Science, Berkeley, USA, August 12-16 2024**

We cordially invite you to contribute to **ICDDPS-5**, the 5th International Conference on Data-Driven Plasma Science, which will be held in **Berkeley, California** (USA) **from August 12 to 16, 2024**.

ICDDPS is the premier forum for researchers from academia and industry to discuss current status and future directions of artificial intelligence and machine learning applied to plasma science and technologies, including, but not limited to, plasma processing and nuclear fusion.

Key Dates

Abstract submission opens:	November 1, 2023
Abstract submission deadline:	**January 12, 2024**
Notice of abstract acceptance:	February 9, 2024
Early registration deadline:	March 1, 2024

Please see https://chemistry.berkeley.edu/icddps-5 for more details on the conference and submission categories.

Contact:
Prof. Ali Mesbah
University of California, Berkeley, USA
mesbah@berkeley.edu

- **The Online Low-Temperature Plasma (OLTP) Seminar Series**

The schedule for OLTP seminars and more information on the program, including links to past seminars, can be found at the OLTP website:

https://theory.pppl.gov/news/seminars.php?scid=17&n=oltp-seminar-series

The seminars are held on Tuesdays at 10:00 am EDT or EST via Zoom and are free to access.

Co-Chairs:
Dr. Mikhail Shneider, Princeton University, USA, shneyder@princeton.edu
Prof. Dr. Vasco Guerra, University of Lisboa, Portugal, vguerra@tecnico.ulisboa.pt

- **IOPS Online Seminars**

The *International Online Plasma Seminar (IOPS)* is continuing to provide the international community with regular opportunities to hear from leading researchers in the field. The program of the IOPS (and links to past seminars) can be found at: http://www.apsgec.org/main/iops.php.

Chair:
Prof. Quan-Zhi Zhang, Dalian University of Technology, China, qzzhang@dlut.edu.cn

- **10th International Conference on Plasma Medicine, Portorož, Slovenia – Save the Dates – September 8-13, 2024**

The **10th International Conference on Plasma Medicine (ICPM10)**, together with **9th International Workshop on Plasma for Cancer Treatment (IWPCT)** will be held in Portorož, Slovenia, from **September 8 to September 13, 2024**. It will be an on-site conference in LifeClass Hotels & Spa Portorož (Hotels Slovenia, Riviera, Grand Hotel Portorož), in the Portorož downtown area on the beach.

As in previous editions of the conference, the ICPM will bring together professionals from the fields of plasma, medicine, biology and biochemistry in order to develop a common language, to better define key challenges and open questions and to move toward effective solutions. This time it will be organized jointly with IWPCT covering plasma for cancer therapy on Monday, September 9.

Prior to the conference, the traditional Summer School will take place, starting on the weekend, Sunday, September 8, and going through mornings from Monday, September 9 to Wednesday, September 11. Registrations for the summer school will be conducted separately from the registrations for the conference.

Abstracts due	**March 11, 2024**
Early registration	**May 27, 2024**
Notification of abstract acceptance	**May 6, 2024**

The ICPM10 Local Organizing Committee
Urška Kisovec, urska.kisovec@ijs.si

Community Initiatives and Special Issues

- **Special Issue on *Nanosecond Discharges: Fundamentals and Applications* in Journal of Physics D: Applied Physics**

  Plasma generated by high-voltage nanosecond pulses has applications in different fields, such as material science, surface science, agriculture, medicine, pollution control, combustion, and energy conversion. These very short discharges generate a large number of reactive species and are characterized by a high degree of non-equilibrium, which can be exploited to overcome the thermodynamic limitations of traditional thermal processes. Their short duration also allows for increased instantaneous power with low energy consumption. This Special Issue *Nanosecond Discharges: Fundamentals and Applications* of *Journal of Physics D: Applied Physics* aims to share expertise on nanosecond discharges in different applications and expand their knowledge to a broader community. We welcome and encourage contributions from diverse fields.

  Submission process: All articles should be submitted using our online submission form for Journal of Physics D. From the "Focus Issue" menu, select 'Special Issue on Nanosecond Discharges: Fundamentals and Applications' in the 'Special Issue' drop down box that appears.

  Deadline for submissions: The target deadline for submissions is **31 March 2024** though we can be flexible where necessary. We encourage early submission, as articles will be published on acceptance without being delayed by other papers in the collection.

  Guest Editors
  - **Paolo Tosi**, University of Trento, Italy
  - **Luca Matteo Martini**, University of Trento, Italy
  - **Tao Shao**, Institute of Electrical Engineering, Chinese Academy of Sciences, China

  Contact:
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  University of Trento, Italy
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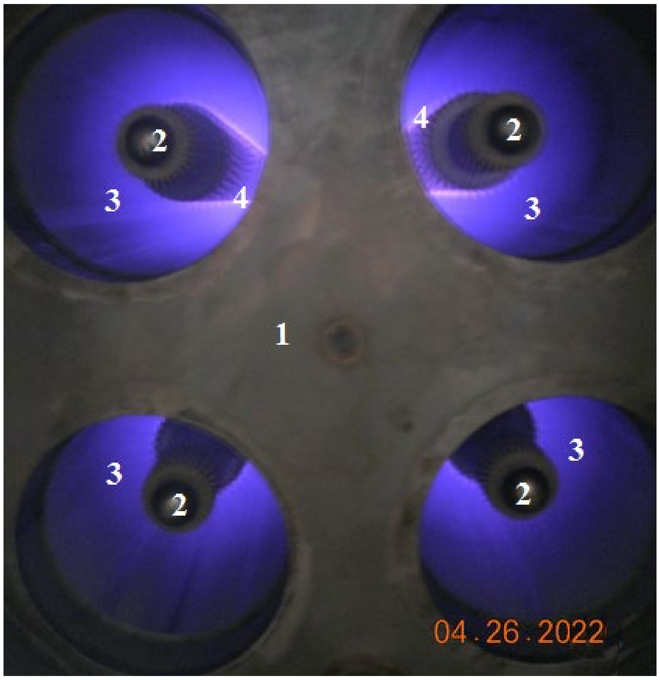
Production of Ammonium Nitrate in Plasma of Nanosecond Streamer Discharge



Static photograph of plasma in RC from a nanosecond streamer corona discharge: Pulse duration 150 ns, repetition rate 200 Hz, exposure 2s.

1. Grounded shell of reactor chambers
2. High voltage electrodes
3. Primary streamer
4. Secondary streamers

Natural gas thermal power plants are sources of nitrogen oxides (NO_x) emissions. With a flue gas volume from one unit of 100 MW ~$10^6 m^3/h$, NOx emission is ~100-200 kg/h. NO_x can be converted of into an aerosol of nitric acid using nanosecond streamer corona discharge (NSCD) at high frequency. In our "CORSTRIM" installations, the conversion is carried out in coaxial reactor chambers (RC) using constant high voltage pulses. In this case, the pulses simultaneously work as gas convectors and electric precipitator.

NOx conversion occurs at specific energy consumption ~$0.03 Wh/m^3 \cdot mg$ as:

$O_2 + e^-(5.1eV) \rightarrow O^* + O$ (gas)
$NO + O \rightarrow NO_2 + h\nu$ (gas)
$NO_2 + OH \rightarrow HNO_3$ (aerosol)

It will be possible to produce fertilizer – ammonium nitrate –NH_4NO_3 (AN) by supplying NH_3 to the RC:

$HNO_3 + NH_3 \rightarrow NH_4NO_3$

A solid NH_4NO_3 powder is formed, which settles on the inner walls of the RC, from where it is washed off with water. NH_3 can also be produced in NSCD from N_2 and H_2

$0.5N_2 + 1.5H_2 + e^-(17eV) \rightarrow NH_3$.

The product of AN resulting from one hour of operating time of one power unit with a capacity of 100 MW from NO_x can provide 20 – 40 hectares with fertilizer.

Contact:
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Air & Plasma Technology SL, Russia
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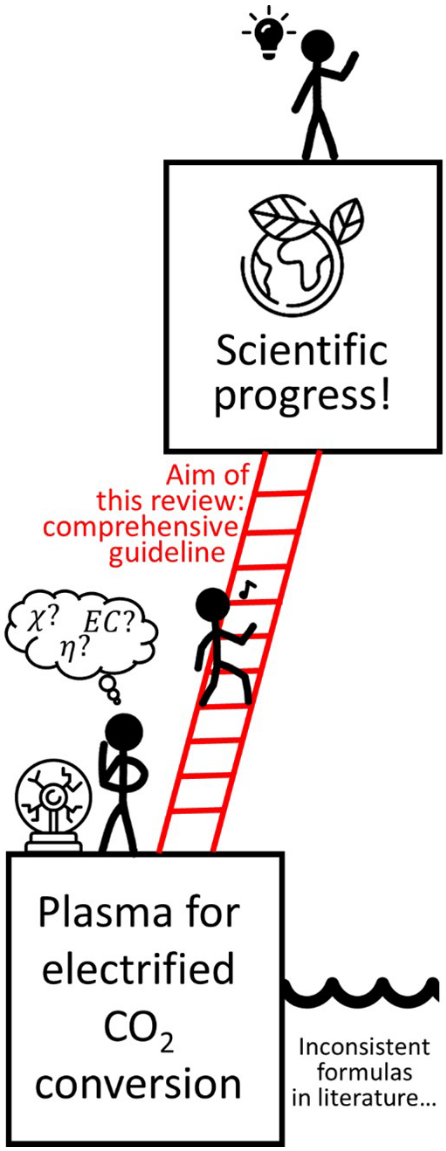
Plasma-based CO_2 Conversion: How to Correctly Analyze the Performance?



This review aims to provide a comprehensive guideline for authors to encourage more consistent calculations.

Plasma-based CO_2 conversion is promising for carbon capture and utilization. However, inconsistent reporting of the performance metrics makes it difficult to compare plasma processes systematically, complicates elucidating the underlying mechanisms, and compromises further development of this technology. In our recent critical review, we therefore summarize the correct definitions for gas conversion in plasma reactors and highlight common errors and inconsistencies observed throughout literature.

We demonstrate that the change in volumetric flow rate is a critical aspect, inherent to these reactions, that is often not taken into account correctly. For dry reforming of methane and CO_2 hydrogenation, we also demonstrate inconsistent reporting of energy efficiency, and through numerical examples, we show the significance of these deviations. Furthermore, we discuss how to measure changes in volumetric flow rate, supported by data from two experimental examples, showing that the sensitivity inherent to a standard component and a flow meter is essential to consider when deriving the performance metrics. Finally, some general recommendations and good practices are provided. This paper aims to be a comprehensive guideline for authors, to encourage more consistent calculations and stimulate the further development of this technology.

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Source: J. Energy Chem., **86**, 180-196 (2023). https://doi.org/10.1016/j.jechem.2023.07.005

Spatiotemporal Inhomogeneities in Packed Bed DBD Reactors for CO_2 Splitting

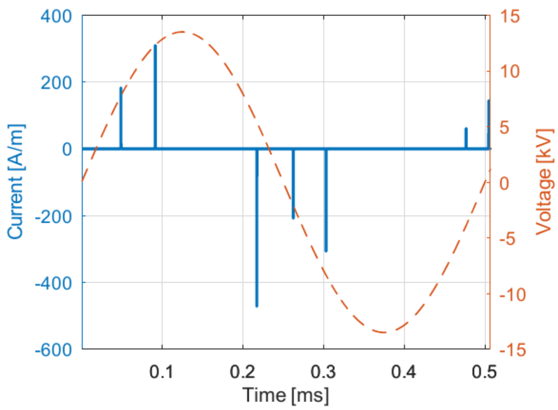

Figure 1. Discharge current (I) - voltage (I-V) characteristics in the first AC cycle. Current values are extrapolated to the total 2D reactor volume.

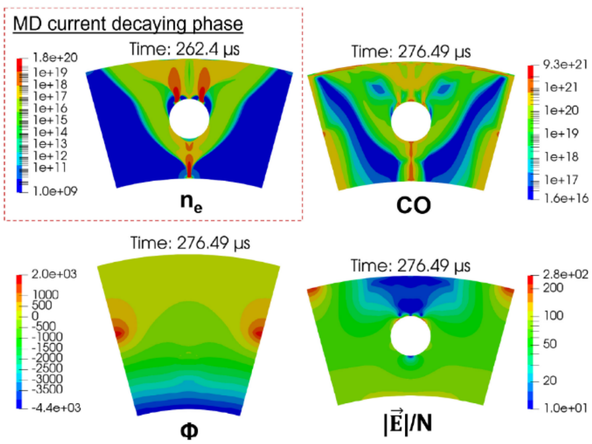

Figure 2. Top-left: Electron density contours (log-scale) [m^{-3}], at the decaying phase of the 4th MD current pulse. Rest: CO density contours (log-scale) [m^{-3}], potential Φ [V] and reduced electric field |E/N| [Td] (log-scale) at the long-term afterglow phase of the 4th MD.

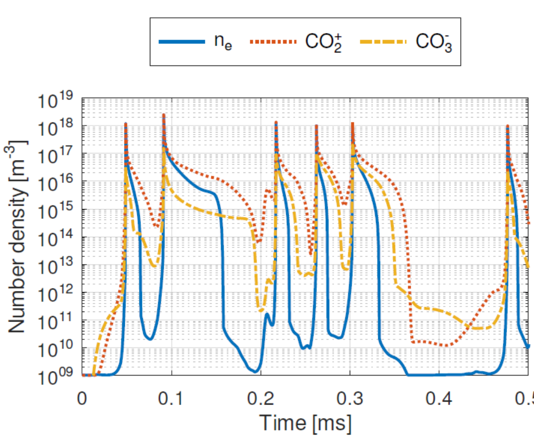

Figure 3. Spatial average (mean) number density (m^{-3}) for dominant charged species vs time during the first AC cycle.

The full-cycle operation of a 2 kHz, coaxial, Packed Bed Dielectric Barrier Discharge (PB-DBD) reactor operating in pure CO_2 and packed with high permittivity dielectric rods (ZrO_2), is analyzed with a two-dimensional (2D) self-consistent plasma model. The numerical results indicate that in the 1st AC cycle, the plasma operates in glow, streamer and SIW modes which present significant spatial inhomogeneities owing to the surface charging and residual space charge effects. The presence and surface charging of the dielectric rods and dielectric layer is crucial for the initiation, propagation, annihilation and afterglow of these microdischarges.

Our calculations show maximum electron and CO_2^+ densities in the order 10^{20} m^{-3}, an average discharge power of 353.42 W/m in the first cycle, microdischarge (MD) peak currents in the order of 50-400 A/m, total half-cycle plasma charge of around 6 µC/m, which compare well with experimental findings. Dominant negative ions are found to be CO_3^-. CO molecules and O atoms are mainly formed during the MDs development and the streamer-surface ionization waves. Molecular oxygen (O_2) is preferentially formed during the glow, current-decaying and afterglow phase of each microdischarge. The spatially average reduced electric field inside the reactor lies in the 20-100 Td range.

Each MD, presents distinct non-uniform and non-repeatable glow and volume/streamer discharges owed to the non-uniform surface charging processes which dictate the complex spatial distribution of produced neutral (and ion) species. These detailed results shed light on crucial, largely non-uniform plasma spatiotemporal characteristics that can help design efficient PB-DBD reactors for CO2 splitting and beyond, while emphasizing the important insights obtained by 2D simulations.

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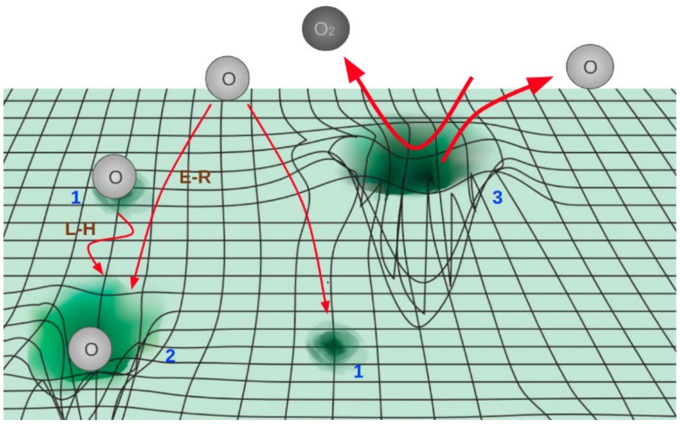
Source:
Kourtzanidis 2023 Plasma Sources Sci. Technol. https://doi.org/10.1088/1361-6595/ad0430

Plasma-Induced Reversible Surface Modification



Graphical representation of the surface and of the reactions involving physisorption (1), stable chemisorption (2) and metastable chemisorption (3) sites. The metastable sites are produced by the impact of fast ions and neutrals and can be destroyed by increasing the plasma pressure.

A novel mesoscopic model is developed for atomic oxygen surface kinetics on silica-like walls, introducing a plasma-induced surface modification, which may impact intermediate pressure plasma reactors. The model is the first to reproduce experimental measurements in an oxygen glow discharge operating in the pressure range between 0.27 mbar (0.2 Torr) and 4 mbar (3 Torr), showing a decrease with pressure of the O recombination probability on Pyrex between 0.27 mbar and 1 mbar. The numerical simulations suggest that a modification is induced by the production and destruction of metastable chemisorption sites at the surface. As such, the Langmuir–Hinshelwood (L-H) and Eley-Rideal (E-R) recombination mechanisms take place involving not only physisorption and stable chemisorption sites, but also metastable chemisorption sites, produced by the impact of fast O_2 ions and neutrals. The presence of metastable sites can be reversed by increasing the plasma pressure.

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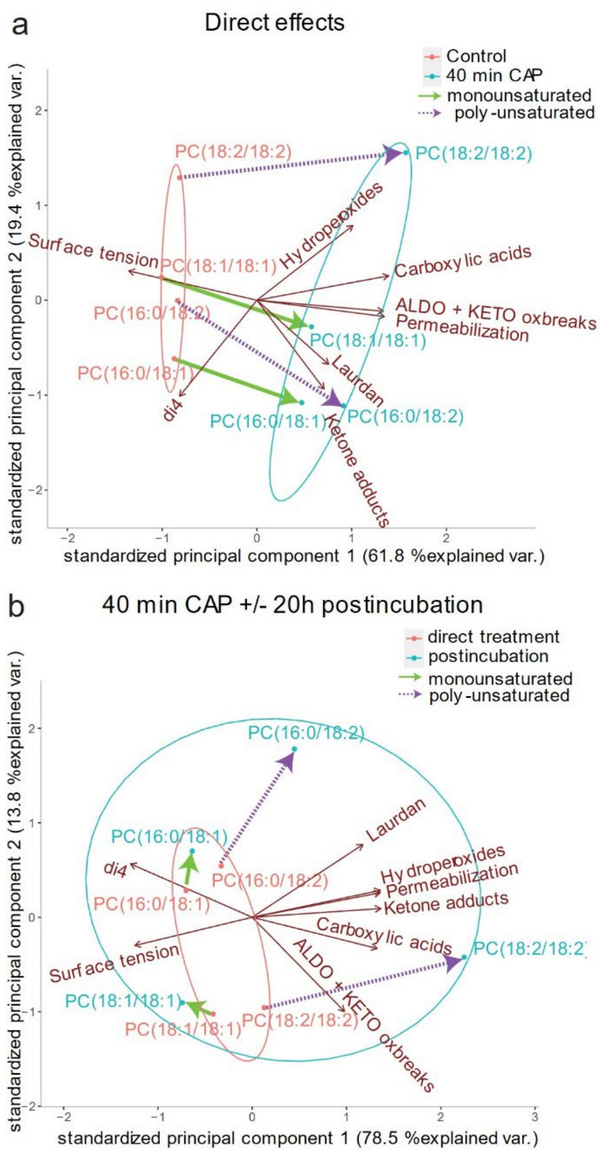
Source:
J. Phys. D: Appl. Phys. **57** 04LT01 (2023)
https://iopscience.iop.org/article/10.1088/1361-6463/ad039b

Two Separate Mechanisms Are Involved in Membrane Permeabilization During Lipid Oxidation When Exposed to a Non-thermal Plasma



PCA analysis of average membrane properties in parallel to the formation of specific OxLipids and changes of biophysical membrane properties and surface tension (brown arrows).

Lipid oxidation is a universal degradative process of cell membrane lipids that is induced by oxidative stress and reactive oxygen and nitrogen species (RONS) in multiple pathophysiological situations. It is unclear how oxidative damage is related to biophysical properties of membranes. We therefore set out to quantify lipid oxidation when using a non-thermal plasma (the kINPen) as source for RONS. Our data revealed complex lipid oxidation that can lead to two main permeabilization mechanisms. The first one appears upon direct contact of membranes with RONS and depends on the formation of truncated oxidized phospholipids. These lipids seem to be partly released from the bilayer, implying that they are likely to interact with other membranes and potentially act as signaling molecules. This mechanism is independent of lipid unsaturation, does not rely on large variations in lipid packing and is most probably mediated via short-living RONS. The second mechanism overtakes after longer incubation periods and depends probably on the continued formation of lipid oxygen adducts such as lipid hydroperoxides or ketones. This mechanism depends on lipid unsaturation and involves large variations in lipid packing. This study indicates that polyunsaturated lipids, that are present in mammalian membranes rather than in bacteria, do not sensitize membranes to instant permeabilization by RONS but could promote long term damage.

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Biophysical Journal (2023)
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Investigations of Fast Electrons Kinetics in the Negative Glow Plasma of Microhollow Cathode Discharge in Helium with Impurities

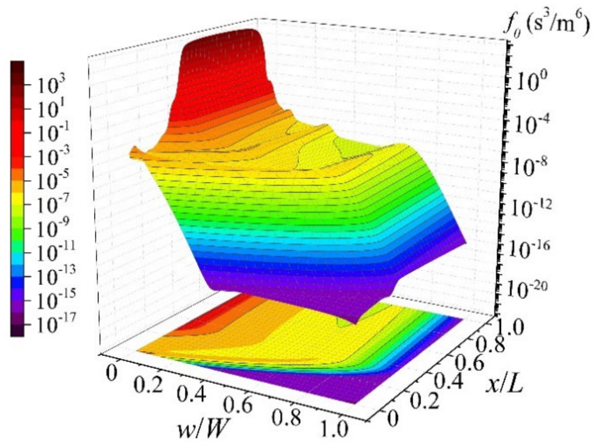

Figure 1. Electron energy distribution function (EEDF) at a pressure p = 30kPa and an interelectrode gap L=0.2mm. The energy w is scaled by W= 450 eV.

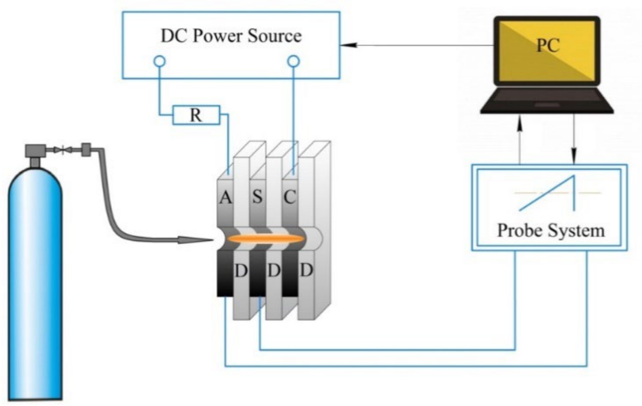

Figure 2. Electrical diagram of the installation.

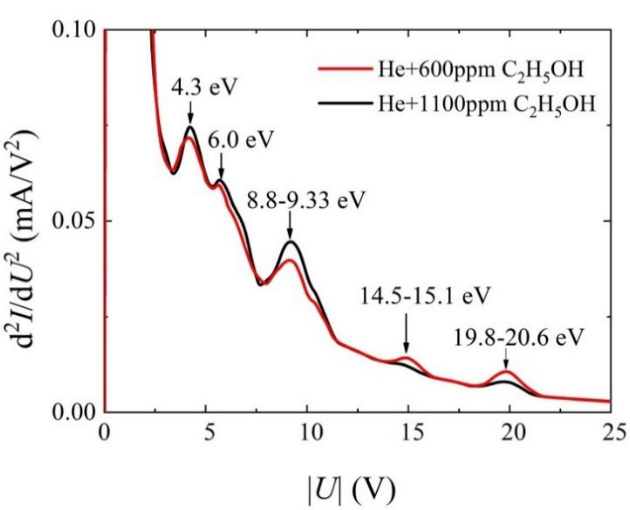

Figure 3. High-energy part of the second potential derivative of probe current for the mixtures:He+600ppm C_2H_5OH and He+1100ppm C_2H_5OH in a 15 mA negative-glow plasma having a microhollow cathode.

We present results of studies of plasma parameters and kinetics of fast electrons in the negative glow plasma of microhollow cathode micro-discharge based on a hybrid model that includes a kinetic description of electrons and a fluid description of the heavy plasma component. Results were obtained that show the formation of the EEDF at each point in space along the length of the discharge gap. The Maxwellian part and the fast part are observed (Fig. 1). The results of numerical calculations are compared with the results of experiments. The experiments (Fig. 2) were based on measuring the probe current-voltage characteristics of a glow discharge plasma with a microhollow cathode using an additional wall electrode. In particular, experiments were carried out for various contents of argon, air and ethanol impurities in helium (Fig. 3). The possibility of experimentally estimating the concentrations of impurities, conversion products of impurity gases, as well as the concentration of metastable helium atoms in negative-glow plasma at high pressure was demonstrated. It is shown that the hybrid model allows one to accurately describe the formation of EEDF peaks from fast electrons resulting from Penning ionization reactions and superelastic collisions. The results of numerical calculations make it possible to predict the parameters of negative-glow plasma in discharges with a microhollow cathode in pure helium and in helium with impurities.

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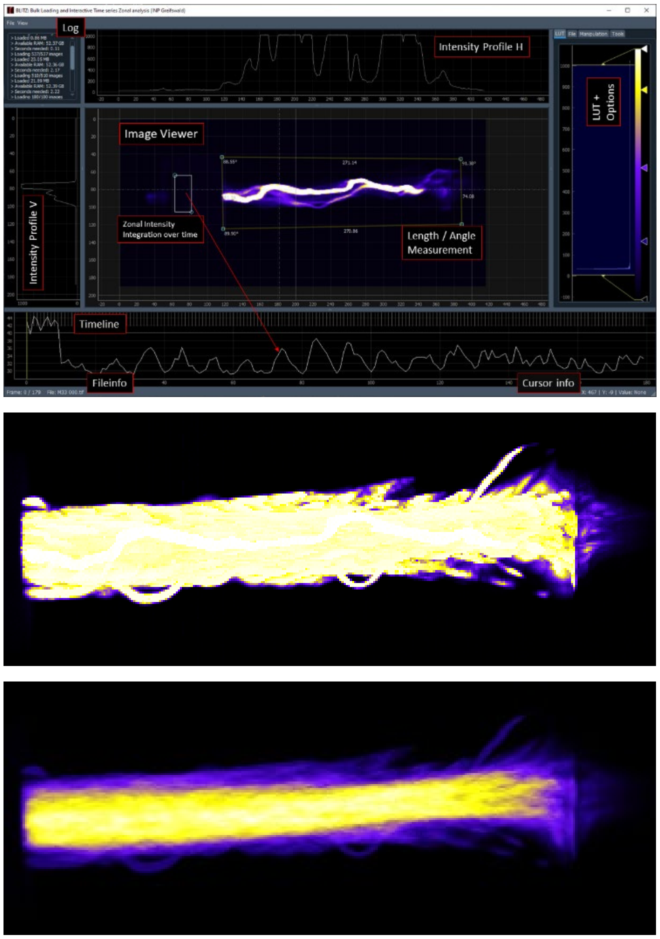
Source:
A. I. Saifutdinov and S. S. Sysoev, 2023 Plasma Sources Sci. Technol. **32**, 114001.
doi:10.1088/1361-6595/ad05f6

BLITZ – Presenting an Open Source Image Viewer Optimized for "Bulk Loading and Interactive Time Series Zonal Analysis"



(top) Overview of graphical user interface while loading a fast framing data set of 180 images at a high repetition rate of 100.000 FPS. Example of post processed images accumulating the **(middle)** maximum pixels and **(bottom)** the standard deviation (c) within the dataset.

Find an animated version **here**.

Efficient image analysis is crucial in plasma research, where handling extensive image series is challenging. Traditional viewers struggle with large datasets, and while macros help, they require expertise and considerable computing time. The INP introduces "BLITZ," a Python-based image viewer using QT and PyQTGraph, designed for rapid performance and scalability. It supports fast loading of large image series, with performance dependent on CPU cores and RAM configuration. BLITZ offers scale reduction, subsetting, and bit depth conversion for loading images.

Stable lookup tables ensure visual consistency, and the user-friendly GUI facilitates interaction. BLITZ processes images as matrices, enabling quick statistical calculations like Mean, Min, Max, and STD. The tool includes measuring tools and image manipulation options such as masking and flipping. The bulk export feature efficiently handles large datasets, utilizing local hardware resources effectively.

An attached image demonstrates BLITZ's functionality using a sequence of images from an atmospheric pressure argon jet (kINPen Science). Exiting its closed beta version, we invite the plasma research community to use the software. Experimenting with the tool using personal or provided samples is key for its development. Feedback and programming assistance are welcome in this open-source project, with active participation highly appreciated.

The BLITZ GitHub Repository can be found here: https://github.com/CodeSchmiedeHGW/BLITZ

The trial data set mentioned above can be found here:

https://doi.org/10.34711/inptdat.812

Contributions to BLITZ were mad by Dr. Philipp Mattern, Richard Krieg, Dr. Hans Höft, Dr. Markus M. Becker, Prof. Klaus-Dieter Weltmann, and Dr. Torsten Gerling

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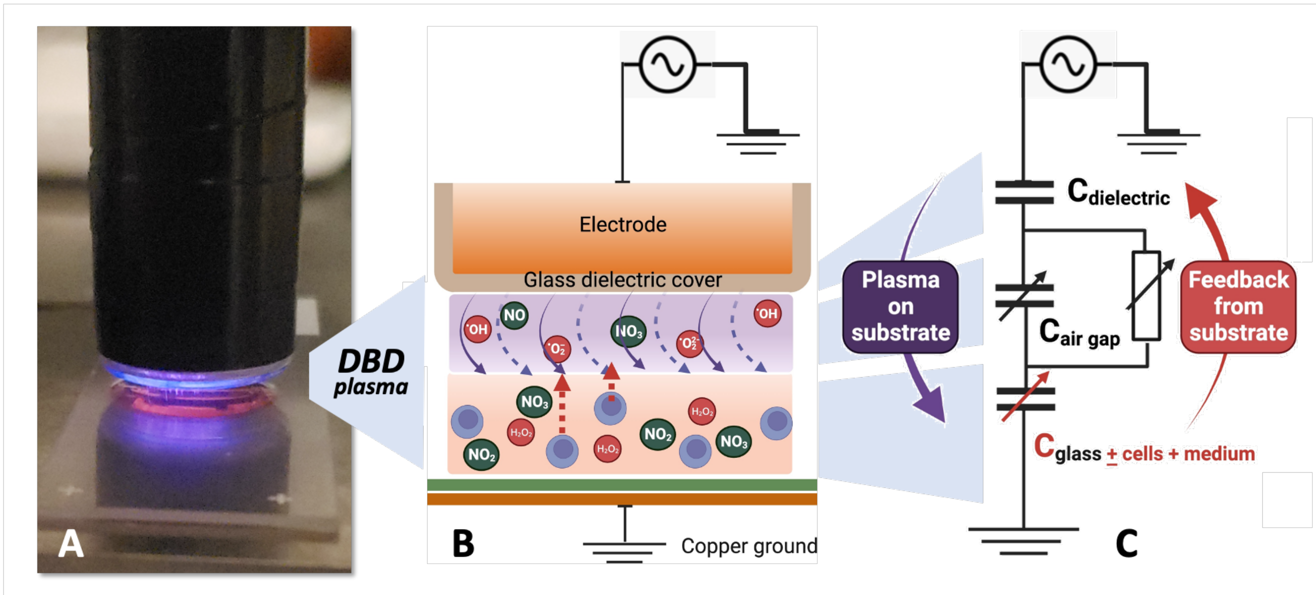
Dr. Torsten Gerling, gerling@inp-greifswald.de
Leibniz Institute for Plasma Science & Technology, Germany

Biological Targets Alter Electrical Characteristics and Chemistry of Non-Thermal Plasma



Application of dielectric barrier discharge (DBD) plasma to cells in medium (A) produces reactive oxygen and nitrogen species (RONS) in the medium surrounding the cells (B). Cells, in turn, modulate RONS concentrations. The presence of cells during plasma application also modulates circuit capacitance and the energy delivered to the cells and medium by plasma (C)

During laboratory investigations involving the application of non-thermal plasma (NTP) to living cells, the biological effects of NTP are typically correlated with the concentrations of long-lived reactive oxygen and nitrogen species (RONS) in the liquid growth medium. These studies generally ignore the influence of the biological target on the properties of NTP and the effects of redox responses mounted by the biological target against NTP-generated RONS. To explore these overlooked effects, we applied floating electrode dielectric barrier discharge (FE-DBD) plasma to cells and determined the impact of cell integrity, size, and viability on NTP electrical characteristics and concentrations of NTP-generated RONS. We demonstrated that changes in cell integrity and viability correlated with changes in circuit capacitance and energy delivered during NTP application. Our analyses also showed that viable cells modulate NTP-generated hydrogen peroxide and nitrite concentrations. This modulation of RONS could be through enzymatic redox responses active in living cells, uptake of RONS by cells, or reactions between RONS and components of the cell membrane. Our studies reveal an important feedback loop in which the biological targets of NTP affect the properties of the plasma delivered to cells as well as the chemical effectors generated during NTP application. A greater understanding of reciprocal interactions between NTP and biological targets is integral to developing clinical uses for NTP.

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Source:
Plasma **2023**, 6(3), 577-591. https://doi.org/10.3390/plasma6030040

New Resources

Please submit your notices for New Resources to iltpc-central@umich.edu.

Career Opportunities (for other career opportunities, see: https://mipse.umich.edu/jobs.php)

- **Research Faculty and Associate Director of the Illinois Plasma Institute, University of Illinois, USA**

  The Department of Nuclear, Plasma, and Radiological Engineering at the University of Illinois Urbana-Champaign (UIUC), in Urbana, Illinois, USA, invites applications for a full-time Research Faculty (assistant, associate, or full) position. The incumbent will carry out responsibilities related to research and public service. The duties associated with the position are to support the research, education, and maintain and establish the vigorous and externally funded research program at the Illinois Plasma Institute (IPI) and serve as the Associate Director of the IPI. This position requires a Ph.D. in plasma engineering or a related field. The successful candidate must have experimental expertise in low-temperature plasmas and/or atmospheric-pressure plasmas. The Department of Nuclear, Plasma, and Radiological Engineering is committed to creating an accessible, supportive environment and an educational experience that recognizes diversity and cultural competence as integral components of academic excellence. Additionally, the candidate is expected to have a record of scholarly achievement as demonstrated by a combination of publications, invited talks, extramural funding, professional service contributions, and other recognized scholarly activities. This is a twelve-month, full-time, benefits-eligible, non-tenure-track, renewable position.

  Questions about the application process should be referred to Kathy Atwood (kbuss@illinois.edu) or the contact below. Applications received prior to **December 15, 2023** will receive full consideration.

  Contact:

  Prof. David N. Ruzic
  University of Illinois at Urbana-Champaign, USA
  druzic@illinois.edu

- **Postdoctoral Opportunity: Chemical & Environmental Engineering / Carbon Containment Lab, Yale University, USA**

  We are seeking candidates for a Postdoctoral Associate position in the area of non-thermal plasma conversion of hydrocarbon gases. The research will be conducted in the lab of **Professor Lea Winter** (winterlab.yale.edu) in the Department of Chemical and Environmental Engineering in collaboration with the Yale Carbon Containment Lab (carboncontainmentlab.yale.edu). The position is available immediately and has an initial appointment period of two (2) years, with a minimum annual salary of $65,000 plus benefits (see postdocs.yale.edu/applicants/yale-benefit-summary). Candidates should be pursuing or hold a PhD in Chemical Engineering, Chemistry, Environmental Engineering, or a related field; expertise in non-thermal plasma or heterogeneous catalysis preferred.

  To apply, applicants should submit a CV including a list of publications, a 1-page statement detailing research experience and interests, and contact information of 1-2 references to Prof. Winter at lea.winter@yale.edu.

  Contact:
  Prof. Lea R. Winter
  Yale University, USA
  lea.winter@yale.edu

- **Scientist: Plasma Diagnostics, Leibniz Institute for Plasma Science and Technology (INP) in Greifswald, Germany**

  The department of Plasma Diagnostics at the Leibniz Institute for Plasma Science and Technology (INP) in Greifswald, Germany, invites applications for a **scientist experienced in plasma diagnostics**. The application-oriented research activities in the Department of Plasma Diagnostics are centered on the development and application of advanced laser-based diagnostics for the characterisation of plasma-chemical processes and plasma-surface interactions. For the evaluation and development of a plasma process aimed to restore reflective metallic surfaces at low pressures, we are looking for the following expert to join us in an ongoing collaboration with an industrial partner from the beginning of March 2024.

  Our institute ranks among the largest and most modern institutions in the field of low-temperature plasmas worldwide. In an international working environment, we conduct socially relevant research within our core areas *Materials & Energy* and *Environment & Health*. Currently the INP employs about 200 scientists and staff at three locations (Greifswald, Rostock and Karlsburg). For further information, please visit our website at https://www.inp-greifswald.de/en/

  Full details of the advertised position can be found under the following link:

  https://inp-greifswald.dvinci-easy.com/en/jobs/20398/0534-scientist-fmd-experienced-in-plasma-diagnostics

  Applicants should send their application (motivation letter, CV, copies of academic degrees, and letters of reference) to Mrs. Gabriele Lembke giving the keyword "0534 Scientist Plasma Diagnostics" - *preferably via our online application form*. Alternatively, the application can also be sent to the Human Resources Department, bewu@inp-greifswald.de.

  Contact:
  Dr. Norbert Lang
  Leibniz Institute for Plasma Science and Technology, Germany
  lang@inp-greifswald.de

- **Postdoctoral Researcher: Computational Plasmas and Plasma Surface Interactions for Materials Synthesis, University of Michigan, USA**

  The Computational Plasma Science and Engineering Group at the University of Michigan, Ann Arbor, USA (https://uigelz.eecs.umich.edu/) has an opportunity for a post-doctoral researcher (PDR) in modeling low temperature plasma chemistry and plasma surface interactions. The group has several projects in atmospheric pressure plasmas for material synthesis and in low pressure plasmas for microelectronics fabrication to which the PDR will contribute. The PDR will develop and apply new computational algorithms for plasma transport (reactor scale) and plasma surface interactions (nano-scale). The position includes interaction with collaborators and sponsors of the research, and supervising/mentoring group members. The position is available in March 2024 and has a term of up to 3-years. The PDR should have completed his/her PhD in a physics or engineering discipline prior to starting the position, and should have a broad knowledge of low temperature plasma physics and chemistry with experience in computations.

  Applicants should submit a cover letter describing their background and research interests and a CV (including a list of publications and at least 2 references) as a single PDF file to the contact below. Please also arrange for 2 reference letters of reference to be sent to the contact.

  Contact:
  Prof. Mark J. Kushner
  University of Michigan, USA
  mjkush@umich.edu

- **Assistant Professor: Plasma-Surface Interactions for Applications in Catalysis, Eindhoven University of Technology, The Netherlands**

The Plasma & Materials Processing (PMP, https://www.tue.nl/en/research/research-groups/plasma-materials-processing) research group in the Department of Applied Physics and Science Education of the Eindhoven University of Technology (TU/e) is searching for an experimentalist with a strong knowledge in plasma physics and chemistry and eager to investigate how plasma energetically excites gas molecules, thereby affecting the activation energy barrier to specific reactions at the catalyst surface. We desire someone who is passionate to unravel the mechanisms of plasma-activated catalysis by in situ diagnostics in the plasma phase as well as at the (sub-)surface of the catalyst. We hope and expect the successful applicant will connect with our (inter)national academic and industrial research network, and to contribute to extending these for others.

Job requirements:

- Motivated researcher, with a PhD in (applied) Physics, chemistry, material science, chemical or electrical engineering, or similar domain, and preferably at least 2 years of experience as researcher.
- Background in low-temperature plasma physics and chemistry, experience with in situ plasma and surface diagnostics and (electro-)catalysis is a plus.
- Ability to teach, shown by experience or assistance in teaching.
- Strong cooperation skills and ability to work in an interdisciplinary team.
- Experience in acquiring external research funding is an asset.
- Effective communication and leadership skills.
- Excellent proficiency in English (written and verbal).

Please visit the vacancy webpage for a complete description, conditions of employment, documents to submit and timeline for recruitment: https://jobs.tue.nl/en/vacancy/assistant-professor-in-plasmasurface-interaction-for-application-in-catalysis-1029504.html

Do you recognize yourself in this profile and would you like to know more? Please contact prof.dr. M. Creatore (m.creatore@tue.nl) or prof.dr.ir. W.M.M. Kessels (w.m.m.kessels@tue.nl).

Please consider that the application deadline is November the 20th. If you need more time to apply, you can contact Josje van Oudenaarden, Senior Recruiter, j.e.v.oudenaarden@tue.nl.

Contacts:
Prof. Dr. Mariadriana Creatore, m.creatore@tue.nl
Prof. Dr. Erwin Kessels, w.m.m.kessels@tue.nl
Eindhoven University of Technology, The Netherlands

- **PhD Student Position: Plasma Diagnostics in the Field of Plasma Conversion Technology, Max Planck Institute for Plasma Physics (IPP), Garching, Germany**

We are looking for interested candidates for a PhD student position that is available at Max Planck Institute for Plasma Physics, in the group of Plasma for Gas Conversion (https://www.ipp.mpg.de/4282842/P4G). The focus of the PhD project is on characterization of different plasma sources and gases (CO_2, CH_4, NH_3 etc.) using spectroscopic techniques (UV-IR)— both emission spectroscopy (OES), and absorption spectroscopies (TALIF, FTIR), with the goal to measure the plasma properties and radical species densities. Several plasma reactors will be investigated, microwave plasmas operating in a pressure range from one millibar up to atmospheric pressure, as well as atmospheric dielectric barrier discharges (DBD) with and without catalyst. To understand the gas conversion process and the most suitable reactor to maximize the conversion and energy efficiency, various plasma diagnostic techniques are used.

The group is working on the topic of plasma conversion of low energy molecules into value-added chemicals, by using low temperature plasmas. The research is contributing to the power-to-gas initiative in the field of energy storage, hydrogen technology, and chemical energy carriers. The focus of our group is on the conversion of carbon dioxide (CO_2) into carbon monoxide (CO), as well as hydrogen production and storage via pyrolysis of methane (CH_4) and synthesis/decomposition of ammonia (NH_3).

The candidate should have a master degree in a related field, e.g. physics or chemistry, with a basic level of plasma physics knowledge. The candidate will get an opportunity to learn how to operate, measure and analyze the results of a different plasma diagnostic techniques (OES, FTIR, TALIF), and the fundamental properties of different discharges (microwave plasma and DBD plasma). Tasks of the candidate will include execution, evaluation and dissemination of the test results to further the understanding of the plasma conversion processes. The ability to interpret experimental data, very good communication skills, and the ability to present scientific results are required.

This is a position for 3 years which is available from now on. Applicants should send a motivation letter and CV to the contact:

Contact:
Prof. Ursel Fantz
Max Planck Institute for Plasma Physics, Germany
ursel.fantz@ipp.mpg.de

- **PhD Project: Plasma-based Methane Decomposition, Swiss Federal Laboratories for Materials Science and Technology, Switzerland**

Materials science and technology are our passion. With our cutting-edge research, Empa's around 1,100 employees make essential contributions to the well-being of society for a future worth living. Empa is a research institution of the ETH Domain (www.empa.ch). Within the framework of an industrial project aimed at the plasma-pyrolytic production of hydrogen with negative CO_2 emissions, the Automotive Powertrain Technology Laboratory offers a PhD position.

- Planning, execution and evaluation of investigations in the field of plasma-based methane decomposition.
- Fundamental investigation of relevant processes in methane-containing (low pressure) plasma.
- Modeling of the plasma, the chemical reactions and the interactions with the flow field.
- Optimization of the process regarding efficiency and structure of the produced solid carbon.
- Scientific publications in journals and at conferences.
- Supervision of students.

Your profile:

- Master's degree in process engineering, chemical engineering, mechanical engineering materials science or similar; admission to doctoral studies at ETH Zurich
- Good technical knowledge and/or high interest in the areas indicated above, including simulation.
- Interest in working in interdisciplinary teams.
- Good knowledge of the English language.

Our offer:

- Interesting and responsible tasks in the field of applied research.
- Development opportunities in an economically and socially important field.
- Contacts to international partners, customers and suppliers.
- Attractive working conditions of the ETH Domain – working place close to Zurich.

We live a culture of inclusion and respect. We welcome all people who are interested in innovative, sustainable and meaningful activities. That's what counts - not age, gender, origin, religion, sexual orientation, etc. We look forward to receiving your online application including a letter of motivation, curriculum vitae, diplomas with references and contact details of two references. Please submit these exclusively via our job portal: https://apply.refline.ch/673276/1845/pub/3/index.html

Contacts:
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Dr. Dirk Hegemann, dirk.hegemann@empa.ch
Swiss Federal Laboratories for Materials Science and Technology, Switzerland

- **PhD Project: Vortex-Enhanced High-Enthalpy Supersonic Plasma Flows, University of New South Wales, Australia**

  The School of Engineering and Technology at the University of New South Wales (UNSW) Canberra, Australia, has an open PhD position in the field of plasma physics and electric propulsion that will investigate vortex-enhanced Inductively Coupled Plasma (ICP) systems.

  ICPs can be used to generate a high-density, partially ionized, plasma that can superheat an input gas to temperatures as high as 10,000 K. This strong gas heating makes ICPs useful for a number of industrial and space applications including materials processing, hypersonics and aerothermodynamics testing, and even electrothermal space propulsion systems. The gas injection configuration however plays a critical role in the overall stability and performance of the system and a limiting factor in many conventional designs is excessive heat losses to the walls. For some applications, such as space propulsion, heat losses currently represent a technical barrier to further technology development. A promising and innovative gas injection configuration is the bidirectional vortex, which makes use of counter-propagating vortices to create a segmented flow field with a cooler outer vortex and a hotter inner vortex. Such vortex flows have successfully been used in liquid propellant chemical rocket engines and offer a number of advantages including improved propellant mixing and heating and reduced heat losses to any bounding walls.

  This project will explore such bidirectional vortex flows applied to supersonic ICPs by using multi-physics simulations that couple fluid dynamics, plasma physics, heat transfer, and electrodynamics. The project will be performed in collaboration with the Research School of Physics at the Australian National University and with the von Karman Institute for Fluid Dynamics in Belgium. The ideal candidate will have a background in physics and/or engineering with strong mathematical, programming (ideally C++ and Python), and communication skills. Express your interest in this project by emailing the contact listed below. Include a copy of your CV and provide a brief motivation that highlights your research experience. More information can be found at the following link:

  https://www.unsw.edu.au/research/hdr/our-projects/vortex-enhanced-high-enthalpy-supersonic-plasma-flows

  Contact:
  Dr. Trevor Lafleur
  University of New South Wales, Australia
  t.lafleur@adfa.edu.au

Collaborative Opportunities

Please submit your notices for Collaborative Opportunities to iltpc-central@umich.edu.

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Prof. Mark J. Kushner, University of Michigan, USA, mjkush@umich.edu

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and Engineering