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CHARACTERIZATION OF THE DIELECTRIC BARRIER-FREE ATMOSPHERIC PLASMA SYSTEM

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Abstract. This work presents a characterization of the new pulse plasma system that's operating at an atmospheric pressure and it be used for a material functionalization and/or surface serialization. The study includes details of developing and operating, in-house made, non-thermal, dielectric-free atmospheric plasma system. The new plasma system allows an increase in the plasma-surface interaction selectivity and reduces plasma induced damages to the surface. The plasma rig creates a plasma discharge in gap from 5 to 60 mm, and in the volume of hundreds of cm^3.

The plasma source has a pulse resonance circuit which allows the creation of a high voltage pulses with the ability to control and reduce a current of the plasma discharge. This ability allows the temperature of the treated sample's (organic or inorganic) material to be kept at room temperature. The study also includes different setting of plasma source to control the ion flux, the ion energy and the plasma chemistry. Plasma pulsing allows new domains of ion energy and radical fluxes to be reached, thereby extending the operating range of plasma generators.

1. INTRODUCTION

The impact of a gaseous plasma on a surface treatments is well known and it has been used for the last several decays. In the past, plasma systems were mainly used in a low pressure (vacuum) environment, and in the semiconductor industry, for two processes, sputtering and etching. In last several years, an atmospheric plasma systems were presented on the market, like Plasma Jets and/or Dielectric-Barrier Discharge (DBD). A plasma jet system creates plasma in a nozzle with flow gas as visible plasma stream long about 3-15 mm. The gas carrier could be argon, helium, but also an ambient air. The plasma jet systems are mainly used for local plasma treatment of a small surface areas. For treatment of the bigger surface areas, it has been used in conjunction with a XYZ position systems. In that case, these systems are useable for bigger surface treatment, but they are also significantly slow down the treatment time, and that is an obstacle for an industrial use, Cullen and Milosavljević 2015. DBD's systems have a two metal electrodes and a dielectric material, that is between the electrodes. In reality, there are many variations of the electrodes' shape, but the basic concept remains the same, Milosavljević and Cullen 2017. The Critical point of any DBD reactor is the quality of dielectric material. Quality and homogeneity of the dielectric material is important, to be avoided a degradation of the isolation layer and the creation of arcing discharge. Inhomogeneity of dielectric material reduce lifetime of DBD system. The main function of this dielectric material is to spread the electrical charge throughout the entire plasma electrodes to increase homogeneity by creating of multiple conducting paths for the discharges to occur. There is also issues during the DBD plasma discharge, the dielectric is degrading, and it will be contaminated by the gas plasma chemistry.

Therefore, the main motivation for this work is developing an atmospheric dielectric barrier free (non-DBD) plasma system, that can produce a stable, reproducible and a homogeneity of the atmospheric plasma discharge. This plasma discharge will be at an ambient atmosphere air, i.e. without any additional gas.

2. EXPERIMENT

The atmospheric plasma system is developed as a complex system that includes: a plasma power supply unit, a high voltage transformer and plasma pin reactor (Figure 1).

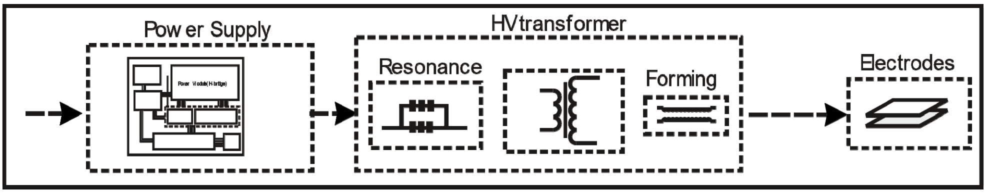

Figure 1: The Basic block diagram of the plasma system.

The Power Supply Unit (PSU) is the most complex part of the whole plasma system. There are independent logical parts implemented to combine functionality, safety, efficiency and configurability. The main parts of PSU are showed in Figure 2: Power Filter, PFC – Power Factor Correction, Internal power 24 V, Measurement and Control Module, Human Machine Interface Module, Input Output Module and Power Module with full H-Bridge.

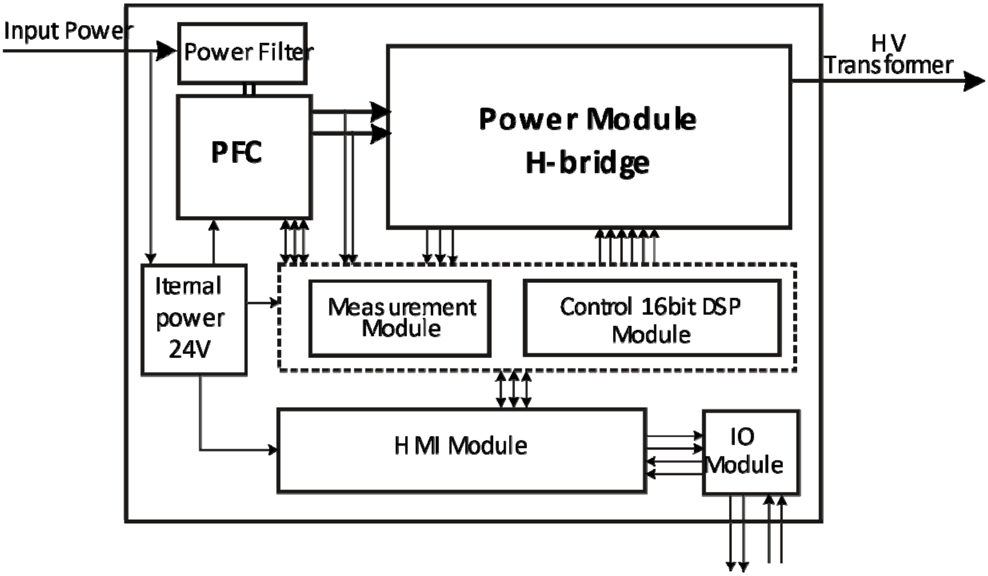

Figure 2: The Block diagram of power supply unit.

The new plasma reactor with a pin top electrode was designed (Figure 3), Gulan and Milosavljević, 2021. The pins have different lengths in the middle and at the edge of the electrode. The pins in the middle are longest and pins at the corners are the shortest. The Pins from the middle to edge of the electrode are a gradually shorter, i.e. the 3D profile of pins allows the removal of a dielectric barrier.

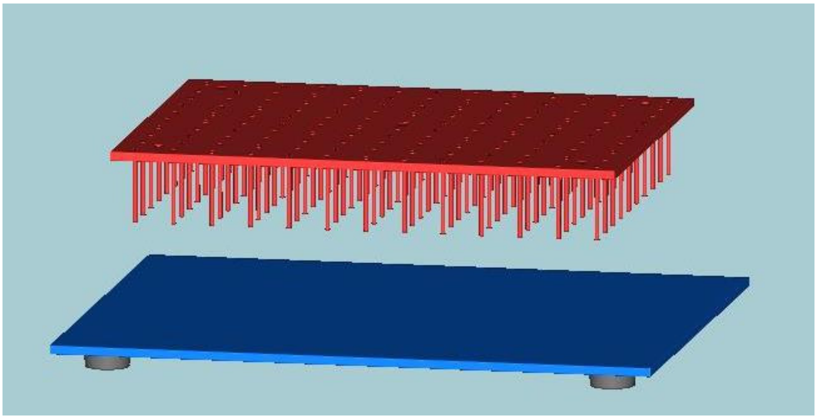

Figure 3: The electrodes of the plasma reactors.

3. RESULTS AND DISCUSSION

Figure 4 is recorded with settings: resonance frequency = 50.0 kHz, discharge frequency = 500 Hz, duty cycle = 42 % and voltage (pick-to-pick) V = 30 kV.

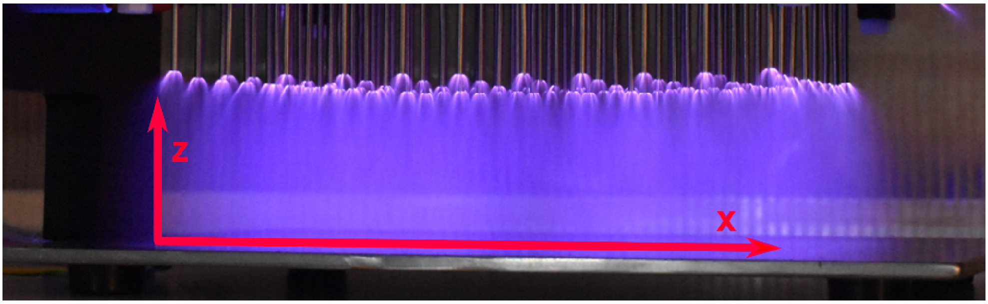

Figure 4: Plasma discharge.

Figure 5a shows a different O_3 concertation at the middle of the plasma reactor and at the edges along of X-axis. Concertation of O_3 dropped at the edges due to its interaction with the ambient air. To reach better homogeneity of O_3 along X-axis, the plastic enclosure box was used around electrodes. This plastic enclosure (Figure 5b) helps to improve homogeneity of O_3 and increase concertation of ozone for about 30 %, Gulan and Milosavljević 2022.

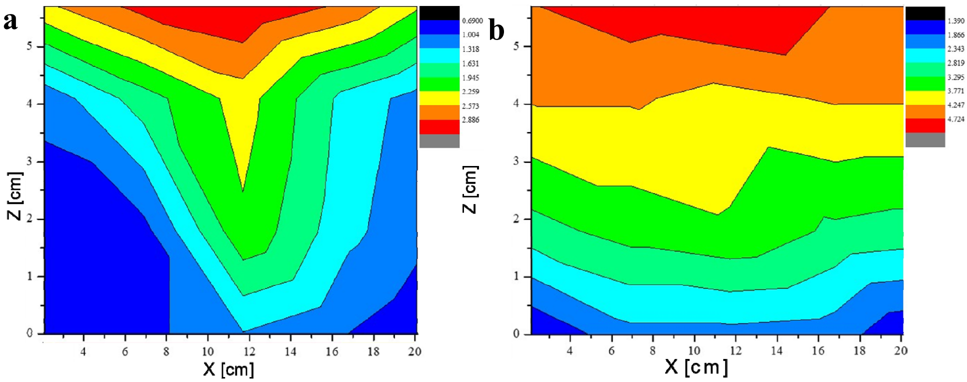

Figure 5: O3 concentration [mg/l] (a) without plastic enclosure box, (b) with plastic enclosure box.

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