–Communication–

Photocatalytic Bactericidal Effect of Powdered TiO_2 on *Streptococcus Mutans*

Kinji ONODA*, Junichi WATANABE, Yoshinori NAKAGAWA and Ikuichiro IZUMI†

Received August 9, 1988 ; Accepted October 24, 1988

1. INTRODUCTION

The semiconductor photocatalytic reaction has been studied vigorously in many fields such as a water decomposition for hydrogen generation[1], the reduction of nitrogen or carbon dioxide[2,3], the photo-Kolbe reaction[4-6], various organic syntheses[7,8] and the bactericidal action[9].
One of the authors has also found out the antibacterial effect[10] of powdered semiconductor on *Streptococcus mutans* (Fig.1) by which dental caries seems to be caused. In this paper, we have reported the antibacterial and bactericidal action from the photocatalytic point of view.

2. EXPERIMENTAL

Experiments were made with the commercially available three kinds of TiO_2 powders which are TP-3 (Fuji Titanium Industry Co.,Ltd., 1.44 μm average particle size, rutile type), TP-2 (Fuji Titanium Industry Co.,Ltd., 1.48 μm average particle size, anatase type) and P-25 (Nippon Aerosil Co.,Ltd., 0.021 μm average particle size, fine-grain particles composed of 70% anatase and 30% rutile).
S. mutans FA-1 was cultured anaerobically in BHI broth (Difco Lab., Detroit, Mich.) at 37°C for about 24hours. A definite amount of culture was diluted with the physiological salt solution and directed to the photocatalytic experiment.
For photocatalytic bactericidal effect on *S. mutans*, the glass vessel with bacterial solution was set 5cm apart from the light source and irradiated with two types of fluorescent lamps (FL20S・BL and FL20SS・W-F/18, Toshiba Corporation). The viable cell count was measured by counting the colony with the pour plate method using BHI agar medium.

3. RESULTS AND DISCUSSION

Figure 2 and 3 show the decreasing behaviour of viable cell count under irradiation with the fluorescent lamp with the maximum spectra in near ultraviolet or visible region. It is emphasized in these results that the irradiated TiO_2 powder has the bactericidal effect on *S. mutans* and also this effect is more prominent in near ultraviolet radiation than in visible radiation. The time required for bactericidal effect is dependent on the kind of TiO_2 powder, as shown in these figures.

Shiken Company (2−5−6, Terada−cho, Tennoji−ku, Osaka 543)
† Department of Chemical Engineering, Nara National College of Technology (22, Yata−cho, Yamatokoriyama 639−11)
Key Words : Photocatalysis, Bactericidal Effect, Streptococcus mutans, TiO_2 powder

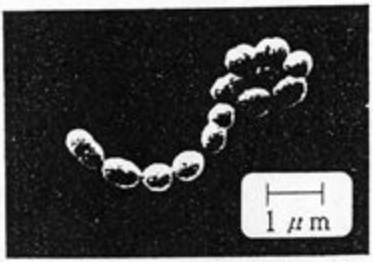

Fig. 1 SEM photograph of *S. mutans* FA−1

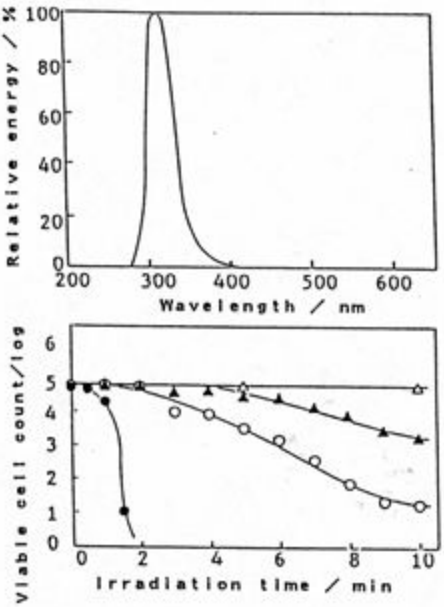

Fig. 2 Photocatalytic bactericidal effect on *S. mutans* under irradiation with FL20S-BL (output 20W) and its spectral distribution

● : 0.1wt.% of P-25 TiO_2 powders ○ : 0.1wt.% of TP-2 TiO_2 powders
▲ : 0.1wt.% of TP-3 TiO_2 powders △ : control (without TiO_2 powders)

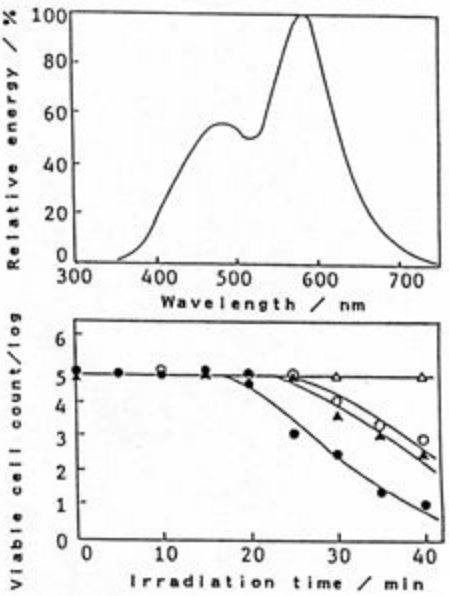

Fig. 3 Photocatalytic bactericidal effect on *S. mutans* under irradiation with FL20SS-W-F/18 (output 18W) and its spectral distribution

● : 0.1wt.% of P-25 TiO_2 powders ○ : 0.1wt.% of TP-2 TiO_2 powders
▲ : 0.1wt.% of TP-3 TiO_2 powders △ : control (without TiO_2 powders)

By a control experiment, it can be revealed that there is no bactericidal effect of TiO_2 in the dark. The superiority of fine-grain TiO_2 in a photocatalytic effect shown in Fig. 2 and 3 will be expected by the theory of fine-grain effect reported by Kawai et.al.[11] in a semiconductor photocatalytic reaction. While, the superiority of anatase TiO_2 compared with rutile TiO_2 in a photo-catalytic bactericidal effect can be attributed to their different band gap energy; 3.2eV and 3.0eV[12] for anatase and rutile TiO_2, respectively. Hence, the bactericidal effect of anatase TiO_2 can be improved by the photo-excited charge carriers of higher energy.

Furthermore, we get a curious and unaccountable phenomenum in which bactericidal effect on *S. mutans* is dependent on the amount of fine-grain P-25 with the optimum condition at the range between 0.01 and 0.1wt.% , as shown in Fig.4.

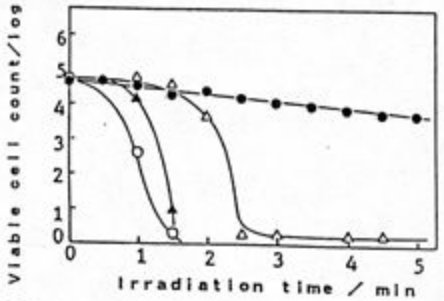

Fig. 4 Dependence of the photocatalytic bactericidal effect on the amount of P-25 TiO_2 powders

● : 0.001wt.% ○ : 0.01wt.%
▲ : 0.1wt.% △ : 1wt.%

REFERENCES
1) T. Sakata, T. Kawai, Hyomen, 17, 618 (1979)
2) J. C. Hemminger, R. Corr, G. A. Somorjoi, Chem. Phys. Let., 57, 100 (1978)
3) G. N. Schrauzer, T. D. Guth, J. Am. Chem. Soc., 99, 7189 (1977)
4) B. Kraeutler, A. J. Bard, J. Am. Chem. Soc., 100, 5985 (1978)
5) I. Izumi, W. W. Dunn, K. O. Wilbourn, F. F. Fan, A. J. Bard, J. Phys. Chem. 84, 3207 (1980)
6) I. Izumi, F. F. Fan, A. J. Bard, J. Phys. Chem., 85, 218 (1981)
7) T. Sakata, Denki Kagaku, 53, 15 (1985)
8) M. A. Fox, Acc. Chem. Res., 16, 314 (1983)
9) T. Matsunaga, J. Antibact. Antifung. Agent, 13, 211 (1985)
10) T. Saito, Y. Nara, T. Morioka, K. Onoda, J. Dent. Hlth. 35, 490 (1986)
11) T. Kawai, S. Kawai, Denki Kagaku, 53, 3 (1985)
12) C. D. Jaeger, A. J. Bard, J. Phys. Chem., 83, 3146 (1979)