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Characteristic of Water Plasmas Generated from O/W Emulsion by DC Discharge under Atmospheric Pressure

O/Wエマルションを利用した大気圧直流放電による水プラズマの特性

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O/W emulsion has been decomposed by a DC water plasma system. 1-Decanol emulsion used as a model substance of water-insoluble organic compound was prepared with emulsifier of Tween60 for plasma supporting gas. The water plasma torch was operated in different arc currents form 6 A to 8 A at atmospheric pressure. The main gases generated from the decomposition were H_2, CO, and CO_2. At arc current of 8 A, the TOC value decreased from 3.40×10^4 mg/L to 1.18×10^2 mg/L, and over 99.6% of carbon in the raw material was decomposed.

1. Introduction

Thermal plasmas have the following advantages: high enthalpy to enhance reaction kinetics, high chemical reactivity, and control over oxidation or reduction atmospheres in accordance with required chemical reactions. These advantages enable thermal plasmas to treat the waste effectively [1-3]. Direct current (DC) water plasma torch generates 100%-water plasma by high temperature arc discharge at atmospheric pressure. Therefore, abundant O and OH radicals which promote waste decomposition are produced in water plasma flame. It is also a portable lightweight plasma generation system that does not require additional plasma forming gas supply and water cooling unit

Although some water-soluble organic materials were investigated in the previous work [2,3], treatment of water-insoluble materials has not been tried. In the present work, the purpose is to investigate the decomposition characteristics of oil-in-water (O/W) emulsion in the DC water plasma system.

2. Experimental Setup

Emulsions are colloids made of two immiscible fluids; one being dispersed in the other in the presence of surface active agents. There are various intermediate or consumer products consisting wholly or partly of emulsions [4]. The emulsion used in this study is a kind of O/W where oil droplets are dispersed in water phase. It is composed of H_2O, 1-decanol and non-ionic surfactant (Tween60). In the samples, the ratio of 1-decanol concentration was 0.1-0.5mol% and the ratio of 1-decanol to Tween60 was 1.00 to 26.54 in the mole ratio.

Schematic diagram of the atmospheric DC water plasma system is shown in Fig. 1. The experimental system consists of four parts: (1) water plasma torch, (2) power supply, (3) condenser, and (4) treated liquid collector. Decomposition experiments were conducted with the batch process as follow; the emulsion fills water the reservoir of the torch, and then the arc is ignited. The emulsion is evaporated spontaneously with the generation of thermal plasma, and it decomposed in the discharge region directly.

The produced gas and liquid from the decomposition were separated by the condenser. Gas phase treated material was analyzed by gas chromatography (GC) equipped with a thermal conductivity detector and a quadrupole mass spectrometer (QMS). In addition, carbon concentration in treated liquid was measured by a total organic carbon (TOC) analyzer.

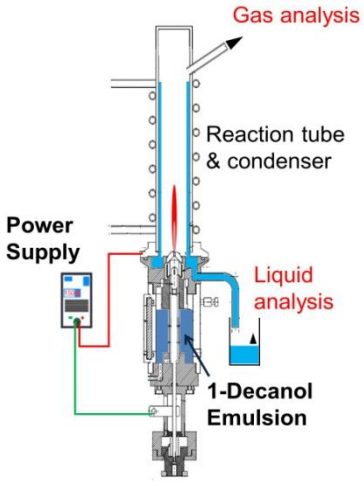

Fig. 1. Schematic diagram of the experimental setup.

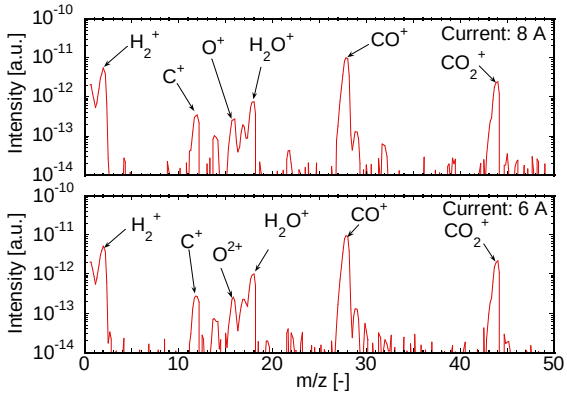

Fig. 2. Spectrum of produced gas of 0.5mol% 1-decanol emulsion at 6 A and 8 A.

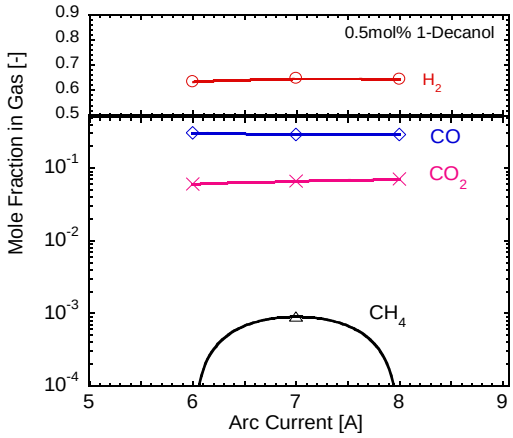

Fig. 3. Effect of arc current on gas composition generated from 0.5mol% 1-decanol emulsion.

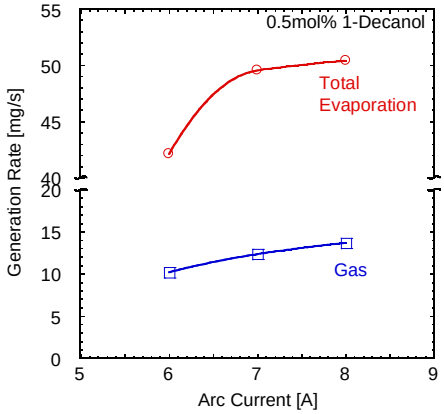

Fig. 4. Effect of arc current on total evaporation rate and gas generation rate.

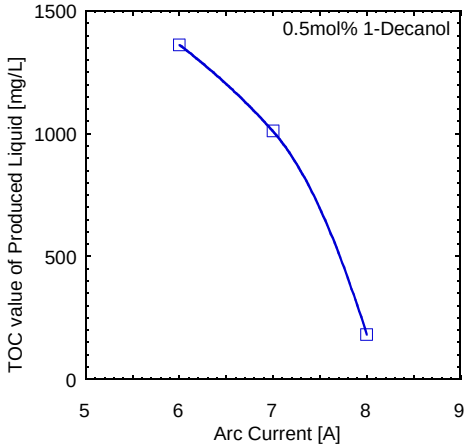

Fig. 5. Effect of arc current on TOC in the produced liquid.

3. Results and Discussion

Fig. 2 represented mass spectrum of the produced gas from the decomposition with the arc current of 6 A and 8 A. H_2, CO and CO_2 were detected, and it also indicates that there were no hydrocarbons composed of more than two carbon atoms in the produced gas. The intensities of each mass peak are similar though the different arc current was supplied.

The produced gas composition was analyzed in detail with GC measurements as shown in Fig. 3. Although CH_4 was detected in the case of 7 A, its concentration is negligible. The mole fraction of H_2 in the produced gas is more than 60%. As the current increases, the concentration of H_2 and CO_2 gradually increase while CO decreases. However, those changes are very small due to the different gas generation rate for arc current as shown Fig. 4. The generated O and OH radicals from H_2O in the water plasma are increased with the increase of the arc current. However, the current increase also leads to the enhancement of raw material evaporation, generating more carbon sources from 1-decanol at the same time. Consequentially, mole fractions of CO and CO_2 are not changed considerably, because of the contradiction phenomena.

The amount of carbon in the treated liquid is presented in Fig. 5. The TOC value decreased with increasing arc current. At 8 A, the TOC value decreased from 3.40×10^4 mg/L in raw material to 1.18×10^2 mg/L in treated liquid. Therefore, over 99.6% carbon in O/W emulsion was converted to CO, CO_2, and soot.

4. Conclusion

1-Decanol O/W emulsion was used as a model substance for treatment of water-insoluble organic compound. Carbon sources in the raw material are easily conversed to CO, CO_2 and soot, and carbon concentration in treated liquid is notably decreased.

References

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