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Editorial: Plasma and related sciences: experimental and theoretical approaches

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Editorial on the Research Topic
Plasma and related sciences: experimental and theoretical approaches

Plasma physics is one of the most important tools for explaining our universe and is extensively used in engineering, industry, medicine, and agriculture to improve the standard of living. Recently, cold atmospheric plasma (CAP) has attracted significant attention due to its ability to generate a cocktail of reactive oxygen species (ROS), reactive nitrogen species (RNS), UV radiation, and charged particles at atmospheric pressure and room temperature. The investigation of CAP intersects multiple disciplines such as physics, engineering, chemistry, biology, biochemistry, and many others. The goal of this Research Topic, entitled "*Plasma and Related Sciences: Experimental and Theoretical Approaches*," is to collect high-quality research related to CAP and plasmas, directly or indirectly, through the associated sciences. Our Research Topic comprises a total of nine articles:

In the first article, Wang et al. performed experiments with a high-power laser on a sinusoidal modulated target modeled after solar spicules, revealing structures with alternating polarity magnetic fields. Simulations suggest strong pulses and magnetic reconnection can create and heat spicules. Using one-dimensional sinusoidal modulated synthetic hydrocarbon (C_8H_8 target), researchers observed multipole magnetic fields, consistent with a strong pulse model. This method simulates solar surface density fluctuations and complex magnetic fields. Future studies should examine spicule heating effects, chromospheric bright points, sunspot micro-jets, and intrinsic oscillations, highlighting the roles of Alfvén waves and magnetic reconnection.

In the second article, Li et al. reported that there is currently limited research on how gas ionization affects the pulse formation process in loads driven by pulsed power sources. Therefore, a simulation method using Particle-In-Cell/Moment-Collision Calculation (PIC/MCC) has been proposed to accurately model gas ionization during electron beam generation in Linear Transformer Drivers (LTD.). This method integrates the electromagnetic field and charged particles with circuit modules, providing a clearer understanding of the impact of gas ionization on pulse shape. Moreover, excessive gas ionization can lead to impedance mismatches and potential load short circuits.

In the third article, Xing et al. explored the conversion of magnetic energy into plasma kinetic and thermal energy using the FLASH code. Their simulations, which align well with experimental results, reveal significant differences in energy conversion under varying resistivity conditions. This study provides valuable insights into the dynamics of magnetic reconnection, contributing to advancements in laboratory and astrophysical research.

In the fourth article, Longo discussed the famous Miller–Urey experiment in light of the developments of two fields: computational chemistry and physics of electrical discharges. He showed that the second provides a much more realistic description for understanding the heterodox experiment and presented the role of the energetic electrons produced by the electric field to generate radicals and ions. The suggested role sheds light on biomolecules' formation from elemental chemical components and a better understanding of the origin of life.

In the fifth article, Maccaferri et al. reported that plasma technologies have garnered significant interest, recently, in the agrifood sector due to their innovative applications. The range of applications spans from direct plasma treatment to indirect methods using plasma-activated media. A key aspect of plasma technology in this sector is its ability to decontaminate surfaces and materials. They systematically compiled studies on the application of CAP for decontaminating packaging materials. Their synthesis of the results indicates that plasma technologies meet the standard requirements typically expected of commercial antiseptics, as the average logarithmic reduction of the pathogen load on the packaging was above 4.

In the sixth article, Aceto et al. investigated the effectiveness of plasma-activated median agricultural applications. Namely, Plasma-Activated Water (PAW) has been evaluated as an innovative irrigation method to improve growth and defense mechanisms in tomato seedlings, including those infected with the Tomato mottle mosaic virus (ToMMV). The results demonstrated that PAW is a sustainable, chemical-free alternative to traditional fertilizers, promoting plant growth, enhancing stress tolerance, and bolstering resilience against pathogens. These findings underscore the potential of plasma technology as a sustainable agricultural solution, paving the way for advancements in the agri-food industry.

In the seventh article, Dvořák et al. reported on diagnostic tools essential to understanding the microscopic processes within plasma. Among these tools, laser-induced fluorescence (LIF) is one of the most important methods for detecting various species, offering *in situ* measurements with high sensitivity, versatility, and spatial resolution. This makes the technique a key method for detecting reactive species in plasmas. The authors focused on the challenges of LIF measurements in a partially saturated regime with spatially dependent laser intensity in the sample (caused by absorption). The Rayleigh-calibrated LIF measurements, corrected using the authors' methods, were experimentally validated through LIF of free tellurium atoms in an atmospheric pressure dielectric barrier discharge (DBD) plasma, comparing fluorescence and absorption measurements. The results demonstrate a high reliability of the LIF methods employed.

In the eighth article, Aceto et al. highlighted cold plasma as a promising tool for enhancing nitrogen fixation processes. Based on theoretical modeling, they suggest that maintaining non-equilibrium conditions in plasma could allow this technology to surpass the efficiency of the traditional Haber-Bosch process used in industrial nitrogen fixation. The synergy between modelers and experimental physicists is essential to achieve these advancements, leading to refined theoretical models that can guide the development of more efficient plasma systems.

In the ninth article, Huang et al. reported that the Plasma Surface Interaction device at the Harbin Institute of Technology (HIT-PSI) could serve as an excellent platform for testing the performance of plasma-facing materials and components in extreme irradiation environments such as tokamak devices. To simulate these conditions, preliminary irradiation experiments on tungsten were carried out at HIT-PSI, with a heat flux exceeding 40 MW/m^2. Moreover, the He plasma beam's emission spectra and heat flux characteristics were measured at different high magnetic field conditions.

In conclusion, our Research Topic presents nine articles that collectively enhance our understanding of plasma physics and its applications. The findings not only contribute to theoretical knowledge but also hold the potential for practical innovations across various sectors. We invite readers to delve into these studies and explore the exciting possibilities that plasma technology offers.

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