Surface tension of water with various kinds of salt under microwave radiation

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Abstract—Surface tension of any fluid is crucial for multiphase systems and is often manipulated during industrial processes by introducing surfactants. Normally, water used in an industry includes impurity such as salt. In this study, effect of salt kinds and concentrations on surface tension of water was investigated under microwave irradiation. It has found that surface tension decreased quickly, while temperature increased during microwave. Once the radiation is turned off, the temperature returns rapidly as expected. However, surface tension recovery was much slower than temperature. Moreover, the recovery and reduction amounts by non-thermal effect depend on salt kinds and concentrations.

Keywords-component; Microwave; surface tension; non-thermal effect

I. INTRODUCTION

Application of microwave irradiation for chemical processes, such as emulsification and polymerization, has been reported [1,2]. Surfactant free emulsion can be produced with the help of microwave irradiation. Surface tension is an important property for the industrial process such as foaming/defoaming, wetting/dewetting and flotation. Similarly, the interfacial tension plays crucial role in separation and mixing process of two immiscible liquids, which are important unit operations of the fundamental chemical engineering. In practice, surface and interfacial tensions are often altered by introducing surfactants.

In our previous research [3], specific property for surface tension of water droplet under microwave radiation was found. For example, lower surface tension after the radiation was measured. The formation of nano-bubble will explain this behavior. However, the exact mechanism is not clear. This study investigates the influence of microwave on surface tension of water with different kinds of salt.

II. EXPERIMENTAL

Figure 1 is the schematic diagram of the microwave reactor (designed and build by Shikoku Instrumentation Co., Inc.) from side view and top view respectively. Pendant method was employed for the measurement of surface tension of water. Since metal is not microwave friendly, Teflon pipe with the dimension of 1 mm inside and 2 mm outside diameter (and 1.4 cm long) was chosen for the experiments. Droplet with salt was produced via injection syringe with exactly 20 micro liter of distilled water. Temperature was measured with the help of Temperature measurement equipment, designed by Anritsu meter Co., LTD (device model: FL-2000 Optical fiber: FS100-M), which was inserted from the top of the reactor to check the temperature inside the droplet during microwave irradiation. Two types of experiment for different concentrations and kinds are conducted and the experimental condition of salt is listed in Table 1.

Care was taken while inserting the temperature probe inside the droplet to ensure uniform shape of the droplet for all experiments. Light source was used from one end of the microwave reactor and high speed camera (Sigma Koki Co., LTD Model SK-TC202USB-AT) was employed from the other end to capture the shape of the droplet. Experiments analysis was divided in three parts.

1. Initial capturing of the image before microwave irradiation to measure initial surface tension of the water droplet with salt.
2. Capturing of the images during microwave irradiation. 600 w was used as microwave power. The microwave was turned off at 120 seconds for all experiments.
3. Capturing of the images after microwave irradiation for 180 sec.

Axisymmetric drop shape analysis (ADSA) in Fig. 2 was employed to measure initial surface tension of the droplet and droplet images captured during and after microwave irradiation [4,5].
Table 1 Experimental conditions

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III. RESULTS AND DISCUSSIONS

A. Effect of salt concentration

Figure 3 is surface tension of water droplet of NaCl solution as a function of time and temperature. Surface tension of water droplet with different concentration of NaCl was plotted. During the microwave radiation, the temperature increased at expected. The surface tension decreased significantly as well [6,7]. The changes are proportional to NaCl concentration. Once the microwave is turned off (at 120 s), the temperature dropped quickly to the room temperature, whereas the surface tension did not recover so much. When NaCl concentration is higher, surface tension can retain at the lowest value after the radiation.

B. Effect of salt kinds

Figure 4 is surface tension of droplet with different salts as a function of time and temperature. Surface tension of water droplet with different salt was plotted. When microwave is turned off, surface tension can retain the lowest value. The reduction amount depends on salt kinds. The results indicated that the surface tension reduction is not due to thermal effect solely. The data after microwave radiation clearly demonstrated the non-thermal behavior of surface tension. However, it can not be explained by properties such as ion strength, size and electrical charge.
The data clearly indicated a non-thermal effect of microwave of surface tension of water. It should be noted that the reduction of surface tension occurs in case of higher concentration of salts. It’s also noteworthy that microwave can only penetrate 1.4 cm deep into water and surface water should be influenced strongly by microwave. Accordingly, it can be explained by the formation of nano-bubbles inside the water droplet due to homogeneous heating [8-10]. Nano-bubble is normally produced by high shear flow, ultrasonic because
network of water molecule is organized at molecular level. It is similarly caused by microwave because water molecule is strongly rotated as well. These nano-bubbles are negatively charged and metal ion is adsorbed on the surface of nano-bubble. Consequently, nano-bubble is more stable and the surface tension after the radiation remains the lower value for longer time. Moreover, water, which include metal ion, absorbs microwave easily because of the higher electric constant. Microwave effect becomes larger in the case of electrolyte aqueous solution.

**CONCLUSIONS**

The surface tension and temperature of water droplet with different salt was measured directly under microwave irradiation. It has found that surface tension decreased quickly during microwave. However, surface tension recovery was much slower than temperature after radiation is off. For the highest concentration of NaCl, the surface tension remains at lower values. It’s conclusive that the surface tension reduction is not due to thermal heating and water with different salts shows different thermal effect. The results shown that retains some “memory” after microwave, which is might be caused by nano-bubble with negative charge. Moreover, water with salt was changed structurally at molecular level during the microwave and cation will be adsorbed on the surface of nano-bubble. Accordingly, this ‘impurity effect’ becomes more stable and the surface tension can keep lower values for longer time. This presents a better physical method to manipulate the interface layer of water.

**REFERENCES**


