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Cold arc-plasma jet under atmospheric pressure for surface modification

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Abstract

A relatively cold arc-plasma jet under atmospheric pressure was developed using a pulse power supply, called a Plasma Energized (PEN)-Jet. A needle electrode was placed in a glass tube, and a cap electrode with a center-hole (3 mm diameter) was placed at the tube end. The electric arc was discharged between the electrodes by applying intermittent bipolar pulse power. By introducing dry air, nitrogen, or oxygen gas into the tube from the other end, the plasma gas of the arc was spewed out from the center-holed cap electrode, and a plasma jet was formed. The length and temperature of this plasma jet was measured as a function of pulse frequency (10–30 kHz). Both were found to increase with the increase in pulse frequency, not being very dependent on the type of gas under present experimental conditions. Maximum jet length was approximately 15 mm at 30 kHz, and maximum temperature at 5 mm from the cap electrode was 250 °C. Various metals and polymers were treated by PEN-Jet. The water contact-angle of these materials was found to decrease.

Keywords: Pulsed arc; Atmospheric pressure; PEN-Jet; Jet length; Temperature; Metal treatment; Hydrophilic property

1. Introduction

Plasmas under atmospheric pressure using electric discharges have shown great promise when applied to change the superficial properties of materials: friction, wettability, adhesion, gas and fluid permeability, biocompatibility, corrosion/wear/scratch resistance, and dye-affinity [1]. Treatment under atmospheric pressure is simpler to set-up, easier and economical to operate, and more productive, compared to traditional vacuum treatment. Atmospheric pressure plasmas can be generated by various methods; corona, glow, arc, dielectric barrier discharge, RF discharge, and microwave discharges, as reviewed in several articles [1–3].

A gliding arc is one of the plasmas with relatively low temperature operated under atmospheric pressure. The gliding arc is usually generated between two diverging electrodes in a submerged gas flow [4,5]. The arc starts at the shortest upstream electrode gap and is then dragged toward a wider electrode gap by an external forcible gas flow [4,5]. Even when the arc reaches the widest electrode gap, the arc column is pushed farther away if the power supply provides enough voltage. The arc is instantly extinguished when the arc voltage exceeds the voltage of the power supply. Immediately thereafter, a new arc starts at the shortest electrode gap. This series of behavior is repeated, usually producing a flat plasma jet. The gliding arc has been used for chemical [6], gas conversion and decomposition processes [4,7,8], gas pollution control [9], and wool surface treatment [10]. Recently, a gliding arc with simultaneous bipolar pulse power has been commercialized for the superficial treatment of hydrophilicity or adherability, irradiating the plasma to the material surface. Such gliding arc treatment is available for polymers. However, for conductive materials such as metals, gliding arc irradiation causes treated surface to suffer serious damage due to the appearance of aggressive arc-spots.

In the present study, using the power supply for a pulse gliding arc, an arc-plasma torch-jet (Plasma ENergized (PEN)-Jet) with relatively low temperature was generated under atmospheric pressure to treat especially conductive materials without any damage. The jet length and temperature were first measured as a function of the pulse frequency, gas flow rate, and gas species. Various metals as well as polymers were treated with the PEN-Jet and the hydrophilicity of the treated surface was examined.

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