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REVIEW ARTICLE

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Process Parameters and Design Consideration to Devise A DBD Excimer Generation System

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INTRODUCTION

The process of plasma surface modification can be divided into four distinct mechanisms: ablation, cross linking, activation and polymerization: Ablation is the process of breaking down weak covalent bonds in a polymer through bombardment with high energy particles.. Processing with inert gases can be used to cross-link polymers and produce a harder surface with improved wear or chemical resistance. Activation is the process of replacement of surface polymer groups with chemical groups from the plasma. The plasma breaks down weak bonds in the polymer and replaces them with highly reactive carbonyl, carboxyl, hydroxyl, peroxyl, amino or other functional groups. Active groups on the surface can change the surface characteristics, such as its wetting properties, adhesivity etc. Polymerization is the process of forming very large molecules by joining many small linkable molecules called monomers. The process involves reaction utilizing a wide variety of gases, organic or organo-metallic vapors which deposit non-volatile polymer films. When the process gas mixture contains hydrocarbons, the hydrocarbon molecules are fractured into free radical fragments. These free radicals initiate polymerization. Plasma can also polymerize materials, which do not form polymers under conventional chemical methods. The properties of the polymer film can be controlled during deposition and combine different features such as good adhesion of the film at the substrate surface and high hardness at the upper film surface.

MATERIAL AND METHOD

One of the motivations for studying the design criteria of DBD driven excimer sources in this work was the fact that although DBD based excimer sources and DBD plasma reactors have been developed, but utilization of these DBD reactor systems in different diverse technological fields requires different process parameters and thus different design considerations of DBD, all of which have not yet been studied. Therefore, in this work attempts were made to study the design criteria of DBD driven VUV/UV source.

Firstly, a comparative study of various non-thermal plasma sources was carried out theoretically to investigate the best suited cold plasma scheme for excimer generation. It was deduced that the electron driven DBD scheme leads to a fertile environment for the generation of excimers in rare gases and rare gas halides. It has a multitude of transient filaments with electron density of 10^{14}-10^{15} cm^{-3} and mean electron energy of typically 1-10 eV, while the gas temperature is ambient. Moreover, in DBD scheme, the plasma parameters (mean electron energy and density) can be easily influenced and optimized for the desired excimer formation process by external means over a wide range by simple variation of process parameters. It has been found that DBD is an ideal tool for excimer generation having a great flexibility with respect to the geometrical shapes, operating medium and operating parameters and therefore, was concluded that due to a simple design combined with low operating gas temperature, highly energetic electrons and scalability, DBD stands out as a promising technology for excimer synthesis.

Further, efforts were made to investigate the process parameters and design consideration to devise a DBD excimer generation system. The miscellaneous electrical and kinetic process parameters governing the design of DBD excimer source were studied. One of the vital process parameter, selection of possible discharge reactor module for producing excimer was considered in detail. The promising hardware realization of DBD in volume, surface and coplanar discharge has been presented and the applicability of these discharge configurations for developing excimer UV sources in different fields was considered.

The design parameters of DBD were considered with an emphasis on the various peculiarities of DBD including their structure, properties, and breakdown mechanisms. The design and simulation of a Multi-Cell Inverter (MCI) in a half-bridge configuration for driving DBD load was presented and the driving circuitry of nonlinear DBD load was simulated in SimPower system block of Simulink to operate at a potential of 1500 V and at a frequency of 10 kHz.

Analysis and modeling of DBD using electrical equivalent network model has also been reported. The equivalent network model of DBD consists of standard circuit element that has been implemented in Matlab to investigate the electrical behavior of the DBD reactor. The model has been described as a combination of the primitive electrical components and one can easily perform a circuit simulation using general-purpose circuit simulator by combining the electrical equivalent model and power supply for driving DBD load. The electrical model of DBD has been implemented in Matlab Simulink tool. The model has been used as an invaluable tool for the determination of discharge design parameters of excimer optical source, in particular, the discharge voltage, discharge current and electric power input. The various discharge parameters governing the electrical behavior of DBD were obtained in terms of plasma current in the gas gap and measured total external current in the external circuit. These discharge parameters determine the plasma properties of the DBD load. The voltages across the dielectric, gap and discharge off current were also investigated and a good correlation was obtained with theoretical analysis.

The simulation of DBD reactor coupled to MCI was carried out to analyze and to design a DBD reactor. A compact Matlab model of MCI coupled to an electrical equivalent model of plasma discharge in DBD was formulated and implemented. In this the plasma in DBD was modeled as a voltage controlled current source which is switch ON when the voltage across the gap exceeds the break down voltage of the gaseous medium. The plasma is modeled as a variable resistance that follows the power law of applied voltage. The electrical equivalent model may also be used to investigate the behavior of the DBD configurations. Therefore, from design consideration using equivalent circuit approach, an adequate idea of optimal driving parameters such as, gas discharge voltage $V_g(t)$, dielectric voltage $V_d(t)$, displacement charge $Q(t)$, active plasma current $I_g(t)$, power input into plasma $P(t)$, and deposited energy $E(t)$ can also be easily obtained for any arbitrary driving source.

CONCLUSION AND RECOMMENDATIONS

The work reported in the present paper can be further extended in the designing of a DBD reactor for surface processing applications. The suitability and applicability of various atmospheric cold plasma techniques for surface modification, particularly for the continuous surface treatment have been presented and discussed. Upon studying and comparing the various schemes, it was concluded that DBD technology offers enormous promise in surface modification, and is therefore the most widely suited plasma reactor for surface modification in continuous surface processing. Therefore, the diversity and versatility of the DBD technology as an enabling tool for application in the field of surface treatment has been discussed in detail. The steps obtained in the designing of the DBD excimer source were extended for designing of a DBD reactor for surface modification, particularly suited to surface modification in the textile and biomedical sector. The process parameters and design criteria of DBD treatment setup for designing a DBD reactor in surface processing were dealt with. The development procedure for DBD reactor involves an optimum choice of process parameters and designing of gas handling system, selection of DBD topology and designing of impedance matching network. The suitable DBD geometry for continuous surface processing of DBD plasma generation system was identified and an electrical analysis of the DBD cell was carried out.

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