# Reduction of $CO_2$ with water over $Ag/Ga_2O_3$ photocatalysts prepared by solution plasma method

Tomoko Yoshida[1], Naoto Yamamoto[2], Tsuyoshi Mizutani[2], Muneaki Yamamoto[2], Satoshi Ogawa[2], Shinya Yagi[2], Hirofumi Nameki[3] and Hisao Yoshida[4]

[1] *Osaka City University Osaka, Japan*
[2] *Nagoya University, Nagoya, Japan*
[3] *Aichi Center for Industry and Science Technology, Kariya, Japan*
[4] *Kyoto University Kyoto, Japan*
...
*E-mail: tyoshida@ocarina.osaka-cu.ac.jp

The photocatalytic reduction of $CO_2$ with water is one of the challenging reactions. Recently, we found that the photocatalytic reduction of $CO_2$ with water proceeded over a bare $Ga_2O_3$ and the activity increased by loading Ag nanoparticles on $Ga_2O_3$ ($Ag/Ga_2O_3$) [1]. The photocatalytic activity is likely to correlate with the chemical states and/or the size of the Ag nanoparticles which depend on the preparing method of the photocatalysts.

In this study, we prepare $Ag/Ga_2O_3$ photocatalysts by using solution plasma method (SPM). The SPM is a new preparing method of metal nanoparticles without any dispersants in an aqueous solution with electrolytes [2]. These metal nanoparticles are synthesized by glow discharge between metal rods in an aqueous solution. The SPM has an advantage of controlling the size of the metal nanoparticles with clean surface by changing the amount of electrolytes. The synthesized Ag NPs were loaded on gallium oxide ($Ga_2O_3$) photocatalyst by filtering the solution with $Ga_2O_3$ powder, and the photocatalytic activities of the obtained $Ag/Ga_2O_3$ samples were evaluated.

The photocatalytic reduction of $CO_2$ with water proceeded over all the $Ag/Ga_2O_3$ photocatalysts to produce CO, $H_2$ and $O_2$. Fig. 1 shows time courses of the CO production rates in the photocatalytic reduction of $CO_2$ with water over the 0.06 wt% $Ag/Ga_2O_3$ samples prepared in the present method and in the conventional impregnation method (IMP). As shown in Fig. 1a, in the initial reaction stage after 1 h, the CO production rate was 2.6 μmol/h for the $Ag/Ga_2O_3$ sample prepared by SPM. However, it decreased to 1.7 μmol/h after the reaction for 5 h. Over the $Ag/Ga_2O_3$(IMP) sample with the same loading amount of 0.06 wt%, the CO production rates were 2.0 and 1.6 μmol/h after the reaction for 1 h and 5 h, respectively (Fig. 1b). It was revealed that the present 0.06 wt% $Ag/Ga_2O_3$ sample prepared by SPM could promote CO production than the corresponding 0.06 wt% $Ag/Ga_2O_3$(IMP) sample at least initially. However, the problem is that they exhibited the pronounced tendency to reduce their photocatalytic activities during the photocatalytic reaction and this tendency was significant for the present sample.

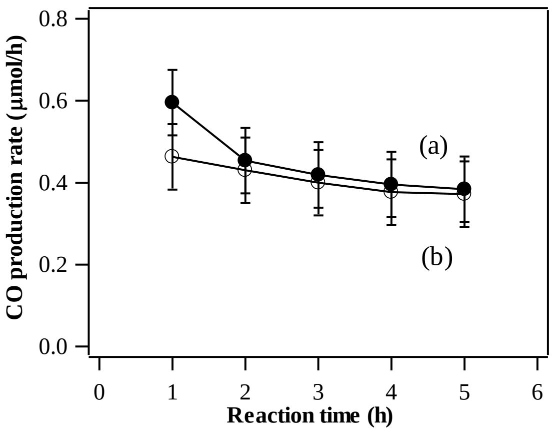


Fig.1 Time dependences of CO production rate for the $Ag/Ga_2O_3$ samples prepared by SPM (a) and an impregnation method (b).

Measurements of XANES spectra and TEM images of the $Ag/Ga_2O_3$(SMP) revealed that a part of the Ag nanoparticles migrated and aggregated on the photocatalyst surface to become larger particles with the size of ca. 20 nm during the photocatalytic reaction, which would cause the decrease of the photocatalytic activity.

## REFERENCES

[1] M. Yamamoto, T. Yoshida, N. Yamamoto, T. Nomoto, Y. Yamamoto, S. Yagi and H. Yoshida, J. Mater. Chem. A, 3 (2015) 16810-16816.
[2] O. Takai, Pure Appl. chem. 80 (2008) 2003-2011.