

Title	Effect of Silica on Spherulite Structure and Photo-oxidative Degradation Behavior in Polypropylene/Silica Nanocomposites
Author(s)	Asuka, Kazuo; Sumino, Ken-ichi; Taniike, Toshiaki; Nitta, Koh-hei; Terano, Minoru
Citation	Journal of Materials Life Society, 19(3): 128-131
Issue Date	2007-07
Type	Journal Article
Text version	publisher
URL	<a href="http://hdl.handle.net/10119/7931">http://hdl.handle.net/10119/7931</a>
Rights	Copyright (C) 2007 マテリアルライフ学会. Kazuo Asuka, Ken-ichi Sumino, Toshiaki Taniike, Koh-hei Nitta, Minoru Terano, Journal of Materials Life Society, 19(3), 2007, 128-131.
Description	

# Effect of Silica on Spherulite Structure and Photo-oxidative Degradation Behavior in Polypropylene/Silica Nanocomposites

Kazuo ASUKA<sup>※\*1</sup>, Ken-ichi SUMINO<sup>\*1</sup>, Toshiaki TANIKE<sup>\*1</sup>  
Koh-hei NITTA<sup>\*2</sup>, Minoru TERANO<sup>\*1</sup>

(Received December 21, 2006, Accepted January 12, 2007)

## Abstract

The physico-chemical interaction between hydrophobic polyolefin materials and originally hydrophilic inorganic nano-particles like surface hydroxylated SiO<sub>2</sub> has not been well understood up to now. In this study, the influences of particle size, content of hydrophilic SiO<sub>2</sub> nanoparticles on the isothermal growth rate of polypropylene (PP) spherulites in various PP/SiO<sub>2</sub> nanocomposites were investigated by polarized optical microscope equipped with temperature controlled hot stage. Moreover, photo-oxidative degradation behavior of the PP/SiO<sub>2</sub> nanocomposites were investigated. It is most interesting to note that the addition of smaller SiO<sub>2</sub> nanoparticles effectively lowered the growth rate of PP spherulites in the composites and the spherulite growth rate became zero for the PP/16nm-SiO<sub>2</sub> nanocomposites with the SiO<sub>2</sub> content above 2.5 wt%. It was found that the sample without spherulite morphology is more stable to photo-degradation. Spherulite structure is considered to have the influence affect photo-oxidative degradation.

Keywords : Polypropylene/silica nanocomposite, Photo-degradation, Spherulite

## 1. Introduction

Nowadays, the development of various polymer-based nanocomposites with new properties has become one of the key research targets in the field of polymer materials from both academic and industrial points of view. It is quite important to develop high performance polymer-based materials with various outstanding properties. One of the most popular procedures of synthesizing polymer-based nanocomposites is to disperse various nano-sized inorganic particles into polymer matrix by melt mixing. Although a great number of polymer-based nanocomposites have been successfully synthesized up to now<sup>1)~3)</sup>, a deep mechanistic

understanding of physico-chemical interactions between inorganic nano-particles and polymer matrix has been far from being achieved. It has been reported that the mechanical and thermal properties<sup>4)~13)</sup> as well as many other performances<sup>14), 15)</sup> could be significantly improved for polyolefin-based nanocomposites compared with the original polyolefins.

Environmental durability is a key feature for polyolefin-based nanocomposites in their processing and usage due to their degradation. There are many factors influencing the degradation of polyolefin materials, such as photo-irradiation, thermo-degradation, oxidation etc., and their combinations. Within the various factors, the photo- and thermal-oxidation plays an important role. Thus, the study on photo- and thermal-oxidative degradation of polyolefin materials is always attracting attention in the field of polymer degradation and stability.

In this work, correlation of the spherulite structure and photo-oxidative behavior in terms of the size, content of silica particles were investigated.

※ Corresponding author

\*1 School of Material Science Japan Advanced Institute of Science and Technology  
(1-1 Asahidai, Nomi, Ishikawa, 923-1292 Japan)

\*2 Department of Chemical Engineering Kanazawa University  
(Kakuma, Kanazawa, Ishikawa, 920-1192 Japan)

## 2. Experimental

### 2.1 Materials

Isotactic PP pellets with an isotacticity index (I.I.) of 98% were donated from Japan Polypropylene Corp.. Weight average molecular weight ( $\bar{M}_w$ ) and molecular weight distribution ( $\bar{M}_w/\bar{M}_n$ ) are  $26 \times 10^3$  and 5.6, respectively. AEROSIL@ 200 SiO<sub>2</sub> with an average particle size of 16 nm and surface area of 200m<sup>2</sup>/g was donated from Aerosil Japan Co.. NanoTek@ SiO<sub>2</sub> with an average particle size of 26 nm and surface area of 110 m<sup>2</sup>/g was purchased from Kanto Chemical Co..

### 2.2 Preparation of PP/SiO<sub>2</sub> nanocomposites

Composites were prepared by melt mixing SiO<sub>2</sub> particles with different diameters of 16nm, 26nm and 100nm respectively. Melt mixing was performed in twin-roller. The PP pellets were kneaded by mixing rollers at 180 °C for 5 min and then a given amount of SiO<sub>2</sub> was added into the kneaded PP. The mixture was kneaded at 180 °C for another 10min. Then, the obtained mixture was pressed into a flat sheet at 230 °C under a pressure of 100kg/cm<sup>2</sup> for 5 min using a compression-molding machine. Two kinds of PP/SiO<sub>2</sub> nanocomposites were prepared at the different cooling conditions ; (a) quenched at 100 °C (spherulites sample), (b) quenched at 0 °C then annealed at 100 °C for 24h under N<sub>2</sub> atmosphere (non-spherulites sample). The content of SiO<sub>2</sub> in the PP/SiO<sub>2</sub> composites was changed from 0 wt% to 5.0wt%.

### 2.3 Spherulite growth behavior of PP/SiO<sub>2</sub> nanocomposites

The polarizing optical microscope (OLYMPUS, B201) equipped with a Mettler FP82HT hot stage was used to examine the isothermal crystallization processes of neat iPP and the composites. An optical polarizing microscope was used. The hot stage was held at a steady temperature to  $\pm 0.2$  K by a proportional controller. A thin sample piece were sandwiched between a microscope slide and a cover glass, heated to 503K and kept for 10 min to melt completely the crystallites. Then the samples were rapidly quenched to a given crystallization temperature and allowed to crystallize isothermally. The radius of a spherulite was measured as a function of time under the isothermal

crystallization condition at the temperatures of 339, 403, and 407K.

### 2.4 Photo-degradation of PP/SiO<sub>2</sub> nanocomposites

Photo-degradation experiments were conducted in the weather meter at 35 °C using four 550W xenon lamps. The oxidative degradation behavior was measured by FT-IR. Carbonyl growth in the region 1500-1800cm<sup>-1</sup> region of the FT-IR spectrum is determined by using carbonyl absorbance defined as follow (see Fig.1).

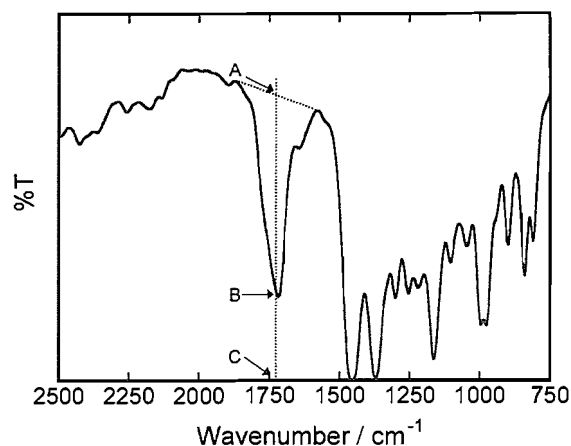


Fig.1 Typical FT-IR spectrum of oxidized PP film.

## 3. Results and discussion

Linear spherulite growth rate for all PP/SiO<sub>2</sub> nanocomposites and neat PP was evaluated by measuring spherulite radius as a function of time. An example of the measurement of growth rate in radial direction is shown in Fig.2, which makes the time when the growth started as the starting point of the time axis. It was possible to reliably determine the growth rates of all the samples because of the linear relationship between the radius of spherulites and crystallization time.

Growth rates measured isothermally at 403K is plotted against the content of SiO<sub>2</sub> particles in Fig.3. The spherulite growth rates of PP spherulites decreased significantly with increasing the SiO<sub>2</sub> content. It is interesting to note that the addition of smaller SiO<sub>2</sub> particles effectively lowered the growth rate of PP spherulite in the composites and the spherulite growth rate became zero for the PP/16nm-SiO<sub>2</sub> nanocomposites with the SiO<sub>2</sub> content above 2.5wt%.

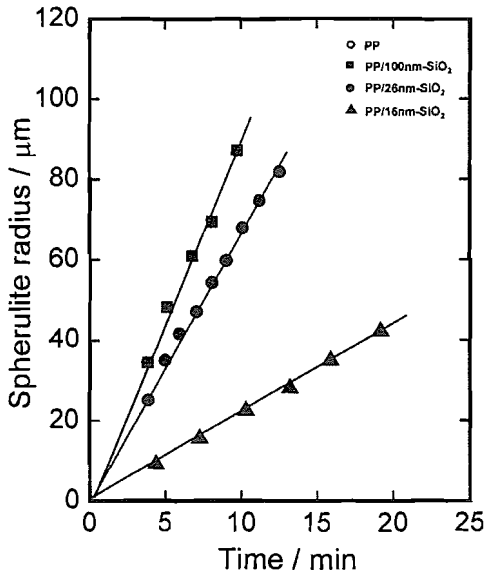


Fig.2 The spherulite radius plotted against the crystallization time for various PP/SiO<sub>2</sub> nanocomposites (SiO<sub>2</sub> content : 0.6 wt%).

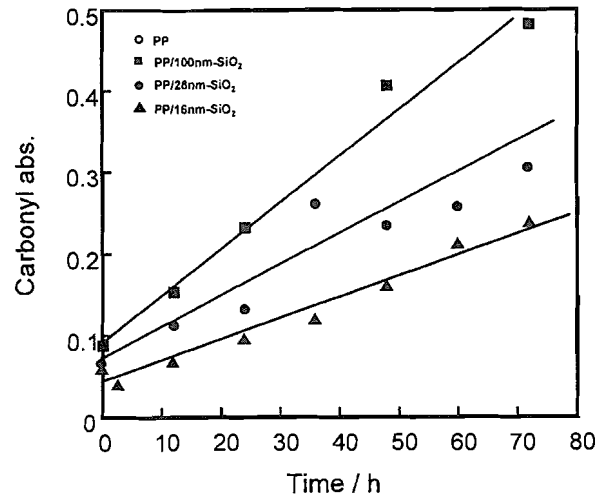


Fig.4 Carbonyl adsorption versus degradation time for PP and various PP/SiO<sub>2</sub> nanocomposites (SiO<sub>2</sub> content : 5 wt%).

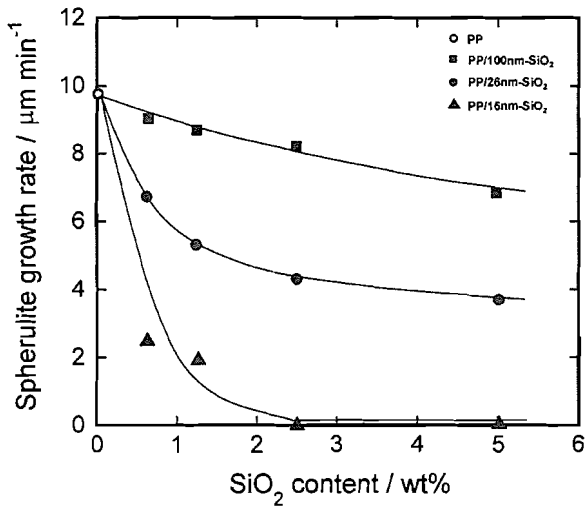


Fig.3 Effect of the SiO<sub>2</sub> content on the spherulite growth rates isothermally measured at 403K.

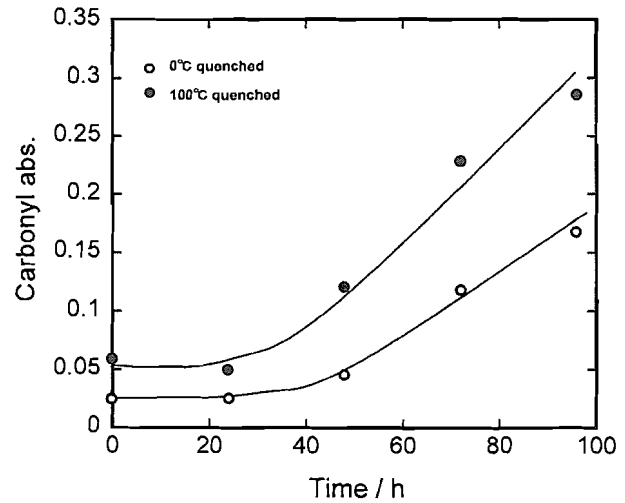


Fig.5 Carbonyl absorbance versus degradation time for various PPs.

Consequently, the PP/16nm-SiO<sub>2</sub> nanocomposite films has non-spherulite morphology.

Fig.4 shows the carbonyl index plotted against the photo-degradation time in the weather meter. The carbonyl index increases with increasing the SiO<sub>2</sub> particlesize. The addition of smaller SiO<sub>2</sub> particles effectively improved the degradation stability. The existence of spherulites morphology may have the important role for the phenomena. In addition, influence on photo-degradation for a sample with spherulite morphology and a sample without spherulite morphology was investigated. Fig.5 shows the carbonyl

absorbance plotted against the photo-degradation time in the weather meter. It was found that the sample without spherulite morphology is more stable to photo-degradation. It seems that since the interface of spherulites did not exist and diffusion of oxygen was restricted, photo-degradation stability became high.

#### 4. Conclusions

It was found that the addition of smaller SiO<sub>2</sub> particles effectively lowered the growth rate of PP spherulite in the

composites and the spherulite growth rate became zero for the PP/16nm-SiO<sub>2</sub> nanocomposites with the SiO<sub>2</sub> content above 2.5wt%. Moreover, it was found that the sample without spherulite morphology is more stable to photo-degradation. Spherulite structure is considered to have the influence on photo-oxidative degradation. This result indicates the real possibility to develop highly stable PP materials, which have been eagerly requested from various application areas.

## References

- 1) Thompson, R. B., Ginzburg, V. V., Matsen, M. W., Balazs, A. C. : *Science*, **292**, 2469 (2001)
- 2) Merkel, T. C., Freeman, B. D., Spontak, R. J., He, Z., Pinnau, I., Meakin, P., Hill, A. J. : *Science*, **296**, 519 (2002)
- 3) Oya, A. in : Polymer-Clay Nanocomposites, T. J. Pinnavaia, G. W. Beall, Eds. John Wiley & Sons, Ltd, (2000), p.151~172
- 4) Liu, X., Wu, Q. : *Polymer*, **42**, 10013 (2001)
- 5) Saujanya, C., Radhakrishnan, S. : *Polymer*, **42**, 6723 (2001)
- 6) Mai, K., Li, Z., Qiu, Y., Zeng, H. : *J. Appl. Polym. Sci.*, **84**, 110 (2002)
- 7) Chan, C., Wu, J., Li, J., Cheung, Y. : *Polymer*, **43**, 2981 (2002)
- 8) Kaempfer, D., Thomann, R., Mülhaupt, R. : *Polymer*, **43**, 2909 (2002)
- 9) Wu, C. L., Zhang, M. Q., Rong, M. Z., Friedrich, K. : *Compos. Sci. Technol.*, **62**, 1327 (2002)
- 10) Zhang, M., Liu, Y., Zhang, X., Gao, J., Huang, F., Song, Z., Wei, G., Qiao, J. : *Polymer*, **43**, 5133 (2002)
- 11) Grady, B. P., Pompeo, F., Shambaugh, R. L., Resasco, D. E. : *J. Phys. Chem. B*, **106**, 5852 (2002)
- 12) Maiti, P., Nam, P. H., Okamoto, M., Hasegawa, N., Usuki, A. : *Macromolecules*, **35**, 2042 (2002)
- 13) Xu, W., Liang, G., Zhai, H., Tang, S., Hang, G., Pan, W. : *Eur. Polym. J.*, **39**, 1467 (2003)
- 14) Asuka, K., Liu, B., Terano, M., Nitta, K. : *Macromol. Rapid. Commun.*, **27**, 910 (2006)
- 15) Nitta, K., Asuka, K., Liu, B., Terano, M. : *Polymer*, **47**, 6457 (2006)