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Editorial

Special Issue on "Advances in Plasma Diagnostics and Applications"

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Plasma is the fourth state of matter, contrasted with the other states: solid, liquid, and gas. It is the most energetic and abundant state of matter, with as much as 99.9% of the Universe's matter composed of plasma. Plasmas can be generated via the combination of energy-induced fragmentation, ionization, and excitation of atoms and molecules, resulting in a vast variety of atomic and molecular species, which can be electrically charged, energetically excited, highly reactive, or any combination of these states. The basic plasma parameters are very broad and cover the density of radicals and charged particles; i.e., electrons and positive and negative ions are subject to their velocity distribution, even in rovibrationally excited electronic states.

Since World War II, many different methods for generating plasmas have been developed. Starting with microwave-driven discharges, a spin-off of radar, in the 1950s, the generation of radio-frequency came into focus in the 1960s, typically in a parallel-plate reactor of a capacitively coupled plasma (CCP), and in the 1980s, the separate control of plasma density and the energy of the ions was the main issue, in terms of discharge, which can be subsidized as electron cyclotron resonance (ECR) and inductively coupled plasmas (ICP).

Subsequently, an array of methods for plasma diagnostics was developed. With the electric probe of Langmuir, only measurements of plasma density and electron temperature in plasmas through inert gases (argon, nitrogen, oxygen) were feasible. But today, investigations into all different types of plasmas, irrespective of being inert or aggressive, are performed. Among them are optical measurements, in particular optical emission spectroscopy (OES) and optical absorption spectroscopy, in the infrared, scattering techniques (such as Rayleigh-, Raman- and Thomson scattering), mass spectrometry, electron paramagnetic resonance spectroscopy, gas chromatography, and various others. Also, the plasma itself became a research topic by self-excited electron resonance spectroscopy (SEERS) and measuring the complex impedance by recording the V(I) characteristics, just to name a few.

Although various mature diagnostic technologies for plasma discharges have been developed, there are still many challenges. A number of things must be done for full knowledge and understanding of plasmas, in order to guide without any break. The measurement precision is not only affected by the diagnostic equipment/techniques, but also the plasma discharge itself. In many applications, direct measurements of the parameters of interest are still not possible. In addition, the plasma environments in application processes are unusually complex, and their reactions are still not fully understood. Plasmas bring together many research fields, including statistical physics, atomic/molecular physics, thermodynamics, electrodynamics, fluid dynamics, heat transfer, electrical engineering, material, chemical engineering, surface science, physics, chemistry, and more recently, aerospace, agriculture, foods, environment, energy, catalysis, biology, and medicine.

This Special Issue on "Advances in Plasma Diagnostics and applications" of *Processes*, collects original research and review articles on the most recent plasma applications and the diagnosis of their processes, to elucidate the characteristics of plasma and mechanisms of plasma-induced processes. Wang et al. introduced the cowl-induced expansion wave, based on the model with an upper-side expansion wall, and analyzed the oblique detonation wave (ODW) dynamics, employing the reactive Euler equations, with a two-step induction–reaction kinetic model [1]. The numerical results show that the upstream movement of Mach stem can be re-stabilized for the unstable structure, which suggests a feasible adjustment method and the corresponding transient phenomena deserve more attention in future work. Xie and coworkers experimentally investigated the control of ramp shock wave in Mach 3 supersonic flow, using a two-electrode Spark Jet (SPJ) actuator, through schlieren images and dynamic pressure measurement results [2]. The ramp pressure is reduced by a maximum of 79%, compared to the pressure in the base flow field. The control effect on the ramp shock, in the case of medium ramp distance, is better when the SPJ exit is located outside the separation zone. Chen et al. characterized the gliding arc plasma, through periodic discharge, current, voltage, and power waveforms, as well as plasma topology related to the air flow rate [3]. The extinction performance of the flame was influenced, deeply, by the static flame instability. Due to the gliding arc plasma adopted, the lean blowout limit of the swirl flame in pulsating flow mode was significantly reduced and was found to be better than the limit of the stable flame.

Xu et al. deposited an Fe-based amorphous alloy, reinforced WC-Co-based coating, on 42CrMo steel, using plasma spray welding [4]. The coatings have a full metallurgical bond in the coating/substrate interface and the powder composition plays an important role in the micro-structures and properties of the coating. The interface, between the spray welding layer and matrix, has a large amount of WC, with a gradient distribution from internal to external in the cross section. The spray welding layer enhances the wear resistance and hardness of the 42CrMo steel.

Hwang and coworkers successfully synthesized the size-controlled carbon nanoparticles (CNPs), using the Ar +CH_4 MHD-PECVD (magnetohydrodynamics-plasma-enhanced chemical vapor deposition) method continuously [5]. The size of CNPs was proportional to the gas residence time in the discharges maintained in the electrode's holes, and the control range of the mean size was between 25 and 220 nm. They confirmed the deposition of carbon-related radicals, as the dominant process for nanoparticle growth processes in plasmas. The radical deposition developed the nucleated nanoparticles during the discharges' transport of CNPs, and the time of flight in discharges controlled the size of the nanoparticles.

Chen, Obenchain, and Wirz developed a single-electrode tiny plasma device to overcome the drawbacks of conventional plasma jets and investigated its physics and interactions with five subjects (DI water, metal, cardboard, belly, and muscle) [6]. For non-conductive subjects, reactive oxygen and nitrogen species (RONS) intensity shows very little change, with distance decreasing from 15 mm to 10 mm, while RONS intensity increases for conductive subjects, with distance decreasing, especially for the muscle. The center temperature of jet–subjects interaction still remains in the comfortable temperature range for human beings, after 2 min interaction, for both 10 mm and 15 mm distances, and there is no damage or burning on the tissues' surfaces. Varnagiris et al. developed a new technique, based on the combination of simultaneous non-thermal air plasma treatment with Mg nanoparticles deposition processes, applying to Mung bean seeds to enhance their quality [7]. This stimulates new chemical bond formations on the seed's surface, leading to a shift in surface characteristics, from hydrophobic to hydrophilic and, in turn, improving water uptake. They reported around two times better germination after 30 min of the plasma treatment, compared to the initial Mung bean seeds. At a more applied level, Attri and coworkers discussed plasma for agricultural applications, from laboratory to farm [8]. They concluded that the direct plasma treatments, working at low/medium/atmospheric pressure, and plasma-treated water (PTW) treatments changed the physical and biochemical properties of the seeds, and emphasized doing the real field experiments with the plasma-treated seeds to make them societally useful. They finally addressed the possibility of using plasma in the actual agricultural field and the prospects of this technology.

The above papers demonstrate the importance of the area of plasma diagnostics and applications, ranging from the formulation of fundamental theory to practical applications. Although the basic principles of plasma in the diagnostics and applications are well understood, the articles address outstanding challenges related to plasma in different areas, in terms of both applications and diagnostic perspectives, and much remains to be explored in the future. With the enormous variety and number of applications currently under development, we feel confident about the longevity and future of this subject.

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