Atmospheric Pressure Planar Radio Frequency Discharge With Isolated Electrodes: Glow Features and Application Prospects

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***Abstract*—Operation characteristics of RF planar barrier discharge in atmospheric pressure argon appropriate for obtaining the discharge extension outside the electrodes in a form of planar plasma jet are determined experimentally. The plasma jet images and spatial distributions of its light emission intensity are presented, and their features are discussed. The prospects of studied jet discharge for creation of liquid crystal alignment and etching polymer materials are demonstrated.**

***Index Terms*—Argon, plasma applications, plasma properties.**

I. Introduction

In THE past decade, RF barrier discharges operating at atmospheric pressure drew essential attention of research due to their ability to achieve relatively high-energy density (>100 W/cm^3) in continuously generated discharge plasma using comparatively low operation voltage (100 V–1 kV). Experimental studies of operation regimes of such discharges [1], [2] as well as their numerical simulations [3], [4] are known. The discharge systems having planar geometry are of special interest, since they can be scaled in one spatial dimension with retaining desired discharge operation regime.

Atmospheric pressure RF discharges usually operate with spacing between electrodes of about 1 mm. For efficient practical application of such discharge plasma one should extend it outside the discharge unit in a form of the plasma jet. Such systems with cylindrical geometry are well known and successfully used for particular applications [5]. However, they cannot be used for such actual task, as substitution of expensive vacuum-based plasma systems for treatment of large-square plane surfaces by efficient devices operating at atmospheric pressure.

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Our preliminary studies of the features of plasma flow outside RF discharge cell [6] have shown its ability to treat polyimide-coated substrates for liquid crystal (LC) alignment. However, used system with inclined cell and asymmetric plasma flow was far from optimum one. Since that time, detailed experimental studies of RF discharge modes were performed [7], [8], and optimum discharge operation regimes were established.

This paper is aimed to experimental study of operation conditions of planar barrier RF discharge which enable its extension outside the discharge cell in a form of spatially symmetrical planar plasma jet directed at normal incidence to treated surface. Polyimide-coated substrate treatment for LC alignment and etching of polypropylene microspheres is performed for demonstration of application prospects of the system under study.

II. Experimental Setup and Methods

Experimental setup was based on the discharge cell and power supply system previously used by us for the studies of planar barrier RF discharge glow modes [8]. Plane discharge electrodes made of 50 − μm-thick copper foil had dimensions of 50 × 10 mm. Al_2O_3 ($\varepsilon = 10$) plates, each having 1-mm thickness, were used as dielectric barriers. The 1-mm spacing between the plates formed the discharge gap (Fig. 1).

The discharge was powered by means of RF (13.56 MHz) generator 5 (MV-1.5, JSC "Selmi," Sumy) using specially designed matching unit six. Each of the discharge electrodes one was powered through its own capacitive divider ($C1$–$C2$ and $C3$–$C4$) thus setting desired electrode voltage values denoted as U_H ("high voltage") and U_L ("low voltage"). It allowed control of both the main discharge voltage (U_H–U_L) and the main discharge plasma RF potential defined by simple average of the voltage values $\approx (U_H + U_L)/2$. Unlike previously used setup arrangement with horizontal placement of the discharge cell [7], [8], in this paper, it was placed vertically for plasma jet extraction outside the discharge cell. This process was also assisted by proper placement of the sample holder four (glass plate) and additional grounded electrode 3 at 3–5-mm distance below the plate.

With the used discharge glow regimes, output impedance of matching unit six exceeded those of the discharge unit by a factor of about 8–10, so that RF power supply system operated practically in current source regime.