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Editorial

Frontiers in Atmospheric Pressure Plasma Technology

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Atmospheric pressure plasmas represent a feasible and eco-friendly alternative to conventional physicochemical methods used in technology today for facing materials. The complex physical and chemical processes occurring when plasma interacts with mater offer a rich source of short- and long-lived chemical species, mostly reactive nitrogen and oxygen species (RNS/ROS). They are also crucial for many applications ranging from the food industry, environmental related fields, agriculture and healthcare, to material science and even automotive. Exciting novel applications of plasma–surface, plasma–liquid, and plasma–gas interactions are at the focus of many challenging multidisciplinary scientific inquiries.

The range of potential plasma applications is broad, from plasma (bio)medicine (antibacterial/disinfectant/antiseptic agent, wound healing promoter, selective treatment of cancer cells and tumors), plasma pharmacology, plasma and food, plasma bioengineering, plasma agriculture (as seed germination inducer or even as a green fertilizer), to plasma and automotive. Nevertheless, all of these plasma fields are plasma–based technologies.

This Special Issue on 'Frontiers in Atmospheric Pressure Plasma Technology' was focused on, but not limited to, recent findings in novel and possible future applications of plasmas in life sciences, biomedicine, agriculture, and the automotive industry.

Papers providing fundamental insights into the understanding of plasmas and detailed analysis of electrical discharges, pushing forward cutting-edge techniques in plasma science and technology, were especially welcomed and received.

On the basis of the background outlined above, this Special Issue of *Applied Sciences* entitled "Frontiers in Atmospheric Pressure Plasma Technology" includes eight original papers [1–8] and two reviews [9,10] providing new insights into the application of atmospheric pressure plasma technology.

Lee et al. [1] used atmospheric pressure plasma irradiation to facilitate transdermal permeability of aniline blue on porcine skin and increase the cellular permeability of keratinocytes and further demonstrated the production of nitric oxide from keratinocytes. Their findings suggest a promoting effect of low-temperature plasma on transdermal absorption, even for high-molecular-weight molecules, as well as that the plasma-induced nitric oxide from keratinocytes is likely to regulate transdermal permeability in the epidermal layer.

Oliveira et al. [2] showed in their study the inhibitory effect of cold atmospheric plasma (CAP), running in helium, on chronic wound-related multispecies biofilms. The report describes the effect of He-CAP on wound-related multispecies biofilms and confirms the safety of the protocol. It was proven that exposure to He-CAP for 5 min provides inhibitory effects for the wound-related multispecies biofilms formed by methicillin-resistant *Staphylococcus aureus* (MRSA), *Pseudomonas aeruginosa* and also *Enterococcus faecalis*.

Furthermore, Nascimento et al. [3] revealed the effects of O_2 addition on the discharge parameters and production of reactive species of a transferred atmospheric pressure plasma jet produced at the tip of a long and flexible plastic tube. They concluded that the addition of O_2 to the working gas seems to be useful for increasing the effectiveness of the plasma

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treatment only when the target modification effect is directly dependent on the content of atomic oxygen.

In a report by Janda et al. [4] the role of HNO_2 in the generation of plasma-activated water by air transient spark (TS) discharge, a DC-driven self-pulsing discharge generating a highly reactive atmospheric pressure air plasma, was studied. Moreover, the authors compared TS with water electrospray (ES) in a one-stage system and TS operated in dry or humid air followed by water ES in a two-stage system, and show that gaseous HNO_2, rather than NO or NO_2, plays a major role in the formation of NO_2^-(aq) in plasma-activated water (PAW) that reached the concentration up to 2.7 mM.

Moreover, Huzum and Nastuta [5] were using helium atmospheric pressure plasma jet source in the treatment of white grapes juice for winemaking purposes. Based on principles of dielectric barrier discharge, an atmospheric pressure plasma jet in helium was used to treat two types of grape white fresh musts, after that, the resulting 1 and 2 year old wine was characterized and the correlation of plasma parameters (mean power, current density, RONS) and the physico-chemical proprieties (pH values, BRIX, UV-Vis and FTIR spectroscopy, CIE L*a*b* and RGB) of white must and wine were assessed.

Ivankov et al. [6] investigated the non-thermal plasma jet excitation modes and the optical assessment of its electron concentration. They proposed and described a new method based on digital holography to estimate electronic concentration for a non-thermal plasma source, taking into account its disadvantages and further applications.

Nastuta and Gerling [7] examined the use of a cold atmospheric pressure plasma jet source operated both in Ar and He, optically and electrically, going from basic plasma properties to vacuum ultraviolet, electric field determinations as well as safety thresholds measurements in Plasma Medicine. They reported that the surface temperature and leakage values of both systems showed different slopes, with the biggest surprise being a constant leakage current over distance for argon jet.

Benova et al. [8] followed up on the characteristics of 2.45 GHz surface-wave-sustained argon discharge for bio-medical applications. Their manuscript presents the characterization and optimization of the active region of surface-wave-sustained argon plasma for biological systems treatment. Their result shows that a discharge tube with a bigger inner diameter is able to obtain a surface temperature of 45 °C, as is required for the treatments in biology, medicine and agriculture.

A review by Borges et al. [9] focuses on the applications of cold atmospheric pressure plasma in Dentistry. Their manuscript outlines the application of cold atmospheric pressure plasma (CAPP) in dentistry for the control of several pathogenic microorganisms, as well as for induction of anti-inflammatory, tissue repair effects and apoptosis of cancer cells, with low toxicity to healthy cells. Therefore, CAPP has the potential to be applied in many areas of dentistry such as cardiology, periodontology, endodontics and even oral oncology.

A review by Zaplotnik et al. [10] is directed towards optical emission spectroscopy (OES), as a diagnostic tool for the characterization of atmospheric plasma jets. They revealed the advantages and limitations of the method, in comparison with other information given by other spectroscopic methods, e.g., VUV, that can bring more insights into the energetic species in the plasma.

This collection of reports on different plasma-based technological applications, gathered in this Special Issue brought from the community a total of 28 citations and more than 8600 views, showing the growing interest of society in such green technologies (without chemicals and by-products).

Finally, the Editor is delighted to have had the honor of organizing this Special Issue for *Applied Sciences*, which highlights the research of distinguished scientists in the field of plasma physics. The Editor would like to thank all the contributors to this Special Issue for their commitment and enthusiasm during the compilation of the respective articles. The Editor also wish to thank the members of the editorial staff at Multidisciplinary Digital Publishing Institute (MDPI) for the professionalism and dedication they have shown in

completing this Special Issue. We hope that the readers will enjoy this Special Issue and be inspired with new ideas for future research in the field of plasma.

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References

1. Lee, S.; Choi, J.; Kim, J.; Jang, Y.; Lim, T. Atmospheric pressure plasma irradiation facilitates transdermal permeability of aniline blue on porcine skin and the cellular permeability of keratinocytes with the production of nitric oxide. *Appl. Sci.* **2021**, *11*, 2390. [CrossRef]
2. Oliveira, M.; Lima, G.; Nishime, T.; Gontijo, A.; Menezes, B.; Caliari, M.; Kostov, K.; Koga-Ito, C. Inhibitory Effect of Cold Atmospheric Plasma on Chronic Wound-Related Multispecies Biofilms. *Appl. Sci.* **2021**, *11*, 5441. [CrossRef]
3. Nascimento, F.; Petroski, K.; Kostov, K. Effects of O_2 Addition on the Discharge Parameters and Production of Reactive Species of a Transferred Atmospheric Pressure Plasma Jet. *Appl. Sci.* **2021**, *11*, 6311. [CrossRef]
4. Janda, M.; Hensel, K.; Tóth, P.; Hassan, M.; Machala, Z. The Role of HNO_2 in the Generation of Plasma-Activated Water by Air Transient Spark Discharge. *Appl. Sci.* **2021**, *11*, 7053. [CrossRef]
5. Huzum, R.; Nastuta, A. Helium Atmospheric Pressure Plasma Jet Source Treatment of White Grapes Juice for Winemaking. *Appl. Sci.* **2021**, *11*, 8498. [CrossRef]
6. Ivankov, A.; Kozhevnikova, A.; Schitz, D.; Alekseenko, I. Investigation of Nonthermal Plasma Jet Excitation Mode and Optical Assessment of Its Electron Concentration. *Appl. Sci.* **2021**, *11*, 9203. [CrossRef]
7. Nastuta, A.; Gerling, T. Cold Atmospheric Pressure Plasma Jet Operated in Ar and He: From Basic Plasma Properties to Vacuum Ultraviolet, Electric Field and Safety Thresholds Measurements in Plasma Medicine. *Appl. Sci.* **2022**, *12*, 644. [CrossRef]
8. Benova, E.; Marinova, P.; Tafradjiiska-Hadjiolova, R.; Sabit, Z.; Bakalov, D.; Valchev, N.; Traikov, L.; Hikov, T.; Tsonev, I.; Bogdanov, T. Characteristics of 2.45 GHz Surface-Wave-Sustained Argon Discharge for Bio-Medical Applications. *Appl. Sci.* **2022**, *12*, 969. [CrossRef]
9. Borges, A.; Kostov, K.; Pessoa, R.; de Abreu, G.; Lima, G.; Figueira, L.; Koga-Ito, C. Applications of cold atmospheric pressure plasma in dentistry. *Appl. Sci.* **2021**, *11*, 1975. [CrossRef]
10. Zaplotnik, R.; Primc, G.; Vesel, A. Optical emission spectroscopy as a diagnostic tool for characterization of atmospheric plasma jets. *Appl. Sci.* **2021**, *11*, 2275. [CrossRef]