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Fundamental properties of 4-in-1 Plasma ENergized-Jet at atmospheric pressure

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A B S T R A C T

The treatment performance of the PEN-Jet (Plasma ENergized-Jet), one of the atmospheric-plasmas, is considered to be enhanced by increasing input power. However, the input power of a PEN-Jet with a single rod electrode is limited to 200 W due to electrode wear at higher power. The 4-in-1 PEN-Jet, which has four rod electrodes in the PEN-Jet body, was developed to generate a plasma jet with higher power. In the present study, the gas temperature of the plasma jet, emission spectra radiated from the plasma and contact angle of treated substrate (AlN), were measured when air or N_2 was used as the working-gas. From air plasma spectrum, the N_2 radical was observed near the nozzle outlet. In contrast, the NO radical was observed to be relatively stronger when N_2 plasma was used. The treatment performance of the 4-in-1 PEN-Jet using air was found to be four times higher than that of the single-electrode PEN-Jet. When N_2 was used, the performance was increased another four times with air.

1. Introduction

Atmospheric pressure plasma has been studied for various industrial applications, such as surface treatment, cleaning, and sterilization [1–3]. Especially, in recent years, it has been intensively studied in the automobile industry, electronics, biochemical and medical fields. In each field, improvement of material hydrophilicity is a representative example of application of atmospheric pressure plasma. Various approaches have been adopted by many researchers. For example, various plasma sources were used including atmospheric glow discharge [4], dielectric barrier discharge (DBD), RF discharge (ICP, CCP), and pulse arc discharge.

The authors have also studied the generation of atmospheric plasma using pulse arc discharge. With this type of plasma, any gas can be used as a working-gas, even air. This type of plasma gas has median temperatures from room temperature up to 500 °C. We call this kind of plasma meso-plasma. The gliding arc, which can provide high plasma density and power, is a representative example of a meso-plasma [5,6]. The authors have developed the PEN-Jet (Plasma ENergized-Jet) as one of these meso-plasmas [7,8]. It is generated between the center electrode in an insulating tube and a nozzle electrode placed at the tube end using a pulse power supply with high repetition frequency. Fast gas is introduced from the other end of the tube, and the non-equilibrium plasma jet is then blown out from the nozzle. According to previous studies, the PEN-Jet is very useful for surface treatment, and its performance is enhanced by increasing input power, e.g. increased treatment speed and greater decrease of contact angle. However, when high input power was employed, the rod electrode of the PEN-Jet wore away. Thus, the input power was limited. The 4-in-1 PEN-Jet, with four rod electrodes in a PEN-Jet body, was developed as a further breakthrough. The 4-in-1 PEN-Jet is thus able to provide four times more power than a PEN-Jet with a single-electrode (single PEN-Jet).

In this study, one of the fundamental characteristics of the 4-in-1 PEN-Jet, the gas temperature of the plasma jet, was measured when air and N_2 were, respectively, used as the working-gas. The spectrum was observed, and the activated species were identified. Furthermore, in order to evaluate treatment performance, AlN substrate was irradiated by the 4-in-1 PEN-Jet and the contact angle of water droplets was measured. AlN has good industrial properties: high electrical resistance and high thermal conductivity. Consequently, it has often been used as a substrate in electrical power devices. Due to surface treatment of AlN substrate, the adhesion strength between it and plated metal film is enhanced.

2. Experimental

Fig. 1 presents a schematic diagram of the 4-in-1 PEN-Jet and its power supply system. Four rod electrodes (Pt, 1.6 mm in diameter)

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