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Surface Modification of Conductive Oxide films and Polymer Materials Employing Atmospheric Cold Plasma Surface Modification of Conductive Oxide films and Polymer Materials Employing Atmospheric Cold Plasma

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Abstract

we have quantitatively investigated the possibility of feeding oxygen radical in air environment. The oxygen radical generation from the plasma was verified and its efficiency was found to be dependent on the cathode material by the analysis with optical emission spectroscopy as well as by the quartz crystal micro-balance method.

Key Words : low temperature plasma, atmospheric pressure, oxygen radical

1.Introduction

Recently we reported that the high rate and vacuum -free ashing was possible by using the atmospheric pressure cold plasma torch which was composed of an insulator barriers cylindrical anode and a needle cathode in the center.[1] The applicability of this plasma was verified to such processes as Si etching[2] and SiO_2 and TiO_2 film deposition using alkoxysilanes[3] and tetraethoxytitanate[4], respectively. Furthermore, fullerene (C_{60} and related carbon clusters) was found to be produced by feeding naphthalene into the Ar / He plasma torch.[5]

This study has been preformed to evaluate quantitatively the effect of cathode material on plasma chemical synthesis of oxygen radical flux and to collect information useful for applying them to film preparation and surface modification processes in open air condition.

2. Experimental

The experimental setup for this study is schematically illustrated in Fig. 1. The cold plasma torch is composed of an rf powered metal

needle cathode (1mm in diameter and 30mm long) and a grounded cylindrical stainless steel anode (5mm inner diameter and 30mm long) with an insulating tubing (0.5mm thick) inserted to cover the inner surface of the grounded anode. The insulator material we used here was alumina. The cathode materials used were stainless-steel, Pd,

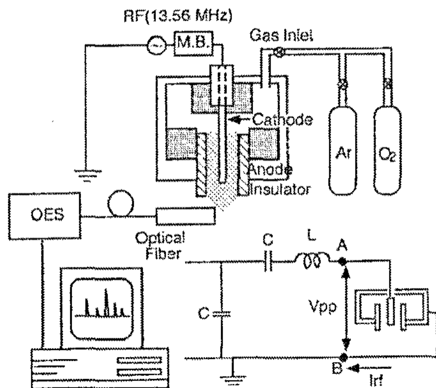

Fig.1. Schematic diagram of cold plasma torch for O radical measurement and electrical characterization.

W, and Pt. Oxygen containing plasma was generated by applying an rf power between 60W and 80W to the cathode in the oxygen (0 - 9.0 sccm) containing Ar flow. The total gas flow was 300 sccm. To evaluate the electrical effect of cathode material for generating plasma, the peak to peak rf bias voltage; Vpp and plasma current; Irf across the plasma were measured by using a high voltage probe and current probe connected one end to the cathode and the other to an oscilloscope. After the measurement, plasma impedance was calculated.

3. Results and Discussion

Based on the I-V measurement by a single probe method on the direct temperature measurement using a thermocouple, the electron temperature (Te) and gas temperature (Tg) were evaluated to be 1.2eV and 240 °C (44.2meV), respectively, for the plasma generated by applying 70W rf power to 1.5% O_2 containing Ar flow.

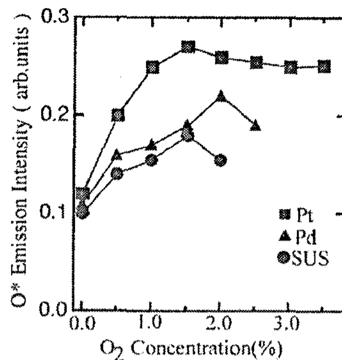

Fig. 2. Relationshop between the concentration of O_2 and emission intensity of O* at 70W rf power.

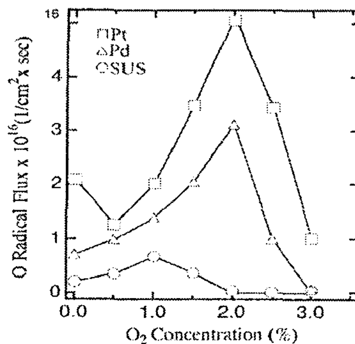

Fig. 3. Relationshop between the concentration of O_2 and O radical at 70W rf power.

Emission lines from Ar and N2 were clearly detected in the wavelength range between 400nm and 700nm in the plasmas of Ar with and without O_2 mixing. No other emission line was detected in this range. The decomposition of O_2 was confirmed by the presence of O^* line at 777.4nm and 844.6 nm in the spectra of O_2 / Ar plasmas. The O^* (844.6nm) / Ar^* (750.4nm) emission intensity ratio was used for quantitative analysis of oxygen radical.

Figure 2 shows the O^*(844.6nm) / Ar^*(750.4nm) emission intensity ratio to generate plasma plotted as a function of O_2 concentration in Ar flow by

applying 70W rf power. The relative O^* emission intensity increased with the increase of O_2 concentration to 1.5 - 2.0 % to reach the maximum and decreased with further increase of O_2 concentration. The O^* emission from the plasma using a Pt cathode was higher than that using a stainless steel or Pd cathode of the same size. The plasma was flashed to Ag film deposited on a quartz sensor.

Figure 3 shows the oxygen radical flux as a function of cathode surface area. Using the cathode with 1.02 cm^2 total surface area, the oxygen radical flux generated was 3.5 x 10^{16} $/cm^2$ x sec by using Pt cathode, more than 8 times higher than the radical flux generated by using the stainless steel cathode. When the cathode surface area increased from the 1.02 cm^2 to 1.85 cm^2 by winding a thin Pt wire around three cathode of Pt, Pd, and SUS, oxygen radical flux increased linearly to be almost same at the surface area 1.85 cm^2. In contrast, by using thin stainless steel wire to change the surface area, the radical flux decreased linearly in case of Pt and Pd cathode to generate plasma.

4. Conclusion

A catalytic effect of cathode material in the plasma process was found by the remarkable efficiency of excited atomic oxygen generation in the plasma, by the replacement of stainless-steel cathode to Pt cathode. Under the conditions of 2.0% O_2 in Ar 300sccm and rf power 70W, the oxygen radical flux increased to 3.5 x 10^{16} $1/cm^2$ x sec by using Pt cathode, more than 8 times higher than the radical flux achieved by using the stainless-steel cathode.

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