International Low Temperature Plasma Community

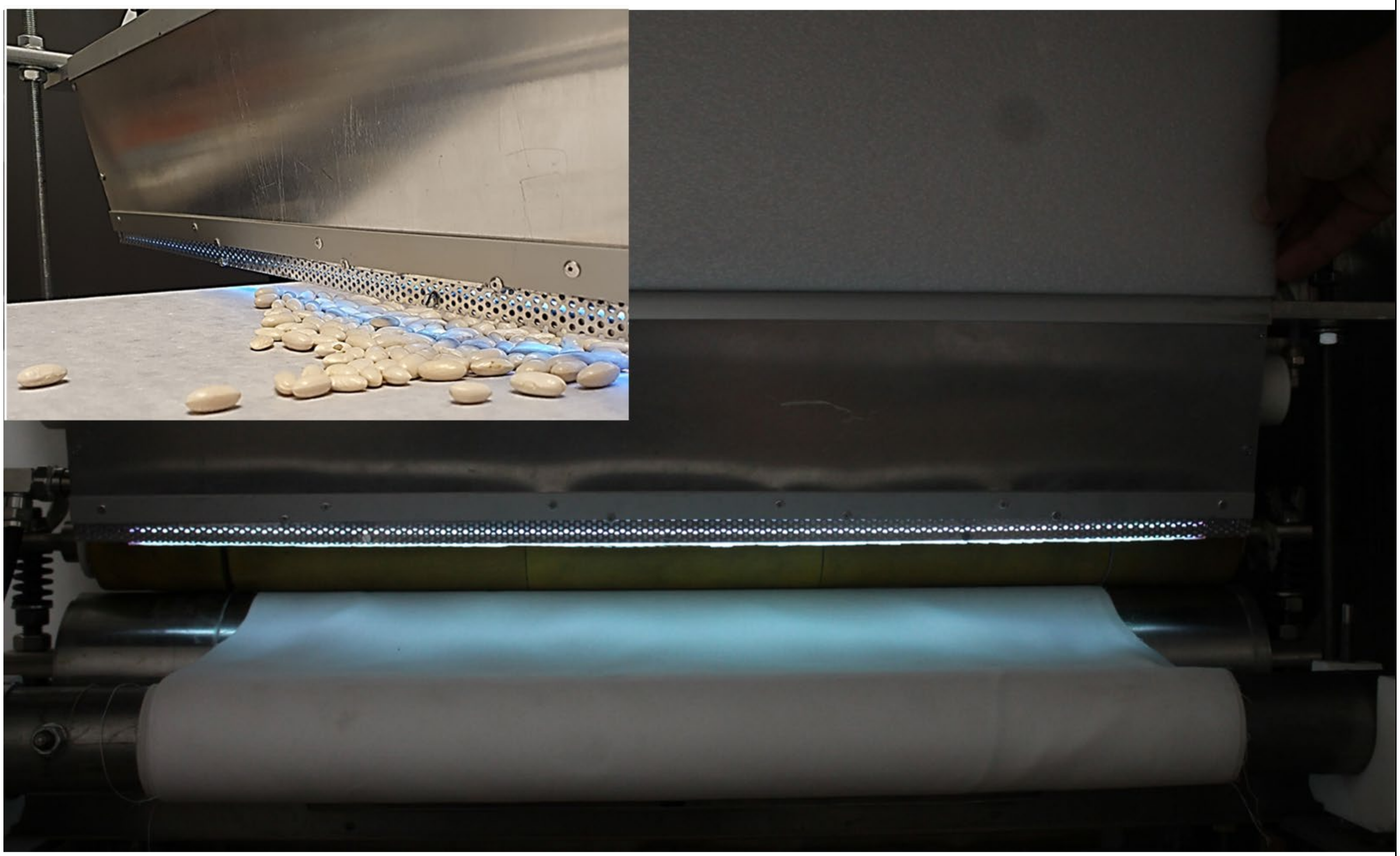
https://mipse.umich.edu/iltpc.php, iltpc-central@umich.edu

Newsletter 29

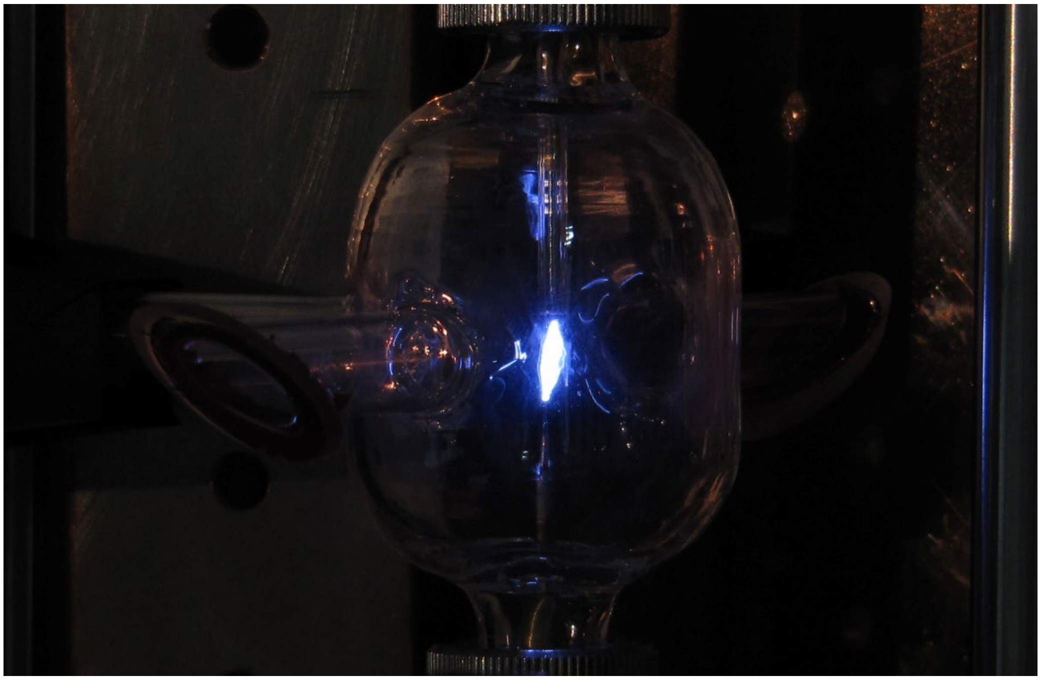
25 January 2023

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.



Cold plasma source for large area processing: A large dimension plasma source, with an active width of 70 cm, consisting of a large number of cold axial DBD jets assembled together is presented. The plasma source is homogeneously operated with less than 1.5 W/cm length of the source in argon, ensured by one mass flow controller which provides the gas flow through all discharge channels, and electrically supplied by the same radiofrequency power generator (13.56 MHz). The source was developed in the National Institute for Laser, Plasma and Radiation Physics, Magurele-Bucharest, Romania. The source has been successfully tested in roll-to-roll operation for surface activation of polymers and plasma induced graft polymerization (**Dr. Veronica Satulu**), as well as for plasma treatment of bean seeds to enhance germination (**Dr. Lavinia Carpen**). The source can be further upscaled. **Prof. Gheorghe Dinescu** (gheorghe.dinescu@inflpr.ro)**, Dr. Maximilian Teodorescu, Dr. Cristian Stancu, Dr. Tomy Acsente, Dr. Bogdana Mitu** (mitu.bogdana@inflpr.ro), National Institute for Laser, Plasma and Radiation Physics, Romania.



Nanosecond repetitively pulsed discharges: Atmospheric pressure nanosecond repetitively pulsed discharges are characterized by a high degree of non-equilibrium and show high efficiency in the conversion of CO_2. The image shows several discharge pulses in CO_2 captured during the same camera exposure time. The electrodes are sharpened tungsten rods enclosed in a quartz chamber equipped with optical windows to perform time-resolved diagnostics (e.g., time-resolved optical emission spectroscopy and collisional energy-transfer laser-induced fluorescence) for understanding the mechanisms of CO_2 dissociation and investigate the discharge progression from the initial breakdown event to the final post-discharge. **Prof. Luca Matteo Martini** (luca.martini.1@unitn.it, University of Trento), **Dr. Giorgio Dilecce** (giorgio.dilecce@cnr.it, CNR-Institute for Plasma Science and Technology ISTP) and **Prof. Paolo Tosi** (paolo.tosi@unitn.it, University of Trento), Italy.

In this issue:	
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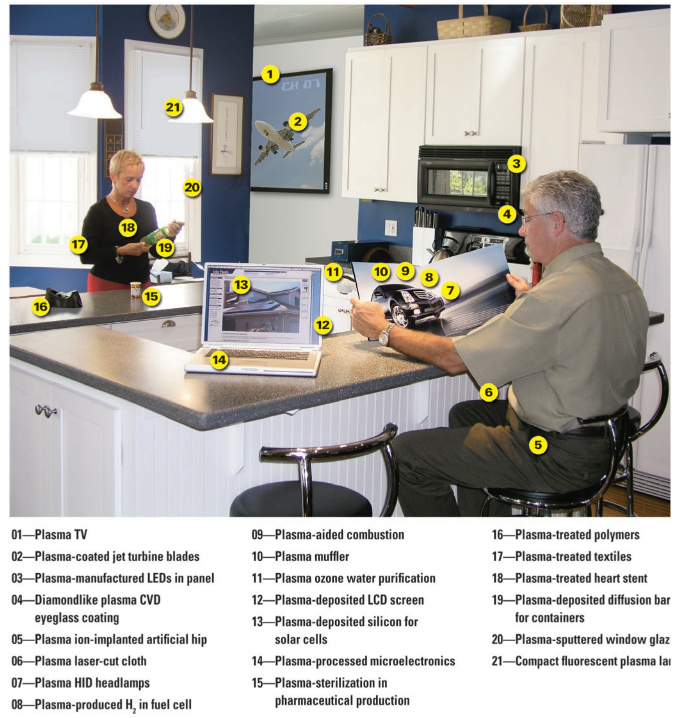
Call for Contributions

Please submit content for the next issue of the Newsletter. Please send your contributions to iltpc-central@umich.edu by **February 24, 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.

Choose Your Research Problems Carefully



The impact of LTPs in everyday life (https://nap.nationalacademies.org/catalog/11960/plasma-science-advancing-knowledge-in-the-national-interest)

The scientific advances of the field of low temperature plasma science can be quickly translated to society benefiting applications. This translational nature of LTP science is something that we should take pride in but also comes with a great responsibility.

The majority of the research performed by the international LTP community in universities, national laboratories and to some extent in industry is funded by governments. Government funding comes from fellow citizens who pay taxes. In this sense, your next-door neighbor is funding your research.

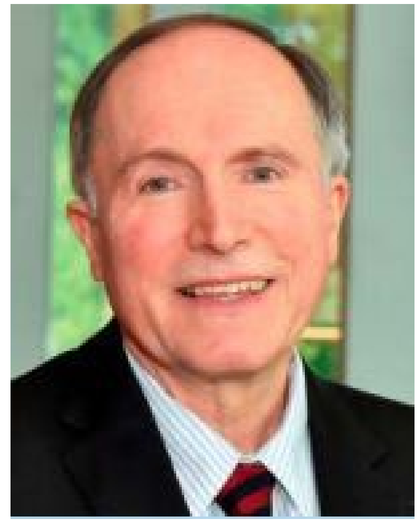
Given the finite resources of governments, decisions on funding priorities need to be made. A former president of the United States, Dwight D. Eisenhower, addressing the American Society of Newspaper Editors in 1953 said: "The cost of one modern heavy bomber is this; a modern brick school in more than thirty cities. It is two electric power plants, each serving a town of 60,000 population…We pay for a single fighter with a half-million bushels of wheat." President Eisenhower was speaking in military terms but the same applies to funding of LTP science. Instead of funding our research, governments could have spent the money on improving healthcare, building new transportation systems, reducing pollution or on foreign aid to relieve hunger and suffering in the developing world. But that was not the decision – our research was funded instead.

Why were those decisions made? Why was our research funded? Certainly, part of the logic for these decisions is based on governments needing to educate the next generation of scientists and engineers. While the primary motivation is indeed investments in the future, these decisions go beyond work force development. Governments believe that our research will, in the long run, do more to improve healthcare and relieve hunger than directly spending that money now on those goals. Indeed, science has fulfilled that promise with, for example, vaccines and synthetic fertilizer that are believed to have saved the lives of a billion people (https://www.visualcapitalist.com/50-important-life-saving-breakthroughs-history/). While many government agencies fund mission driven research that directly targets technological innovation, they also fund basic research not directly linked to future technologies. This basic research has shown to be responsible for major, often serendipitous, discoveries that benefit our society. Investigations in fundamental science enable diverse creativity, a corner stone of science and is equally important as mission driven research. *However, that does not relieve the fundamental researcher from choosing problems that have relevance to society.*

There is a very large opportunity cost that is borne by society, by governments and by your next-door neighbor, to fund our research. LTP has in large part met the expectation that our research, funded by our next-door-neighbors, has indeed provided value in countless areas ranging from enabling the semi-conductor revolution to water disinfection and space propulsion. We have a collective responsibility to continue to do so by choosing our research challenges and research questions carefully to ensure they benefit society.

Prof. Mark J. Kushner, University of Michigan, USA, mjkush@umich.edu
Prof. Peter J. Bruggeman, University of Minnesota, USA, pbruggem@umn.edu

Professor Gottlieb Oehrlein – A Scientist and Mentor for All Seasons



As one of the top low temperature plasma scientists in the world, Professor Gottlieb Oehrlein has made key contributions in deepening our understanding of plasma-surface interactions. Gottlieb Oehrlein is a Professor in the Department of Materials Science and Engineering and the Institute for Research in Electronics and Applied Physics (IREAP) at the University of Maryland, College Park, USA. He received his Vordiplom in physics from Würzburg University (Germany) in 1976, and M.S. and Ph.D. degrees in physics from the State University of New York at Albany in 1978 and 1981, respectively. He further received the SUNY Chancellor's Distinguished Dissertation Award for his PhD research on defects in solid state materials. Upon graduation, he joined IBM as a Research Staff Member at the IBM T. J. Watson Research Center in Yorktown Heights, NY.

While at IBM, he leveraged his graduate school work on defectivity in semiconductors by applying it to the new field of low temperature plasmas, most notably employing surface analysis techniques such as x-ray photoelectron spectroscopy and ellipsometry. Focusing on the plasma surface interactions that occur when exposing the materials to novel plasma chemistry, he helped determine the role of gas chemistry admixtures such as O_2 and H_2 to CF_4, CHF_3 and CF_4/H_2 on the etching of SiO_2, Si and other materials in capacitively coupled plasmas. His work identified the near-surface damage and presence of reaction layers such as SiC, and CF_x, which are now instrumental in enabling selective patterning.

From 1993-2000, he returned to his Alma Mater in Albany, as a Professor of Physics, where Eric (a co-author of this profile) had the pleasure of meeting him and becoming a member of his research group. While working in his lab, the focus of Prof. Oehrlein's research turned to the characterization of inductively coupled plasmas and the detailed understanding of the mechanisms behind the evolution of the fluorocarbon reaction layer during dielectric etching. His graduate students had many discussions over lunch debating the fluorocarbon film formation and its role as a function of ion energy. One theory was that it was an inhibiting layer to which its thickness governed the selectivity between various dielectric films, while the other theory was that it was a source of fluorine which could enable unique etch enhancements. Ultimately, the research proved that the fluorocarbon film was both an inhibiting layer and a source of fluorine.

In 2000, Prof. Oehrlein relocated to the University of Maryland and shifted his research focus to the mechanistic understanding of plasma-surface interactions behind dielectric etch selectivity to photoresist materials, as 193 nm resists became prevalent in the industry. Here, Sebastian and Bobby (co-authors of this profile) joined the lab as graduate students. The group's research was key to understanding the role of polymeric structure and sidegroups, such as methyl adamantyl methacrylate, in determining etch rate selectivity as a function of ion energy and plasma chemistry. The highly competitive and inspiring environment that brought about many a discovery is fondly remembered while the group collaborated with a world-class team including Professors David Graves, Grant Willson and Ray Phaneuf to investigate plasma interactions with polymers and photoresists.

Beginning in 2010, IBM had awarded Prof. Oehrlein with an IBM Faculty Award and we all had the opportunity to collaborate again on the experimental validation of Atomic Layer Etching (ALE). In this seminal work, Prof. Oehrlein and his group were able to validate prior models of fluorination profiles, thin film formation and resulting selectivities, and demonstrate the ability to achieve self-limited cyclical etching of SiO_2 using fluorocarbon gas chemistries. Somehow the thread of this work that started over 20 years ago in Albany continued to be improved upon in College Park from graduate student to graduate student and ultimately resulted in a graduate student generational meeting at the most fitting place: an ALE house during AVS 2022 in Pittsburgh, PA.

Prof. Oehrlein has coauthored more than 300 publications with ~12,000 citations and H index of 60. He is a Fellow of AVS (1998), International Union of Pure and Applied Chemistry (2000), and International Plasma Chemistry Society (2017). He received the Electronics Division Award of the Electrochemical Society (1992), the IBM Faculty Award in 2002 and 2010, the Plasma Prize of the Plasma Science and Technology Division of AVS (2005), the DPS Nishizawa Award (2019) and the AVS John A. Thornton Memorial Award (2019). In March 2023, Prof. Oehrlein will receive the Plasma Material Science Hall of Fame Award in Nagoya.

Overall, Prof. Oehrlein is best known for his work understanding plasma surface interactions. His research methods continue to lead to groundbreaking insights in his current work on plasma material interactions using atmospheric pressure plasma sources for modification of organic materials, biomolecules, foods, control of microorganisms, and catalysts to produce renewable fuels.

Dr. Eric A. Joseph, Dr. Sebastian Engelmann and Dr. Robert (Bobby) Bruce
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General Interest Announcements

- **NSF Partnerships for Innovation Webinar for ECLIPSE and SWx Communities, USA**

The US National Science Foundation (NSF) is hosting a Partnerships for Innovation (PFI) webinar on February 21, at 2pm EST specifically targeted at plasma science and engineering, as well as space weather communities. Register in advance for this webinar at:

https://nsf.zoomgov.com/webinar/register/WN_GgO-BKe0TlG1zrmj7RxsBg

The NSF PFI program is managed by the new Directorate for Technology, Innovation and Partnerships (TIP), and offers researchers from all disciplines of science and engineering funded by NSF the opportunity to perform translational research and technology development, catalyze partnerships and accelerate the transition of discoveries from the laboratory to the marketplace for societal benefit.

Partnerships for Innovation program has five broad goals:

(1) identifying and supporting NSF-sponsored research and technologies that have the potential for accelerated commercialization;

(2) supporting proof-of-concept work, including the development of technology prototypes that are derived from NSF-sponsored research and have potential market value;

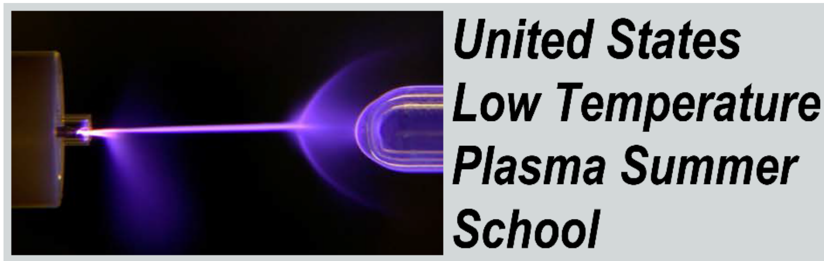
(3) promoting sustainable partnerships between NSF-funded institutions, industry, and other organizations within academia and the private sector with the purpose of accelerating the transfer of technology;

(4) developing multi-disciplinary innovation ecosystems which involve and are responsive to the specific needs of academia and industry;
(5) providing professional development, mentoring, and advice in entrepreneurship, project management, and technology and business development to innovators.

The webinar will describe the PFI program and project / principal investigator eligibility, as well as allow for extended Q&A. Note that the definition of projects "derived from NSF-sponsored research" is expected to include projects funded by NSF, as well as by our Partner Agencies as a result of proposals submitted to and reviewed by NSF. The webinar will be recorded.

Contact:
Dr. Vyacheslav (Slava) Lukin
National Science Foundation, USA
vlukin@nsf.gov

- **2nd US Low Temperature Plasma Summer School, June 26-30 2023**



The 2nd United States Low Temperature Plasma Summer School (USLTPSS) will be held June 26-30, 2023 on the campus of the University of Michigan, Ann Arbor, MI, USA. The USLTPSS is intended to provide an opportunity for graduate students and researchers new to the low temperature (LTP) field to be immersed in the fundamentals and applications of LTPs for one week and to learn from leading researchers in their field. The lecturers and topics for the 2nd USLTPSS are listed at https://mipse.umich.edu/summer_school_2023.php. There will also be hands-on session in diagnostics and modeling, posters sessions and special topic mini-workshops.

As part of the registration fee, accommodations will be provided for students and post-doctoral scholars in university dormitories. Breakfast, lunch and several dinners will be provided. For attendees not staying in university housing, lunch and several dinners will be provided.

Attendance at the USLTPSS is limited. To apply to attend the USLTPSS, please fill out this application: - ***Apply Here***

Applications received by **March 15** will receive full consideration. The application portal will be closed on **April 1, 2023**.

Contacts:
Prof. Peter J. Bruggeman, University of Minnesota, USA, pbruggem@umn.edu
Prof. Mark J. Kushner, University of Michigan, USA, mjkush@umich.edu

Meetings and Online Seminars

- **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 from anywhere in the world.

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

- **20th International Conference on Plasma Physics and Applications, Iași, Romania, 14-16 June 2023**

We cordially invite you to the 20th International Conference on Plasma Physics and Applications (CPPA), on 14-16 June 2023, fully in person. The conference venue is Alexandru Ioan Cuza University of Iași, Romania (http://www.uaic.ro/).

The International Conference on Plasma Physics and Applications is organized by the Alexandru Ioan Cuza University of Iași (UAIC) and the National Institute for Laser, Plasma and Radiation Physics, Bucharest (INFLPR), every two years, alternatively in Bucharest and Iasi. The Conference is focused on advances in plasma fundamentals and applications and provides a forum for discussion and scientific collaborations for Romanian and international plasma community.

CPPA welcomes any contribution on plasma physics, from fundamentals to applications. The contributions will be assigned to one of the four major topics:

CPPA 2023
XXth International Conference on Plasma Physics and Applications
14th - 16th June 2023, Iași, ROMANIA

- T1. Processes in plasma, modelling and simulation
- T2. Gas discharge physics, plasma sources and diagnostics, space, dusty and laser plasmas
- T3. Plasma material processing and fusion technology
- T4. Plasma applications in environment, biology, medicine and agriculture

Please check the webpage (https://www.plasma.uaic.ro/cppa/cppa2023/) for the international scientific committee, the local organizing committee and practical information.

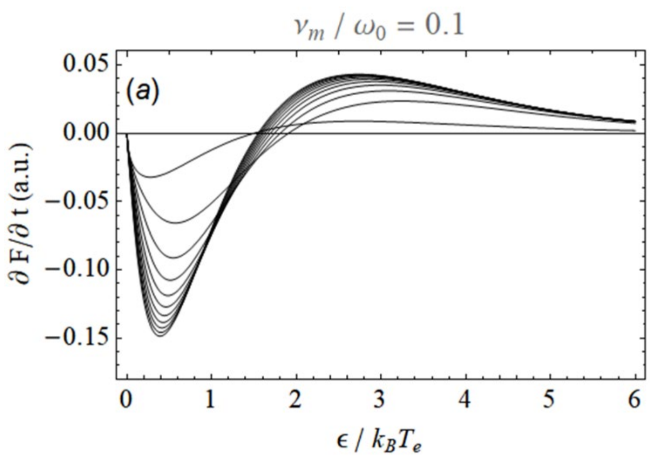
Contacts:
Prof. Lucel Sirghi, Dr. Bogdana Mitu, Conference Chairs
Assoc. Prof. Ionut Topala, Dr. Monica Magureanu, Scientific Secretaries
Alexandru Ioan Cuza University of Iași, Romania
cppa2023@uaic.ro

Community Initiatives and Special Issues

Please submit your announcements for Community Initiatives and Special Issues to iltpc-central@umich.edu.

Research Highlights and Breakthroughs

Describing Local and Non-local Electron Heating by the Fokker-Planck Equation



Visualization of the general heating operator for an exponentially decaying (z-direction, decay length s) and harmonically oscillating electric field (angular frequency ω_0) at constant elastic collision frequency $\nu_m / \omega_0 = 0.1$ evaluated for a Maxwellian distribution function with an electron temperature T_e. The operator is presented for the electron energy distribution function $F(\varepsilon)$ as a function of the kinetic energy ε. On the ordinate $\partial F / \partial t$ is normalized to $-m_e \langle v_E^2 \rangle_V \omega_0 n_e / \sqrt{\pi}$, where $\langle v_E^2 \rangle_V$ denotes the volume average with $v_E(z) = e E_0(z) / (m_e \omega_0)$. The curves are for different values of the dimensionless thermal parameter $\alpha = k_B T_e / \varepsilon_s = 0, 1, 2, 4, 8, 16, 32$, where $\varepsilon_s = m v_s^2 / 2$ and $v_s = s\,\omega_0$. The amplitudes of the curves increase monotonously with α, highlighting the role of thermal motion. Negative values of the operator remove particles from the distribution and positive values insert these particles back into the distribution. The positive and negative areas are identical so that particle number conservation is ensured. Zero crossing is at the mean thermal energy of $3/2\, k_B T_e$.

Local Ohmic and non-local (stochastic, collisionless) heating in plasmas is revisited in a recent paper, by applying the Fokker-Planck equation in combination with the Langevin equation for the derivation of the heating operator. The paper provides on the one hand a review of the present knowledge on the basis of the Boltzmann equation, while on the other hand new research results are introduced. This includes, in particular, the use of the Fokker-Planck equation for describing the electron-field interaction, a generalized plasma dispersion function (for arbitrary distribution functions, considering a velocity dependent elastic collision frequency), and a concept for integrating the heating operator in a local Boltzmann solver. The latter concept allows calculating the global distribution function in the non-local regime at low pressures. The general concept is investigated in detail for the case of inductively coupled radio-frequency plasmas (ICPs). Particular emphasis is on using a self-consistent electric field profile. Finally, yet importantly, the role of elastic collisions in converting energy gained in the field into heat, characterized by irreversibility, is investigated. The paper is written in a tutorial style and all concepts are derived from first principles. It should serve as an introduction to the field for advanced students as well as a reference for experienced researchers.

Contacts:

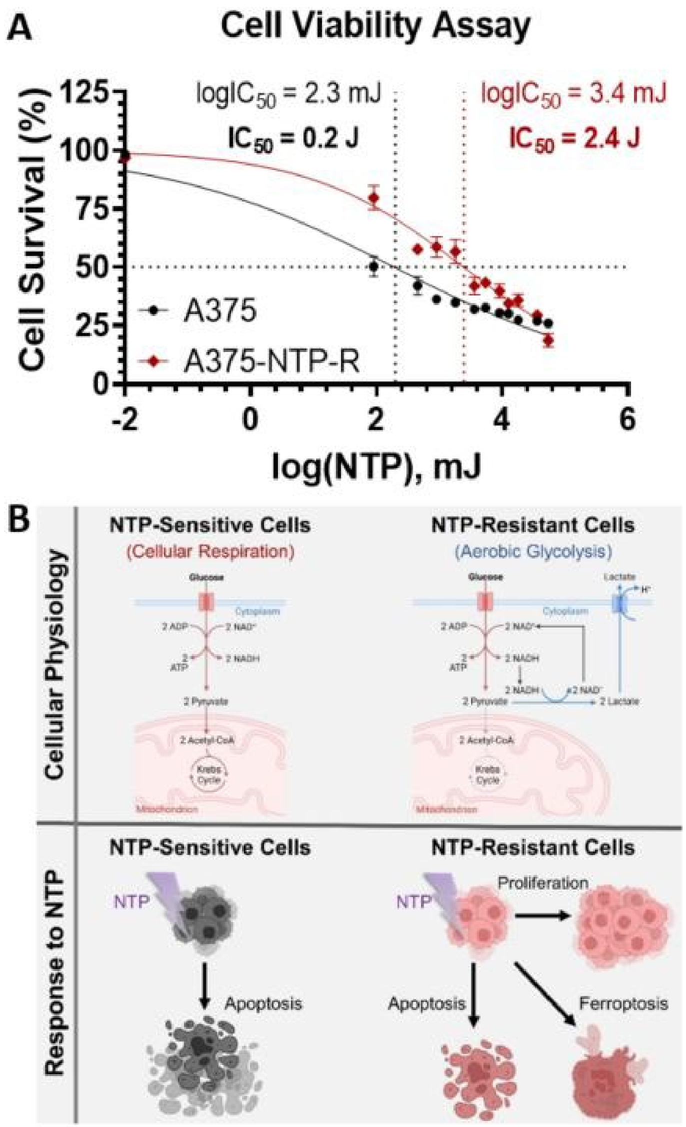
Prof. Uwe Czarnetzki, Ruhr University Bochum, Germany, uwe.czarnetzki@rub.de

Prof. Luís Lemos Alves, Universidade de Lisboa, Portugal, llalves@tecnico.ulisboa.pt

Source:

Reviews of Modern Plasma Physics **6**, 31 (2022).
https://doi.org/10.1007/s41614-022-00086-0

Acquired Non-Thermal Plasma Resistance Mediates a Shift Towards Aerobic Glycolysis and Ferroptotic Cell Death in Melanoma



For 12 consecutive weeks, melanoma cells were treated with NTP and re-cultured in order to develop an NTP-resistant cell line (A375-NTP-R) with the same genetic profile as the parental, NTP-sensitive cells (A375). A) The A375-NTP-R cells acquired 10x's more resistance to NTP compared to the parental A375, as determined by the half maximal inhibitory concentration (IC50). B) A summary of the reported physiological changes, with new insights and hypothesis for NTP sensitivity versus resistance is shown.

Over time, cancer patients undergoing treatment often develop resistance to therapy. This acquired therapy resistance represents a major obstacle as it leads to poor patient outcomes. Therefore, the potential for cancerous cells to acquire resistance should be investigated, especially for novel, developing treatments like non-thermal plasma (NTP).

In this study, we developed, for the first time, an NTP-resistant cell line (A375-NTP-R) from a previously sensitive melanoma cell line (A375) to investigate NTP sensitivity and resistance pathways. After 12 consecutive weeks of repeat NTP exposure and reculturing, the cell line became nearly 10 times more resistant to NTP compared to the parent cell line of the same age. RNA sequencing analysis showed several altered metabolic and cell death pathways. Further metabolic evaluation showed that the NTP-resistant cells demonstrated a shift from cellular respiration to aerobic glycolysis. Cell death analysis revealed that NTP-resistant cells were more vulnerable to lipid peroxidation and ferroptosis, while NTP-sensitive cells were more prone to apoptosis.

Altogether, we uncovered fundamental insights and new hypotheses into NTP sensitivity and resistance. We also established a valuable new method for studying these mechanisms, which can be applied to other cell lines/cancer types. We hope these insights could provide the first steps towards identifying potential treatment biomarkers for NTP therapy.

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Prof. Annemie Bogaerts, annemie.bogaerts@uantwerpen.be, University of Antwerp, Belgium

Source: Drug Resistance Updates **67**, 100914 (2023). https://doi.org/10.1016/j.drup.2022.100914

New Resources

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

Career Opportunities

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

- **Post-doctoral Researcher in Plasma Catalysis, AG Experimental Plasma Physics, University of Augsburg, Germany**

  The position is within the field of the power-to-gas initiative and relates to experimental characterisation of plasma sources (predominantly DBDs) in view of catalyst-enhanced ammonia formation and hydrogen storage. The position is at the University of Augsburg, Germany. The official employment ad will shortly be published. For early information, please make inquiries to the contacts.

  Contacts:
  Dr. Roland Friedl, roland.friedl@physik.uni-augsburg.de
  Prof. Ursel Fantz, ursel.fantz@physik.uni-augsburg.de
  University of Augsburg, Germany

Collaborative Opportunities

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

Disclaimer

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Editors:
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