Novel microwave plasma source for wastewater treatment and prevention of chemical pollution in the environment

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This paper introduces a pilot investigation into a novel microwave plasma source, the Ar plasma torch at 2.45 GHz, designed for wastewater treatment and the mitigation of chemical pollution, with a primary focus on combatting the proliferation of per- and poly-fluoroalkyl substances (PFAS) in the environment. The utilization of plasma torch technology originates from its exceptional capacity to generate an array of reactive species including charged particles, hydrogen, and oxygen radicals, coupled with the emission of ultraviolet radiation and the establishment of a microwave field. These unique characteristics render plasma torches highly effective in degrading organic contaminants present in wastewater.

The research methodology encompasses a comprehensive characterization of the plasma torch system, particularly identifying and optimizing key operational parameters such as microwave power and gas flow rate. Through systematic experimentation, the plasma torch's performance in producing reactive species crucial for pollutant degradation will be rigorously evaluated. Furthermore, the study aims to elucidate the mechanisms underlying the interaction between the plasma torch and PFAS compounds, shedding light on the efficacy of this innovative technology in mitigating PFAS contamination. The presented plasma source is based on Utility model registration with certificate № 4602/2023 from the Patent Office of Republic of Bulgaria for „DEVICE FOR CREATING LOW-TEMPERATURE PLASMA TORCH". A diagram of the plasma source is presented in Fig. 1.

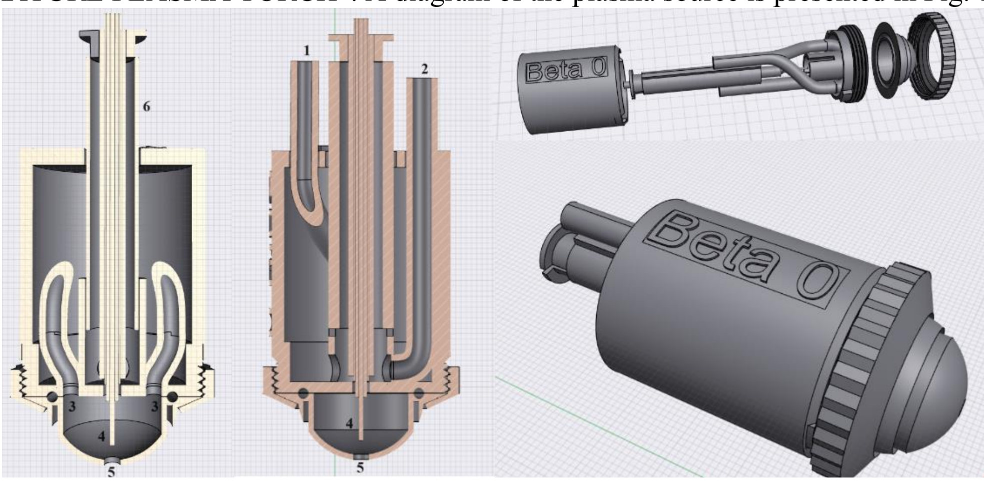
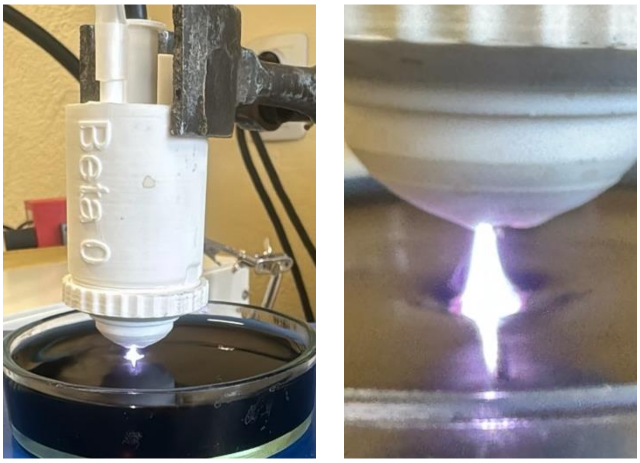


Fig. 1. Diagram of the plasma source in two projections, assembled and axially disassembled. 1 – working gas input; 2 – cooling gas input; 3 – working gas output; 4 – antenna; 5 – plasma torch gap; 6 – antenna guide.

The device is designed to operate efficiently with either argon (Ar) or other inert gases, as well as gas mixtures, offering versatility in its application for wastewater treatment. To enhance the device's performance and stability, additional cooling of the antenna has been integrated, particularly crucial for ensuring reliable operation even at high input microwave power levels. Moreover, the flexibility of the device allows for the adjustment of the antenna depth, enabling the creation of optimal conditions to align the plasma torch with the radiated wave power while minimizing reflected wave power, thereby enhancing overall efficiency.

Furthermore, this research endeavors to conduct a systematic investigation into fundamental plasma torch characteristics. Parameters such as torch length and temperature will be meticulously studied across varying input wave power levels, gas velocities, and antenna positions. This comprehensive analysis aims to provide insights into the intricate interplay between these parameters and their impact on plasma torch performance. By elucidating these relationships, the study seeks to optimize the device's operational parameters to maximize its efficacy in wastewater treatment and PFAS decontamination applications.

The study will comprehensively present the results of wastewater treatment alongside the investigation into plasma characteristics. This integrated approach allows for a holistic understanding of the plasma torch's performance in both pollutant degradation and fundamental plasma torch behavior. By juxtaposing the outcomes of wastewater treatment with the corresponding plasma characteristics studies, a comprehensive analysis of the device's efficacy and operational parameters can be achieved. This unified presentation ensures that insights gained from plasma torch characterization directly inform and enhance the efficiency of wastewater treatment processes, thereby advancing the development of sustainable solutions for environmental remediation. Images from the treatment process are presented in Fig. 2, providing visual context to complement the analytical findings.



` Fig. 2. Operating plasma source treating wastewater

The outcomes of this research hold immense potential in advancing sustainable wastewater treatment strategies, especially in addressing the pressing challenge of PFAS pollution. By harnessing the capabilities of plasma torch technology, this study paves the way for the development of efficient and environmentally friendly solutions for wastewater treatment and chemical pollution prevention based on plasma devices, contributing to the preservation of water quality and ecosystem health.

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