Enhanced Photocatalytic Activity of ZnO-rGO Nanocomposites in Degradation of Gaseous Acetaldehyde

Yu-Chih Chen[1], Ken-ichi Katsumata[2¥] and Yung-Jung Hsu[1]*

*E-mail: yhsu@cc.nctu.edu.tw
¥E-mail: katsumata.k.ab@m.titech.ac.jp

1. Department of Materials Science and Engineering, National Chiao Tung University
1001 University Road, Hsinchu, Taiwan 30010, Republic of China

2. Materials and Structures Laboratory, Tokyo Institute of Technology
4259 Nagatsuta, Midori, Yokohama, Kanagawa 226-8503, Japan

Development of semiconductor photocatalysts, which can be used in the eliminations of aqueous and gaseous pollutants, is a good approach to solve the ever-rising environmental pollution problems [1]. The basic concept of photocatalysis using semiconductor involves the generation of charge carriers within semiconductors upon light irradiation, followed by the utilization of these carriers to carry out chemical reactions. Recently, many studies concerning photocatalysis have proposed the combination of semiconductors with graphene nanosheets which have high conductivity, superior electron mobility, extremely high specific surface area, and relatively low production cost [2-4]. For semiconductor/graphene nanocomposites, graphene can serve as an efficient electron scavenger for semiconductor. The photoexcited free electrons of semiconductor would thus preferentially transfer to the grapehene domain, leading to the effective separation of charge carriers and the improvement of the subsequent photocatalysis [5].

Till now, most of the studies about semiconductor/graphene nanocomposites are focused on liquid-phase photocatalysis, and their performance in gaseous photodegradation is rarely reported. We believe that this composite can show high photocatalytic efficiency in gas-phase photodegradation since grephene has high specific surface area which may promote the adsorption of gaseous molecules. In this work, we investigated the photocatalytic activity of ZnO/graphene nanocomposites in the degradation of gaseous CH_3CHO. The samples were prepared by depositing single-crystalline ZnO nanoparticles on the surface of reduce graphene oxide (rGO) nanosheets in the hydrothermal reaction. Graphene oxide (GO) was first synthesized using the typical Hummers method [6]. During the hydrothermal process, reduction of GO was accompanied with the deposition of ZnO nanoparticles, resulting in the formation of ZnO-rGO nanocomposites. By modulating the amount of GO employed in the hydrothermal reaction, the density of ZnO deposited on RGO surface can be readily controlled. Because of the difference in band structure between ZnO and rGO, the rGO nanosheets can serve as an electron acceptor for ZnO nanoparticles, which resulted in effective charge separation upon light irradiation. The charge carrier separation of ZnO-rGO nanocomposites was revealed by their superior photocatalytic performance in degradation of gaseous CH_3CHO.

Figures 1(a) and (b) show the TEM and HRTEM images for the as-obtained ZnO-rGO nanocomposites. The deposited ZnO nanoparticles were single crystalline and had a diameter of 50-100 nm. The photocatalytic performance of ZnO-rGO nanocomposites with different rGO contents were then compared through the photodegradation of gaseous CH_3CHO. Figure 1 (c) shows the result of CH_3CHO degradation, whereas Figure 1 (d) displays the comparison of CO_2 generation. Note that the ZnO-rGO samples were denoted as ZG-X, where X represents the weight percentage of rGO. Evidently, there is an optimal rGO content for improving the photocatalytic activity of ZnO nanoparticles. Besides, it is interesting to note that ZG1 had the highest photocatalytic efficiency toward CH_3CHO degradation, while ZG3 showed better performance in CO_2 generation. This result indicated that rGO content may have determined the degradation kinetics of CH_3CHO. The demonstration from this study may pave the way for the advancement of semiconductor/graphene nanocomposites, especially their gas-phase photocatalysis.

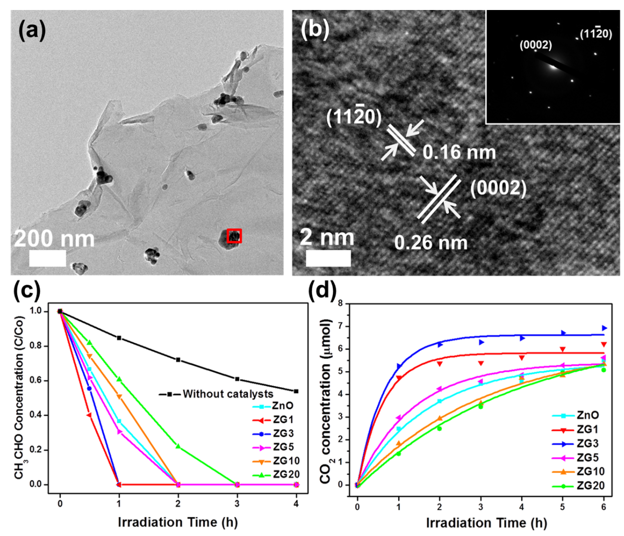

Figure 1. (a) Typical TEM and (b) HRTEM images of ZnO-rGO (ZG3). Photocatalysis results under UV illumination by using various samples: (c) CH_3CHO degradation, (d) CO_2 generation.

References

1. S. Malato; P. Fernández-Ibáñez; M. I. Maldonado; J. Blanco; W. Gernjak *Catal. Today*, **147**, 1 (2009).
2. A. Cao; Z. Liu; S. Chu; M. Wu; Z. Ye, Z. Cai, Y. Chang; S. Wang; Q. Gong; Y. Liu *Adv. Mater.* **22**, 103 (2010).
3. Y. H. Ng; A. Iwase; A. Kudo; R. Amal *J. Phys. Chem. Lett.* **1**, 2607 (2010).
4. X. Pan; Y. Zhao; S. Liu; C. L. Korzeniewski; S. Wang; Z. Fan *ACS Appl. Mater. Interfaces* **4**, 3944 (2012).
5. Q. Xiang; J. Yu; M. Jaroniec *Chem. Soc. Rev*. **41**, 782 (2012).
6. W.S. Hummers; Jr. R. E. Offeman *J. Am. Chem. Soc.* **80**, 1339 (1958).