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Editorial: Prospects of plasma generated species interaction with organic and inorganic materials

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Editorial on the Research Topic
Prospects of plasma generated species interaction with organic and inorganic materials

The fourth state of matter, plasma, comprises high-energy particles like ions, electrons, and protons. With up to 99.9% of the Universe's matter containing plasma, it is the most energetic and abundant form of matter. Two primary groups of plasma systems are typically distinguished: thermal plasmas and non-thermal plasmas, in which the temperatures of the various plasma species differ. Due to growing interest in industries like aerospace, microelectronics, material processing, plasma chemical synthesis, metal melting and welding, vapor deposition, arc spraying, and waste disposal, thermal plasma technology has advanced over the past few decades [1]. Low excitation selectivity and extremely high gas temperatures are the main limitations of thermal plasmas. The extensive quenching and electrode concerns limited the energy efficiency and utility of thermal plasma sources. On the other hand, due to the excellent selectivity in plasma chemical processes, ability to function at low temperatures, and a minimum of quenching, non-thermal plasmas have been employed for many applications [2–5].

Non-thermal plasma sources like low-pressure glow and RF plasma, dielectric barrier discharges, microwave discharges, laser-produced plasmas, and atmospheric-pressure plasma jet, have been explored for their high selectivity in chemical processes because of their effectiveness at low temperatures. In the last many years, numerous sophisticated plasma diagnostic equipment has been developed, but still, there are many challenges. For example, direct measurements of the relevant plasma parameters are still not viable in many cases. Nevertheless, the plasma environments used in application processes are exceptionally complicated, and our understanding of how they behave is still lacking. The numerous research fields are combined through plasmas like atomic/molecular physics, heat transfer, fluid dynamics, material science, chemical engineering, surface science, etc. More recently, sterilization, water purification, pollution control applications, volatile organic compound removal, polymer surface treatment, oncology, wound healing, CO_2 and N_2 conversion, and plasma agriculture are growing exponentially.

The aim of this Research Topic "Prospects of plasma generated species interaction with organic and inorganic materials", contains five contributions as original articles and reviews. This issue focuses on the chemical and physical behavior of non-thermal plasma both experimental and computational focuses attention on the fundamental plasma, industrial, agricultural and medical applications. The critical topics of this issue are the role of VUV radiation on the surface functionalization of polymers, the degradation of organic dye, and its probable mechanism. And the reviews focused on wound healing, disinfection, food, and textiles, and detailed discussion on the role of neutral chemical reactive species in modifying solid materials at low pressure.

Zaplotnik and Mozetič explain the difficulties in the separation of specific reactants, plasma characterization, and difficulty understanding the atomic scale interaction. Numerous polymers, notably hydrophobic polymers with a high fluorine content, have trouble achieving the appropriate surface modification. Only a small number of scientists who examined polytetrafluoroethylene's activation by subjecting it to oxygen plasma observed enhanced wettability [7]. The authors even mentioned instances when there was an improvement in the water contact angle, which led to enhanced hydrophobicity rather than surface activation [8, 9]. The authors concluded that it is impossible to activate fluorinated polymers with oxygen atoms since any surface functionalization involves etching. As a result, these materials' wettability is insufficient following oxygen plasma treatment. In spite of this, exposing fluorinated polymers to VUV radiation without the presence of reactive oxygen species is a viable technique for surface functionalization. The VUV radiation releases fluorine by breaking C-F bonds. By treating with neutral oxygen atoms in the ground state, the dangling C- bond is wrapped up with oxygen atoms.

In another article, Kumar et al. showed a plasma jet's direct and indirect use for Acid Blue 25 dye removal. Pin-type plasma jet was investigated to degrade the Acid Blue 25 dye solution. Authors reported that HO and O radicals were essential short-lived species that degraded the Acid Blue 25 dye molecules. The removal rate of Acid Blue 25 by plasma jet depends upon the initial Acid Blue 25 concentration. The dye removal efficiency was about 87% and 73% for 25 and 50 mg/L for 5 min treatment with 11 W power deposition. On the other hand, indirect Acid Blue 25 dye degradation using plasma-activated water and with solutions containing main plasma-activated water chemicals and their mixture (H_2O_2 + NO_3^- + NO_2^-). The highest removal efficiency of 71% was detected using plasma-activated water. However, individual reagents such as NO_3^- and NO_2^- do not participate in the degradation. The depletion of Acid Blue 25 was faster for direct plasma treatment than plasma-activated water treatment.

The review paper by Primc describes the function of neutral reactive plasma species in surface chemistry at low pressure modification of solid materials. In addition to chemical processes like chemical etching and surface functionalization; the neutral reactive particles collaborate to create stable compounds. The type of material facing the plasma, which controls the atoms' density in the plasma reactor, affects the surface association likelihood. The density of source gas molecules would have determined the density of atoms in the plasma reactor if the recombination coefficients were zero. The surface morphology and type of plasma-facing material influences real recombination coefficients.

Reema et al.'s review of the textile and food processing industries is included here. Plasma effectively transforms a variety of industrial fields dealing with microbial inactivation, surface modification, sterilization, and disinfection. SARS-CoV-2 was recently found to be inactivated in plasma and plasma-activated water. Plasma technology can aid in organically extending the shelf-life and enhancing the quality of textiles and food products in the fast-moving consumer goods industries of food and textiles. According to a cost-benefit study, plasma technology is economically advantageous since it is less expensive to invest in and operate than the traditional post-combustion treatment known as flue gas treatment. Although there are some difficulties in the application of plasma technology in various fields, it is clear that they may be quickly resolved with the help of the study findings and that this technology has the potential to be ground-breaking and reasonably priced.

Garner and Mehlhorn, review is based on highlighting the opportunity of cold plasma to improve acute trauma treatment. Plasma treatment enhanced wound healing, transdermal delivery, burn treatment, and surgical applications. The authors discussed that optimizing plasma through novel plasma reactor design and synergistic combination with traditional treatment technologies can address numerous surgical and emergent care applications. The authors recommended continuing system development to address larger wounds and regenerative medicine, as well as designing and testing portable, battery-powered devices for treating wounds right away for ambulances and trauma on the battlefield.

These publications demonstrate a range of non-thermal plasma applications. Despite the devices' simplicity, the physical-chemical phenomena that underlie them are complicated interactions between reactive species movement, plasma-surface interaction, and chemical reactions. To understand the mechanism underlying the plasma events, significant computational and experimental research efforts will be required in the future.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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