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Design and Development of a Novel Large-Gap Cold Atmospheric Pressure Plasma Device for Medical Sterilization Applications

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ABSTRACT

Introduction: Cold atmospheric pressure plasmas (CAPPs) have garnered significant attention in diverse fields, particularly within the realm of medicine. CAPPs are particularly adept at producing reactive species such as ions, radicals, and electrons, even at temperatures close to room temperature. CAPP sources operate under non-equilibrium conditions and can generally be categorized based on their generation mechanisms and electrode configurations. In this report, we introduce a novel atmospheric pressure CAPP source that addresses the limitations of conventional CAPP sources, such as arc formation and restricted gap distance.

Materials and Methods: Our study applied a novel patented configuration to diffuse large air gap discharge using a perforated dielectric. Typically, achieving a gas gap over 10 mm in atmospheric pressure plasma requires extremely high voltage or inert gas. This method uses a DC to AC ratio of 93:7 with a patterned dielectric, generating plasma at a reduced peak voltage of about 23 kV. The copper wire (0.51 mm in diameter) acted as the powered electrode and was placed to cover the dielectric holes. Also, multiple parallel cylindrical electrodes were used as the grounded electrode.

Results and Discussion: Atmospheric pressure diffuse discharges can be initiated with short-rise time voltages applied via a sharp electrode, generating runaway electrons, and x-ray emissions. Our design utilizes a rise time of two microseconds and a fall time of 103 microseconds to replicate similar discharge characteristics. To reduce sparks, optimizing the insulator's thickness and pinhole diameter is essential. Larger pinhole diameters are inadequate for sustaining glow discharge, while a thinner dielectric can decrease applied power and allow plasma operation at lower voltages, considering the streamer head's defined radius.

Conclusion: The present study introduces an innovative cold atmospheric-pressure plasma source designed to produce large, uniform plasma volumes at low voltages, thus avoiding arc formation. The device features a perforated dielectric structure with parallel copper wires and cylindrical electrodes as the grounded component to improve plasma uniformity. This setup enables stable, diffuse plasma generation in ambient air at gap distances up to 80 mm, surpassing standard atmospheric-pressure plasma systems. Due to its non-thermal nature and wide operational range, this system shows significant promise for sterilizing medical devices.

Keywords: Air discharge, Atmospheric pressure plasma, Cold plasma, Large-gap discharge, Plasma source

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