Effect of Ultrasonic Irradiation on Heterogeneous Photocatalytic Reaction System

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1. Introduction

A system combining photocatalysis and sonolysis, named a sonophotocatalysis system, was performed. Several laboratories have reported influences of ultrasonic irradiation on heterogeneous photocatalytic reaction systems. For example, by the combined effects of sonolysis and photocatalysis in the presence of TiO_2, water has been decomposed into O_2 and H_2 continuously and stoichiometrically [1]. Generation of O_2 from water is thought to be important. It has been also reported that reduction of CO_2 and generation of O_2 were achieved by the simultaneous irradiation of light and ultrasound in the presence of TiO_2 photocatalyst [2].

In this presentation, sonophotocatalysis of $NaHCO_3$ solution was examined in order to construct the artificial carbon cycle system. Furthermore, the acceleration of the rate of photocatalytic reaction and the change of products distribution were discussed.

2. Experimental

As the powdered photocatalyst, TiO_2 (Rutile, Soekawa Chemicals) was used. The Pyrex glass reactor (250 ～ 350 ml) containing the reactant solution was irradiated from one side with a 500-W Xenon lamp (Ushio) and from the bottom surface with a 200-W ultrasonic generator (Kaijoh, 200 kHz.). The reactor was sat up in a temperature-controlled water bath made by a Pyrex glass at 25℃. Before irradiation, the reactor was filled with argon gas of atmospheric pressure. The amounts of gaseous reaction products were analyzed by gas chromatography. Hydrogen peroxide in the solution was analyzed by colorimetry (JASCO V-530, 407 nm) using a titanium sulfate solution (Nacalai Tesque).

3. Sonophotocatalysis

3-1. Sodium hydrogen carbonate solution

Sonophotocatalysis of $NaHCO_3$ solution was carried out. This is a useful material for playing an important role in the carbon cycle process because CO_2 can be evolved easily from a $NaHCO_3$ solution. Thus, $NaHCO_3$ is considered to be CO_2 in the solid state, and this material could be easily transported from CO_2 sources to the reactor.

As shown in Fig. 1, CO_2, CO, H_2, and O_2 were obtained. CO_2 evolved from $NaHCO_3$ solution by a thermal reaction. The yield of CO_2 increased with the increasing of the concentration of $NaHCO_3$. CO was obtained from the CO_2 by sonolysis. H_2 and O_2 were produced from H_2O (solvent) by sonophotocatalysis.

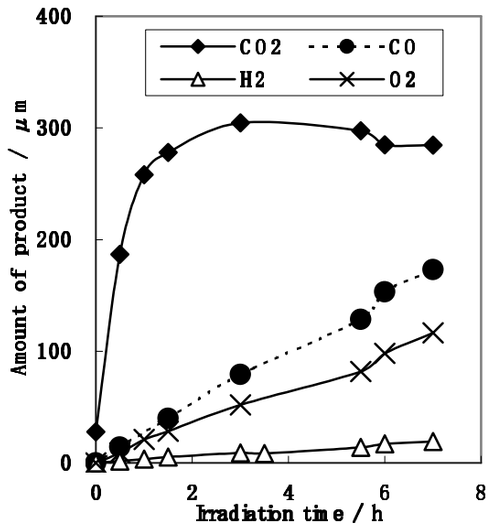

Fig. 1 Sonophotocatalysis of $NaHCO_3$ solution. Reactant: 0.5 M solution 50 ml; sonication: 200 kHz, 200 W; photocatalysis: TiO_2 (Soekawa, Rutile, 200 mg), 500 W-Xe lamp; atmosphere: Ar, temperature: 25 ℃.

3-2. Oxalic acid solution

It was known that the rate of heterogeneous photocatalytic reaction was accelerated by ultrasonic irradiation [3]. Fig. 2 shows effect of sonication on yield of products. Decarboxylation was accelerated by ultrasonic irradiation. Different product distribution was also observed. Hydrogen and carbon dioxide were evolved in all cases. Carbon monoxide, however, could not be detected in the case of photocatalysis.

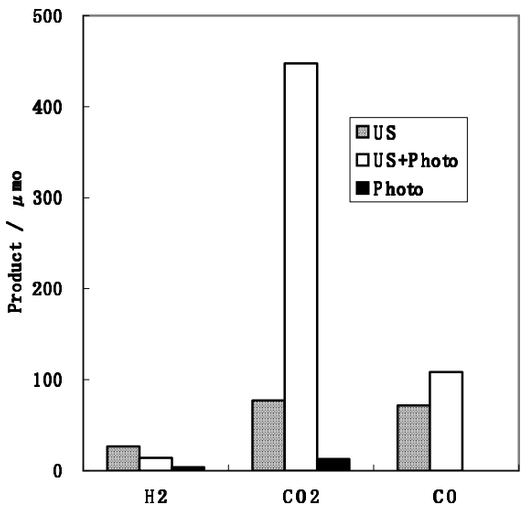

Fig. 2 Reaction products from oxalic acid solution. Irradiation time: 2 hours. Reactant: 0.8 M solution 50 ml; sonication: 200 kHz, 200 W; photocatalysis: TiO_2 (Soekawa, Rutile, 200 mg), 500 W-Xe lamp; atmosphere: Ar, temperature: 25 ℃.

References

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[3] Y. Kado, M. Atobe, and T. Nonaka, *Ultrasonics Sonochem.*, **8**, 69 (2001) and *Electrochemistry (Denki Kagaku)* **66**, 760 (1998).