An Analysis of the Decomposition of Sodium Dodecyl Sulphate Aqueous Solution by Atmospheric-pressure Non-equilibrium Microwave Discharge Plasma Treatment

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Abstract: An atmospheric-pressure non-equilibrium discharge plasma in Ar or Ar + H2 mixture gas was used to treat an SDS aqueous solution, and the absorbance was measured by a spectrophotometer. Our results showed that, over time, the peak value dependent on SDS decreased and the pH value changed so that the aqueous solution became more acidic. We found that the nitric acid content increased due to radicals, and this led to decomposition of the surfactant aqueous solution. The use decomposition of sodium dodecyl sulphate aqueous solution by atmospheric-pressure non-equilibrium microwave discharge plasma treatment is significant to improve efficient a liquid detergent.

Keywords: Atmospheric-nonequilibrium plasma, surfactant, pH value, Ar+H2 mixture gas, Microwave discharge.

1.Introdution

Today, typical households use many synthetic detergents, such as dish detergents and laundry detergents. These synthetic detergents contain large amounts of surfactants as the main ingredient for their cleansing action in removing dirt [1]. For example, in typical households, it is common to use a combination of laundry detergent and fabric softener that contains surfactants.

The anionic surfactants contained in laundry detergent and the cationic surfactants contained in fabric softener will bond together to form a state where their enhanced cleansing action and softening action cancel each other out, and the surfactants do not easily decompose in an aqueous solution. As a result, when surfactants are drained to waterways, they have not decomposed and can cause environmental damage and pollution to ecosystems, oceans, and waterways. Most surfactants are sources of water pollution in rivers, streams, lakes, oceans, and other bodies of water, and this water pollution adversely affects aquatic life and harms the environment [2].

Previously, the authors of this study conducted research where an atmospheric-pressure non-equilibrium plasma could be used to treat an organic matter aqueous solution containing pigments, and they were able to successfully control color changes of the pigments in the aqueous solution itself and the pH value within the aqueous solution by using the radicals (OH, O*, O_2, etc.) given off from the plasma [3].

In this study, an aqueous solution containing anionic surfactants was treated by an atmospheric-pressure non-equilibrium microwave discharge plasma jet using an $Ar+H_2$ mixture gas.

2. Experimental setup

Figure 1 shows a diagram of the experimental equipment. In the experiment, a glass petri dish containing sodium dodecyl sulfate (SDS; $CH_3(CH_2)11OSO_3Na$) aqueous solution (30mL) classified as an anionic active agent was placed at a position 5.0 mm from the nozzle of the atmospheric-pressure non-equilibrium microwave discharge plasma jet (ADTEC Plasma Tech. Co.). At the surface of the aqueous solution, plasma was emitted to test whether the surfactants were decomposed by the plasma treatment for the aqueous solution containing surfactants.

The atmospheric-pressure plasma was generated using a plasma jet torch electrode, and a steady discharge was maintained using a microwave power supply (2.45 GHz) for generating plasma. The plasma input power for generating the plasma was 100-150 W, and the plasma used an Ar gas or an Ar + H_2 mixture gas (10-20 L/min).

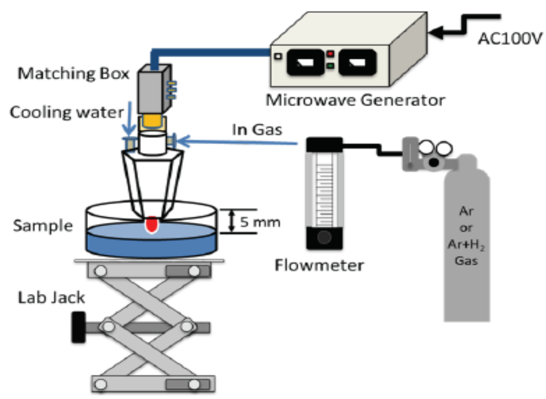

Fig. 1. Schematic diagram of the experimental setup.

The absorbance was measured. In the same way, a pH meter (HORIBA; pH / COND METER D-54) was used to measure the hydrogen ion concentration index in the aqueous solution after plasma treatment for confirming the change in the hydrogen ion concentration index. To find out the decomposition mechanism of the aqueous solution containing surfactants that was treated by plasma, the analysis method used the methylene blue absorptiometric method (JIS K 0102) with spectrophotometer (SHIMADZU; Multispec-1500).

3. Results

Figure 2 shows that the absorbance value decreased noticeably as the plasma treatment time increased. In the same way, when examining the plasma input power and plasma generated gas, increasing the input power and plasma generated gas flow rate resulted in a significant decrease in absorbance by the ionic associates due to the increased generation of radicals and their longer lifetimes. The oil component and hydrophilic group itself of the SDS aqueous solution are decomposed by the radicals that contribute to the generation of OH and H2 from the plasma due to the plasma treatment on SDS, which the associates are derived from.

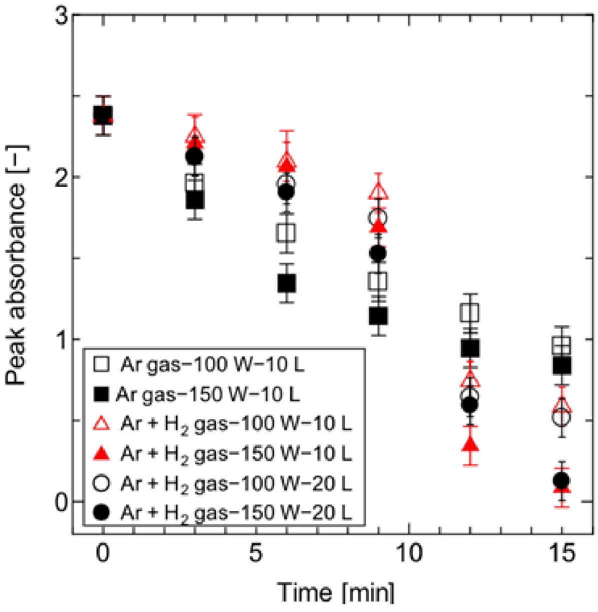

Fig. 2 Relationship between the maximum absorbance of plasma gas flow rate and plasma power and the plasma treatment time of the atmospheric-pressure non-equilibrium microwave discharge plasma jet.

And so, it is thought that the oil component and hydrophilic group itself of the SDS aqueous solution are decomposed by the radicals that contribute to the generation of OH and H2 [3-6] from the plasma due to the plasma treatment on SDS, which the associates are derived from.

Figure 3 shows the relationship with the pH value of aqueous solution containing surfactants for each plasma treatment time when an Ar gas or Ar+H2 mixture gas is used. When plasma treatment was performed on purified water using an Ar gas or Ar+H2 mixture gas, the pH value of the aqueous solution showed 3.0 to 4.0. This figure shows that, as the plasma treatment time increased, the pH value decreased, and the acidity became stronger. In the same way, this shows that, as the plasma input power and plasma gas flow rate increased, the pH value decreased, and the acidity became stronger. The primary reason for this is that the surfactants are decomposed by a chemical reaction with the aqueous solution due to OH radicals and H2 radicals generated from the Ar or Ar+H2 mixture gas.

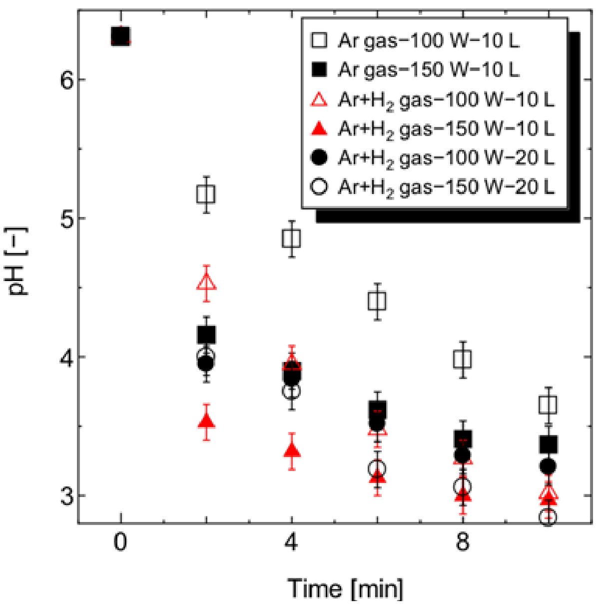

Fig. 3 Relationship between the pH value and plasma gas flow rate and plasma power and the plasma treatment time of the atmospheric-pressure non-equilibrium microwave discharge plasma jet.

The shift of the pH to a more acidic state is thought to be due to the generated OH radicals and H2 radicals reacting with nitrogen in the air for certain types of gases and radicals given off from the plasma so that a chemical reaction occurs between the hydrogen ions and nitrate ions in the aqueous solution to generate nitric acid. In the future, we plan to test atmospheric-pressure plasma treatments for developing an atmospheric-pressure plasma treatment technology for decomposition processes of aqueous solutions containing surfactants where cationic surfactants and anionic surfactants have bonded [7-9].

4. Conclusion

An atmospheric-pressure non-equilibrium discharge plasma in Ar or Ar + H2 mixture gas was used to treat an SDS aqueous solution, and the absorbance was measured by a spectrophotometer. Our results showed that, over time, the peak value dependent on SDS decreased and the pH value changed so that the aqueous solution became more acidic. We found that the nitric acid content increased due to radicals, and this led to decomposition of the surfactant aqueous solution. In the future, we plan to test atmospheric-pressure plasma treatments for developing an atmospheric-pressure plasma treatment technology for decomposition processes of aqueous solutions containing surfactants where cationic surfactants and anionic surfactants have bonded.

5. References

[1] E. Andrews, S. M. Larson, Environ. Sci. Technol., 27, 857 (1993).

[2] M. Soda, H. Okochi, H. Ogata and H. Okawa, BUNSEKI KAGAKU, 62, 589 (2013).

[3] T. Atsushi, Y. Ono, S. Fukui, S. Ikawa and K. Kitano, Applied physics letter, 100, 254103 (2012).

[4] B. Pateyron, M.-F. Elchinger, G. Delluc, and P. Fauchais, Plasma Chemistry and Plasma Processing, 12,421(1992).

[5] H. Kuwahata and T. Yamaguchi, e-J. Surf. Sci. Nanotech. 13, 474 (2015)

[6] T. Yuji, H. Kawano, S. Kanazawa, T. Ohkubo and H. Akatsuka, IEEE Transactions on Plasma Science, 36, 976 (2008).

[7] K. Tachibana and K. Yasuoka, International Journal of Plasma Environmental Science & Technology 8,117 (2014).

[8] A. A. Joshi, B. R. Locke, P. Arce, and W. C. Finney, Journal of Hazardous Materials, 41, 3 (1995).

[9] C. Douat, S. Hübner, R. Engeln and J. Benedikt, Plasma Sources Science and Technology, 25, 025027 (2016).