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Coloring Effect on the Metal Surface by using Helium/Oxygen Atmospheric Pressure Plasma

ヘリウム/酸素混合ガスを用いて生成した大気圧プラズマ照射による金属の発色効果

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In this study, we generated atmospheric pressure plasma with helium/oxygen mixture gas to promote the generation of oxidants, and evaluate the coloring effect as compared to helium for copper surface. As the result, total optical emission of the plasma for helium/oxygen mixture gas decreased with that for helium gas. Surface color in the case of helium/oxygen mixture gas is not changed. These results indicated that the generated oxidants in the plasma generated by the helium/oxygen mixture gas decreases with that by the helium gas.

1. Background

The coloring of metal surfaces without the use of pigments or dyes is a method of adding value to industrial applications. To obtain the metal surface coloring without pigments or dyes, structural or oxidation coloration have been considered [1]. Oxidation coloration is caused by generating an oxide layer on the metal. Anodic oxidation coating and laser oxidation have both been demonstrated to be viable techniques for obtaining this layer [2-3]. The coloration of the metal with the oxidation coloration is possible to control a thickness of oxide layer.

Atmospheric pressure plasma is easy to generate oxidant as atomic oxygen, ozone, and hydroxyl radicals in the atmosphere. Complicated equipment for generating atmospheric pressure plasma is not required. Therefore the atmospheric pressure plasma is used in various industrial fields such as chemosynthesis environmental purification, and medical applications [4-5]. In previous research, the surface color of copper is slightly changed from the natural copper to the gold after the plasma irradiation [6]. The oxygen rate on the depth of copper plate increases as a function of the time of the plasma irradiation. Oxidation layer on the sample depends on the generated oxidants in the plasma.

In this study, we evaluate the relation between the coloring effect and the generated oxidant in the atmospheric pressure plasma using a helium/oxygen mixture gas.

2. Experiment apparatus and method

Figure 1 shows an oxidation coloration system using atmospheric pressure plasma. The atmospheric pressure plasma is generated with a dielectric barrier discharge (DBD), which consists of an inverter power supply and electrodes covered by a dielectric of alumina. The size of aluminum electrode is set to be 20×150×10 mm. To observe the oxidation coloration using atmospheric pressure plasma, a sample plate as oxygen-free copper (99.99 %) is set on the lower covered electrode. In this study, the voltage and the frequency of the power supply were 18 kV_{pp} and 45 kHz, respectively. To sustain the plasma, the dielectric barrier discharge is introduced buffer gas as helium (10 L/min) and helium/oxygen (10/0.5 L/min) mixture gas. The samples after the plasma irradiation have been observed surface color with a digital camera. A time-resolved spectrometer observes the active species and optical emission intensity of plasma.

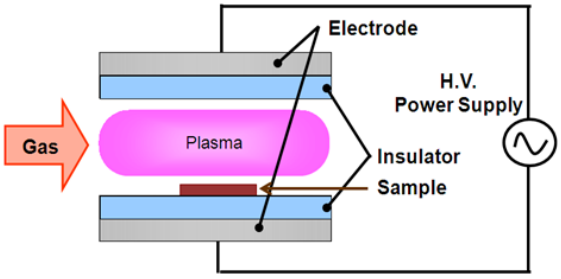


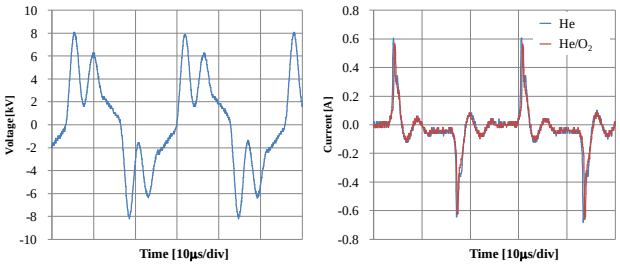
Fig. 1 Schematic view of dielectric barrier discharge for metal coloring

3. Experiment results

Figure 2 shows measured current and voltage waveforms for each buffer gas by using a high voltage probe and a current transformer. As shown in Fig. 2, we can see that the peak current is estimated to be 1.33 App for helium gas and 1.22App for helium/oxygen mixture gas. Average input power is calculated from observed current and voltage. As a result, the average input power is estimated to be 108 W in case of helium gas and 106 W in case of helium/oxygen mixture gas. In both cases, the input power in the plasma is almost same from the current and voltage waveforms.

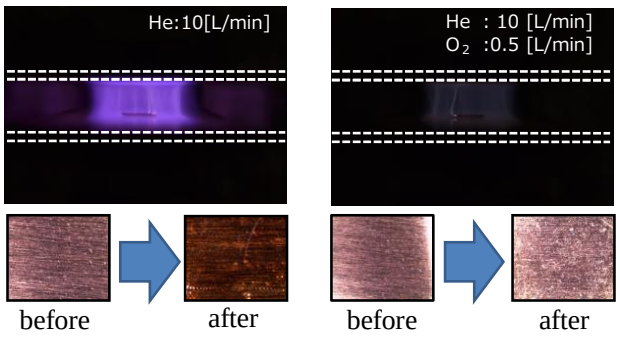
Figure 3 shows photographs of atmospheric pressure plasma and surface color of copper plate after 2 min of the plasma irradiation. From the photographs of the plasma generation, optical emission intensity of the plasma for helium/oxygen mixture gas is smaller than that for helium gas. The copper surface color using helium gas is changed from the bronze to brown. However, surface color using helium/oxygen mixture gas is not changed after the plasma irradiation.

Figure 4 shows the optical emission spectrum for each buffer gas from the atmospheric pressure plasma. The spectra of oxidants as atomic oxygen and hydroxyl radicals were estimated by NIST database [7] in the measure spectrum.



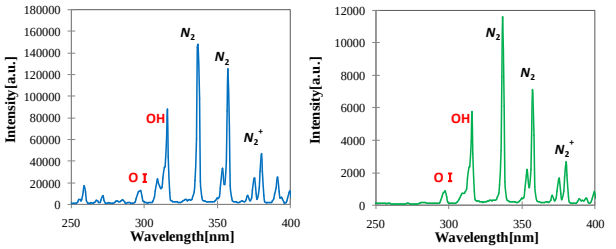
(a) Voltage (b) Current

Fig. 2 Typical input voltage and current waveforms each buffer gas



(a) He (10L/min) (b)He/O_2 (10/0.5 L/min)

Fig. 3 Photographs of atmospheric pressure plasma and copper surface color after the plasma irradiation



(a) He (10 L/min) (b) He/O_2(10/0.5 L/min)

Fig. 4 Emission spectrum as a region from 250 nm to 400 nm

As shown in Fig. 4, the emission intensity in the case of helium/oxygen mixture gas was lower than that in the case of helium gas.

From the above results, the effect of oxidation on the sample by using helium/oxygen mixture gas was smaller than that by using helium. It means that the generated oxidants in the plasma using the helium/oxygen mixture gas decreases with that using the helium gas.

4. Conclusion

To promote the generation of oxidants for the coloring effect on the copper surface, atmospheric pressure plasma with helium/oxygen mixture gas has evaluated. The results indicate that the optical emission intensity from the plasma for helium/oxygen mixture gas decreases with that for helium gas. Surface color in the case of helium/oxygen mixture gas is not changed. It means that the generated oxidants in the plasma using the helium/oxygen mixture gas decreases with that using the helium gas.

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