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The Modification of Polypropylene by the Blending of a Polymeric Fine Powder with Crosslinkage

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In order to improve the properties of polypropylene (PP), the modification of PP by the blending of a polymeric fine powder with crosslinkage (PFPC) was investigated. PFPC, prepared by the radical polymerization of vinyl monomers and divinyl benzene (DVB), was blended into PP, and the properties of the polymer composite were studied. The dyeability of the composite was much improved. PFPC with a reactive functional group was especially available, because the dye could be fixed perfectly in the substrate. On the other hand, it was found that the addition of PFPC did not much cause the following properties to deteriorate: the transparency, the thermal stability, the melt index, and the pressure coefficient of the polymer efflux rate at 230°C and in the applied pressure range of 20—40 kg/cm^2.

The poor dyeability of the polypropylene is a serious drawback in its practical use: many devices for the improvement of the dyeability have been proposed—graft polymers have been prepared,[1-7] dyeable substances have been blended,[8-15] and some functional groups have been introduced into the polypropylene chain.[16-17] The blending of dyeable substances may be considered to be a practical process because of its ease. For example, the polypropylene fibers spun from the composites of polypropylene and such vinyl polymers as polystyrene,[18] polymethyl methacrylate,[18] the 2-methyl 5-vinylpyridine-styrene copolymer,[18] the styrene-glycidyl methacrylate copolymer,[15] and the vinyl toluene-glycidyl methacrylate copolymer[15] were easily dyed by dispersed dyes. However, the homogeneous blending is generally difficult because of the immiscibility.[19] This was shown by the microscopic observation of the dyed fiber cross-section; that is, only the vinyl polymer finely dispersed in the substrate was colored, while

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[1] G. Natta, E. Beati and F. Seberini, *J. Polymer Sci.*, **34**, 685 (1959).

[2] K. Kawai and S. Tsutsumi, *Nippon Kagaku Zasshi (J. Chem. Soc. Japan, Pure Chem. Sect.)*, **80**, 92 (1959).

[3] K. Kawai and S. Tsutsumi, *Kobunshi Kagaku, (Chem. High Polymers Japan)*, **18**, 64 (1961).

[4] M. Lazar, R. Rado and J. Parlinec, *J. Polymer Sci.*, **53**, 163 (1961).

[5] S. Torikai and E. Mukoyama, *Kobunshi Kagaku (Chem. High Polymers Japan)*, **19**, 337 (1962); **19**, 344 (1962).

[6] R. F. Stamm, E. F. Hosterman, C. D. Felton and C. S. Hsia Chen, *J. Appl. Polymer Sci.*, **7**, 753 (1963).

[7] F. Gelegi and L. Odor, *J. Polymer Sci. Part C*, **2**, 1223 (1963).

[8] P. Ginstiani, G. Natta and G. Mazzanti, U. S. Pat. 3115478.

[9] U. Riboni and L. Bartolucci, U. S. Pat. 3116966.

[10] T. Tanekoda, K. Akamatsu, T. Okamoto and K. Matsui, Japanese Pat. 26284 (1963).

[11] M. Kubo and O. Fukumoto, Japanese Pat. 291 (1965).

[12] K. Nishidate, Japanese Pat. 289 (1965).

[13] Y. Arata and O. Fukumoto, Japanese Pat. 290 (1965).

[14] R. Oda and N. Takeda, Japanese Pat. 12170 (1965).

[15] M. Kubota, M. Katayama and O. Ishizuka, *Kogyo Kagaku Zasshi (J. Chem. Soc. Japan, Ind. Chem. Sect.)*, **66**, 725 (1963).

[16] K. S. Minsker, I. Z. Shapiro and G. A. Razuvayev, *Polymer Sci. U. S. S. R.*, **4**, 1 (1963).

[17] S. Morimoto, O. Ishiwari and S. Uchida, Japanese Pat. 4683; 4733 (1963).

[18] Y. Mizutani, S. Matsuoka and K. Yamamoto, This Bulletin, **38**, 2045 (1965).

[19] H. Hatakeyama, Japanese Pat. 25788 (1964).

polypropylene itself was not colored.[15,18] The dye and some of the vinyl polymer were easily extracted from the fiber by acetone.[15,18] This fact indicates that the dye remains in the vinyl polymer by means of the intermolecular affinity between the dye and the vinyl polymer.

In order to improve the fastness of dyeing, the polymeric fine powder with crosslinkage and an affinity for dyes (PFPC) was blended into polypropylene in this study. The use of PFPC is of merit in that PFPC was finely dispersed and could not be extracted by any solvent. The method is, however, insufficient to bestow an excellent fastness in dyeing, since the dye is not perfectly fixed on PFPC and is extractable by acetone. Provided that PFPC has a reactive functional group which can combine with the dye by the chemical bond, the dye can be fixed in the substrate. In this case, an excellent fastness of dyeing can be expected. The utility of a polymer with a reactive functional group has already been discussed by Imoto,[20] Iwakura,[21,22] and Kern *et al.*[23]

The PFPC used in this paper was prepared by a new method: the vinyl monomer and divinyl benzene (DVB, a crosslinking reagent) were polymerized in a specified solvent (for example, an aliphatic hydrocarbon or an aliphatic alcohol) by the radical polymerization mechanism. Especially for the preparation of PFPC with a reactive functional group, an aliphatic hydrocarbon was a good solvent because of its inertness,

From the general considerations described above, and from a consideration of the practical applicability of PFPC as a mordant, the properties of the polymer composite consisting of polypropylene and PFPC were investigated, taking special account of the dyeability, the melt index, the transparency, the thermal stability, and the tension test.

Experimental

Materials. The properties of the polypropylene samples used are shown in Table 1. The polypropylene pellet was a commercial one. All the reagents used, such as monomers, solvents, and benzoyl peroxide, were of a chemical grade. The DVB content in commercial DVB was 50% by weight.

Table 1. The properties of polypropylene

Sample	Melt index g/10 min	Specific gravity
Powder under 30 mesh	2.9	0.912
Pellet	4.8	0.914

The Preparation and the Properties of PFPC. The vinyl monomer and DVB were polymerized in a solvent, such as kerosene, *n*-heptane, or *n*-butanol with stirring. The PFPC thus polymerized was then filtered off, washed with petroleum ether or methanol, and dried up at 50°C under a vacuum. The grain size of the PFPC was determined by the use of an electron microscope, Type HU-10A, from Hitachi, Ltd. The contents of the monomer unit containing nitrogen and the GMA unit were determined by elementary analysis. The content of the maleic anhydride unit was determined by titration with a 0.1 N aqueous solution of sodium hydroxide after hydrolysis.[24]

Blending of PFPC with Polypropylene and the Spinning Thereof to the Fiber. The polypropylene powder and the PFPC were well mixed as the methanol slurry or the *n*-heptane slurry in a mixer. The quantity of added PFPC was regulated at 3.8% by weight. Then, the polymer was filtered, 0.2% of 2,6-di-*t*-butyl *p*-cresol was added as an acetone solution, and the mixture was dried up under a vacuum. The polymer mixture thus obtained was made into pellets by the use of an extruder, Type MK-1, from the Modern Machinery Co., Ltd. The fiber was spun at 240—260°C through a spinneret 0.5 mm in diameter, and was taken up on a bobbin.

As an alternate method, PFPC and the commercial polypropylene pellet were blended by the use of an extruder, Type MK-1, from the Modern Machinery Co., Ltd.; the polymer extruded was once made into a pellet, then this pellet was extruded twice, and the polymer obtained was again made into a pellet. The extruding temperature was 190—220°C. This pellet was used to investigate the properties of the polymer composite.

Dyeing. The ordinary dyeing method[15] was used. The dyes used were Celliton Blue Extra, Duranol Red X3B, Estrol Orange 5R, and Estrol Fast Violet B.

Specific Gravity. The sample was annealed at 120—130°C for 10 hr under a nitrogen atmosphere. The specific gravity was determined at 23°C by the use of an ethanol/water density-gradient tube.

The Volatilization Curves. The volatilization under a nitrogen atmosphere and air was determined by the use of a differential thermal analysis apparatus, DT-1A, from the Shimadzu Seisakusho Co., Ltd. The heating rates were 2°C/min under air and 4°C/min under a nitrogen atmosphere.

Tension Test. The yield strength and elongation were determined at room temperature by the use of an autograph, Type IS-2000, from the Shimadzu Seisakusho Co., Ltd. The sample was prepared as follows: The polymer was melted in a mold between two heating plates, allowed to stand at 200°C for 30 min, and then cooled rapidly in a press under a pressure of 65 kg/cm². From the polymer plates thus obtained, a sample of the dambel-No 3 type[25] 1.6 mm thick was cut out.

The Pressure Coefficient of the Efflux Rate of the Molten Polymer. The efflux rate of the polymer was determined at 230°C under a pressure of 20—40 kg/

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[20] M. Imoto, *Yuki Gosei Kagaku Kyokaishi (J. Soc. Org. Synth. Chem., Japan)*, **15**, 325 (1957).

[21] Y. Iwakura, *ibid.*, **20**, 813 (1962).

[22] Y. Iwakura, T. Kurosaki and N. Nakabayashi, *Makromol. Chem.*, **44/46**, 570 (1961).

[23] W. Kern and R. C. Schulz, *Angew. Chem.*, **69**, 153 (1957).

[24] Al. Steyermark, "Organic Analysis," Vol. II, ed. by J. Mitchel Jr., *et al.*, Interscience Publishers Inc., New York (1954), p. 10.

[25] JIS-K 6723.

cm² by the use of a Koka-Flow Tester[26] (nozzle radius: 0.025 cm, nozzle length: 1.0 cm) from the Shimadzu Seisakusho Co., Ltd., while the pressure coefficient of the efflux rate of the polymer was calculated from the following equation:[27]

$$\frac{d \log Q}{d \log P} = n \tag{1}$$

n: pressure coefficient of the efflux rate
Q: efflux rate (cc/sec)
P: applied pressure (kg/cm²)

The Crystallinity by Infrared Spectrum Analysis. The sample used was the same as that used for the measurement of specific gravity. The crystallinity of polypropylene is shown by the ratio of optical densities, $D_{10.03\mu}/D_{10.30\mu}$[28] after the correction for the effect of the PFPC content. The spectrophotometer used was a Type AR-275 from the Shimadzu Seisakusho Co., Ltd.

Results and Discussion

The Preparation and the Properties of PFPC. Tables 2 and 3 show examples of the preparation of PFPC. All the PFPC samples were spherical in form, and their diameters were in the range of about 0.1 μ or less (Photo. 1). The monomers used were soluble in the solvents, but their polymers were insoluble; DVB may be effective both in promoting the separation of the polymer from the solvent and in making the polymer a very fine powder. The details on the

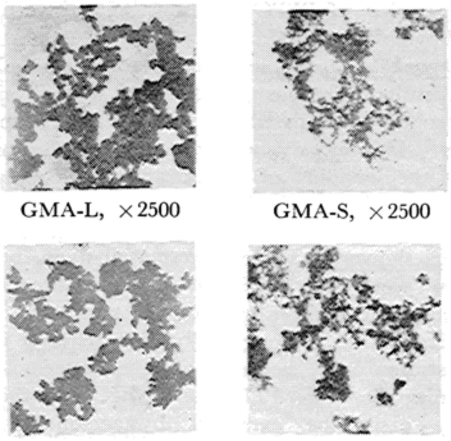
GMA-L, ×2500 GMA-S, ×2500
GMA-St, ×2500 St-MA, ×2500

Photo. 1. The electron microphotograph of PFPC.

TABLE 2. THE PREPARATION OF PFPC AT 80±5°C AND ITS PROPERTIES

Sample	Polymerization condition						PFPC	
	M_1 g	M_2 g	DVB g	Solvent ml	BPO g	Yield g	M_2 content %	Grain size μ
A	St, 24	—	3	K, 100	0.2	19	—	0.1—0.2
B	St, 32	MA, 5	4	K, 100	0.1	20	23	0.1
C	St, 24	AN, 10	2	K, 100	0.2	10	33	0.1—0.2
D	MAc, 20	—	2	K, 150	0.1	9	—	0.1—0.2
E	MAc, 10	MVP, 10	3	K, 150	0.1	8	38	0.1
F	VAc, 20	AA, 5	5	B, 150	0.3	—	33	0.1
G	GMA, 44	—	7	K, 400	0.3	38	—	0.1
H	MAc, 20	AA, 5	5	B, 150	0.1	—	12	0.1

St: styrene, MA: maleic anhydride, AN: acrylonitrile, MAc: methyl acrylate, MVP: 2-methyl-5-vinylpyridine, VAc: vinyl acetate, AA: acryl amide, GMA: glycidyl methacrylate, K: kerosene, B: *n*-butanol

TABLE 3. THE PREPARATION OF PFPC WITH THE REACTIVE FUNCTIONAL GROUP AT 80°C UNDER NITROGEN ATMOSPHERE AND ITS PROPERTIES

Sample	Monomer				*n*-Heptane	BPO	Time hr	Yield %	PFPC	
	GMA (M_1) g	MA (M_1) g	St (M_2) g	DVB g	l	g			M_1 content %	Grain size μ
St-GMA	100	—	200	50	2.65	10	2.9	31	37.7	0.1—0.2
GMA-L	380	—	—	20	2.6	10	2.1	82	—	0.1—0.2
GMA-S	300	—	—	50	2.65	10	2.0	80	—	~0.1
St-MA	—	100	375	25	2.5	15	2.5	40	40.4	~0.1

GMA: glycidyl methacrylate, MA: maleic anhydride, St: styrene,
DVB: divinyl benzene (purity: 50%), BPO: benzoyl peroxide

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[26] T. Arai, "A Guide to the Testing of Rheological Properties with Koka-Flow Tester," Maruzen Co., Ltd., Tokyo (1958).

[27] T. Arai, *ibid.*, p. 22.

[28] R. G. Quynn, J. L. Riley, D. A. Young and D. H. Noether, *J. Appl. Polymer Sci.*, **2**, 166 (1959).

preparation of PFPC are now being investigated and will be reported soon.

Dyeability. Table 4 shows some examples of the results. The blending of PFPC was effective in improving the dyeability of the polypropylene fiber. This may reasonably be interpreted provided that the blending of the linear dyeable polymers was effective and the dyeable polymers were finely dispersed in the substrate.[14,15,18] The fibers shown in Table 4 were well dyed, but the dyes were extracted by acetone except the fibers containing sample-G or sample-B. This indicates that as long as the dye remains in the substrate only because of the intermolecular affinity between PFPC and the dye, the dye may easily be extracted by acetone.[15] The fixation of the dye in the fiber containing sample-G was considered to be as follows.

Table 4. The dyeing result with the dispersed dyes

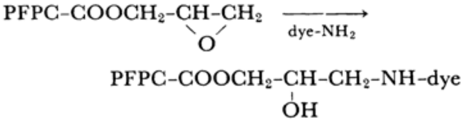
Sample blended	Color after dyeing	Color after acetone-extraction*1
A	++	−
B	++	− or ++*2
C	++	−
D	++	−
E	++	−
F	++	−
G	++	++
H	++	−

*1 The extraction was carried out for 8 hr by the use of a Soxhlet extractor.
*2 ++ for Estrol Fast Orange GRUF, − for Celliton Blue Extra
++ medium colored, − does not colored.

Table 5. Dyeing fastness

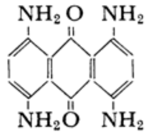
Sample blended	Fastness for dry cleaning with trichloroethylene*1		Fastness for washing with soap*2	
	Dye	Fastness	Dye	Fastness
B	EO	1	CB	2
B	CB	2	EO	2
C	CB	1—2	EO	1—2
D	EO	1	CB	2—3
D	EV	1	DR	1—2
E	EV	1	EO	2
E	CB	3—4	DR	1—2
F	EV	1	EO	2
G	CB	4—5	CB	5
H	EO	1—2	DR	1—2

*1 JIS L-1506
*2 JIS L-1045 BC-3
EO: Estrol Orange 5R, EV: Estrol Violet B,
CB: Celliton Blue Extra, DR: Duranol Red X3B



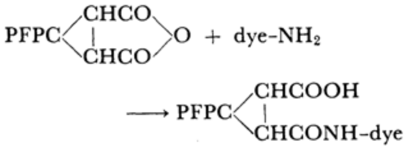
$$\mathrm{PFPC{-}COOCH_2{-}\underset{\diagdown O \diagup}{CH{-}CH_2}} \xrightarrow[\text{dye-NH}_2]{} \mathrm{PFPC{-}COOCH_2{-}\underset{OH}{CH}{-}CH_2{-}NH{-}dye}$$

Celliton Blue Extra Type

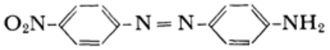


As is shown in Table 5, the dyeing fastness of the fiber containing sample-G was most excellent; this was attributed to the perfect fixation of the dye described above. Hence, it became clear that the use of PFPC with a reactive functional group was advantageous and recommendable.

Another example is shown as follows.



Estrol Fast Orange GRUF



It is well-known that the maleic anhydride unit reacts with an amino group or a hydroxyl group.[29] Therefore, the dyes described above could be fixed in the substrate; the fact is elucidated by the acetone-extraction, as is shown in Table 4. However, when Celliton Blue Extra Type was used, the fiber was well-dyed, but the dye was extracted easily by acetone, because the basicity of the amino group of the dye was too weak to react with the maleic anhydride unit, as has been shown by Kern *et al.*[23] Furthermore, the fiber was apt to become yellowish in the spinning process at elevated temperatures (above 270°C).

As a very important factor in the practical use of PFPC as a mordant, the dispersion state of

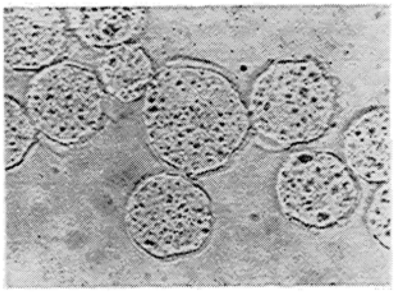


Photo. 2. Microphotograph of the cross-section of the fiber containing sample-D.
Magnification: 250

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29) L. F. Fieser and M. Fieser, "Textbook of Organic Chemistry," Maruzen Publishing Co., Ltd., Tokyo (1952), p. 182.

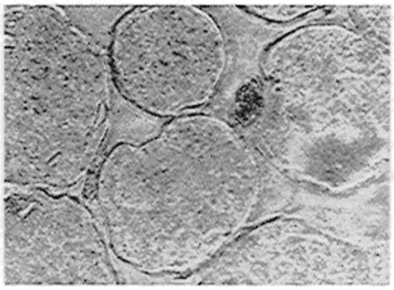

Photo. 3. Microphotograph of the cross-section of the fiber containing sample-G after acetone-extraction.
Magnification: 250

PFPC in the substrate must be investigated. Therefore, the cross-section of the dyed fiber was examined, as is shown in Photographs 2 and 3. It became clear that only PFPC was dyed, while polypropylene was not dyed. The dispersion state of PFPC may be considered to be fairly good, and the size of the colored particles suggests the agglomeration of PFPC.

In conclusion, PFPC with reactive functional groups, especially the glycidyl group, was found to be most useful as a mordant. Judging from a comparison of the size of PFPC with the diameter of the conventional fiber, 10—30 μ,[30] it may be both possible and necessary to improve the dispersion state of PFPC. The details of the behavior of PFPC as a mordant are now under investigation and will be reported soon.

Melt Index of the Polymer Composite. Figure 1 shows the relation between the PFPC content and the melt index. Apparently, with an increase in the PFPC content, the melt index decreases linearly. Since the melt index of the polypropylene pellet was increased to 7.0 g/10 min from 4.8 g/10 min by extruding, the degradation of polypropylene might have occurred. Therefore, the decrease in the melt index shown in Fig. 1 may be attributed mainly to the physical effect of PFPC—that is, the blending of PFPC lowers the fluidity of molten polypropylene, but this is not a serious drawback for spinning.

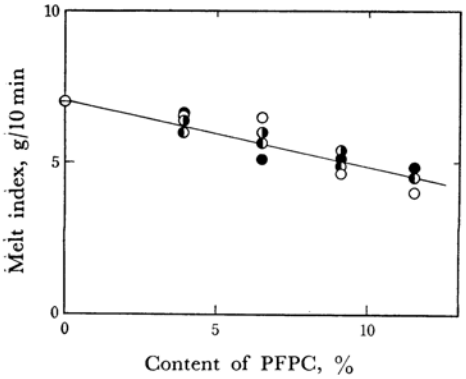

Fig. 1. The relation between the content of PFPC and melt index.
◐: Polypropylene containing St-GMA
●: Polypropylene containing GMA-L
○: Polypropylene containing GMA-S
◑: Polypropylene containing St-MA
⊖: Polypropylene

Specific Gravity and Crystallinity of the Polymer Composites. The relation between the PFPC content and the specific gravity is shown to be linear for each sample in Fig. 2. This suggests that there was no striking physical effect of PFPC on the crystallinity of polypropylene, contrary to the results obtained by Nakazawa *et al.*:[31]

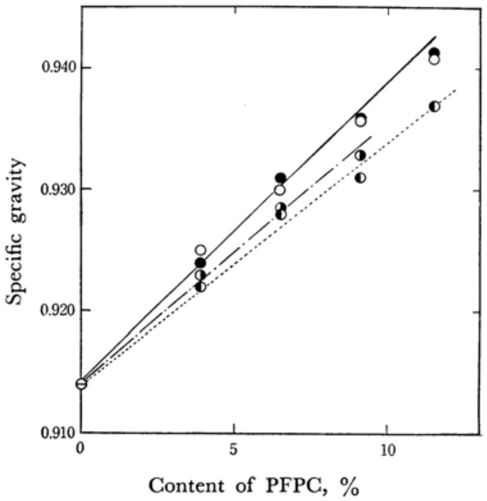

Fig. 2. The relation between the content of PFPC and specific gravity. The symbols were same as shown in Fig. 1.

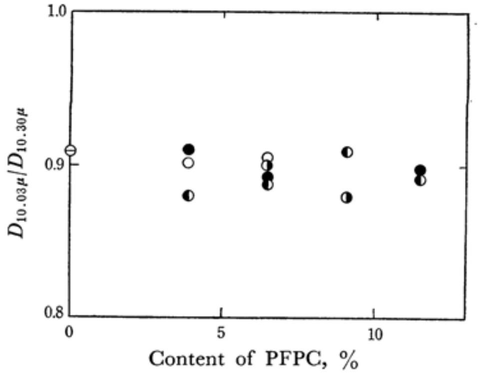

Fig. 3. The relation between the content of PFPC and the ratio of optical densities.
The symbols were same as shown in Fig. 1.

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[30] J. L. Riley, "Polymer Processes," ed. by C. E. Schildknecht, Interscience Publishers Inc., New York (1956), p. 836.

[31] H. Nakazawa, K. Machida and N. Adachi, Japanese Pat. 16908 (1964).

they showed that the addition of silicic acid anhydride to polypropylene enhanced the crystallinity of polypropylene. It is well-known that the specific gravity of a crystalline polyolefin is a relative measure of the crystallinity,[32] but the specific gravity could not be used as a relative measure of the crystallinity in this study because of the addition of PFPC. Therefore, the crystallinity of polypropylene was measured by means of infrared spectrum analysis, Fig. 3 shows that the addition of PFPC does not change the crystallinity of polypropylene; it also shows that the chemical interaction of PFPC and polypropylene by extruding may be accounted as negligible. Since the interaction between PFPC and polypropylene was negligible, the specific gravity of polypropylene containing PFPC was determined by the equation shown below:

$$\text{Specific gravity of the sample} = 0.914\ (1-\alpha) + \alpha\cdot x \qquad (2)$$

α: PFPC/(PFPC+polypropylene) by weight
x: specific gravity of PFPC

Therefore, the apparent specific gravity of PFPC itself could be calculated, as is shown in Table 6.

Table 6. Apparent specific gravities of PFPC

Sample	Specific gravity
St-GMA	1.11
St-MA	1.13
GMA-(L, S)	1.15

Transparency. The transparency of polypropylene containing PFPC is a very important factor in the practical use of PFPC. In order to compare the transparency of the polymer composites, polymer plates 1.6 mm thick were placed on the printed matter in the order shown below:

	PP	
PP+St-GMA 3.9%	PP+St-GMA 6.5%	PP+St-GMA 9.1%
PP+GMA-S 3.9%	PP+GMA-S 6.5%	PP+GMA-S 9.1%
PP+St-MA 3.9%	PP+St-MA 6.5%	PP+St-MA 9.1%

pp: polypropylene
(The figure shows the PFPC content.)

Polypropylene containing PFPC of the St-GMA-DVB system or the St-MA-DVB system was opaque, while polypropylene containing PFPC of the GMA-DVB system was transparent (Photo. 4). Therefore, PFPC of the GMA-DVB system may practically be preferable and advantageous.

Photo. 4. The comparison of the transparency of polypropylene containing PFPC.

The Pressure Coefficient of the Efflux Rate of the Polymer. Figure 4 shows the relation between the applied pressure and the efflux rate of the polymer composite. The slope of the line in Fig. 4 shows the pressure coefficient, n, shown in Eq. (1).[27] Figure 5 shows the relation between the pressure coefficient and the PFPC content. The pressure coefficient was approximately independent of the kind and the content of PFPC and was approximately the same value as that of polypropylene itself.

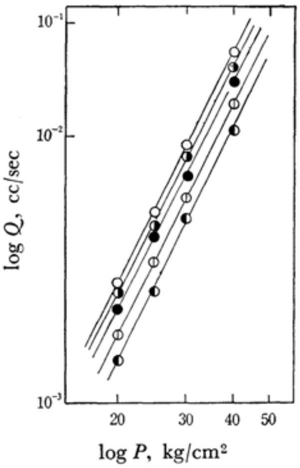

Fig. 4. The relation between the applied pressure and the efflux rate of the polymer.
○: Polypropylene
◐: Polypropylene containing 9.1% GMA-S
⦶: Polypropylene containing 9.1% St-GMA
◑: Polypropylene containing 3.9% St-GMA
●: Polypropylene containing 9.1% St-MA

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[32] J. A. Fancher and F. P. Reding, "Crystalline Olefin Polymer Part I," ed. by R. A. V. Raff and K. W. Doak, Interscience Publishers, a division of John Wiley & Sons, New York (1965), p. 681.

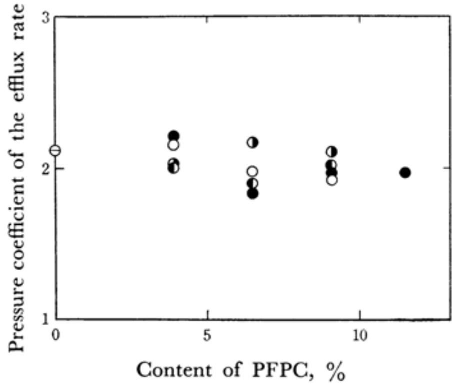

Fig. 5. The relation between the pressure coefficient of the efflux rate of the polymer and the content of PFPC.
The symbols were same as shown in Fig. 1.

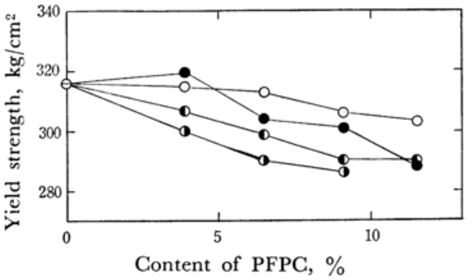

Fig. 6. The relation between the content of PFPC and the yield strength of the polymer.
The symbols were same as shown in Fig. 1.

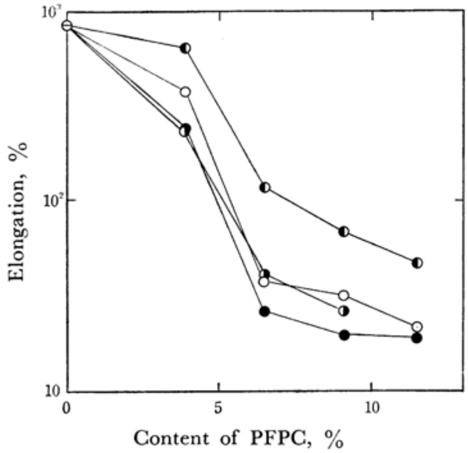

Fig. 7. The relation of the content of PFPC and the elongation of the polymer.
The symbols were shown in Fig. 1.

Tension Test. With an increase in the PFPC content, both the yield strength and elongation were decreased, as are shown in Figs. 6 and 7. The decrease in the latter was especially striking. As the yield strength is dependent upon the rigidity of the polymer composite, the decrease in yield strength may be attributed to the diminished the rigidity of the polymer composite with an increase in the PFPC content. On the other hand, the decrease in elongation could be explained as follows: since the stretching of polypropylene caused an unfolding of the lamellar structure of the crystallite, PFPC blended in polypropylene may hinder the unfolding of the lamellar structure.

The Thermal Stability of the Polymer Composite. The thermal stability of the polymer composite is very important for its practical use, and so the volatilization curves under air or a nitrogen atmosphere were determined to be as in Figs. 8—10. The addition PFPC showed no striking effect on the thermal stability of the polymer composite. However, when the PFPC content of the GMA-DVB system was 11.5%, the temperature when volatilization will begin under a nitrogen atmosphere was lowered to 260—265°C. On the other hand, polypropylene containing

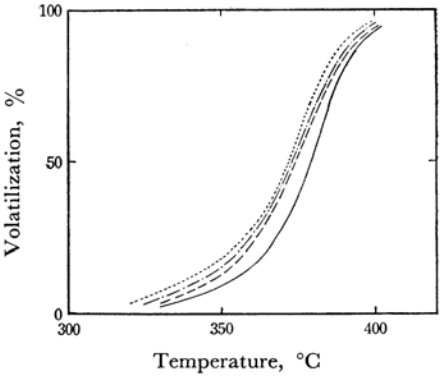

Fig. 8. Volatilization curves under a nitrogen atmosphere.
——: Polypropylene
······: Polypropylene containing sample-A
----: Polypropylene containing sample-C
·—·: Polypropylene containing sample-E

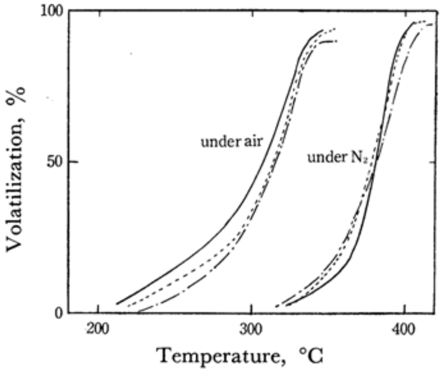

Fig. 9. The volatilization curves of polypropylene containing St-GMA.
——: Polypropylene
······: Polypropylene containing 3.9% St-GMA
·—·: Polypropylene containing 11.5% St-GMA

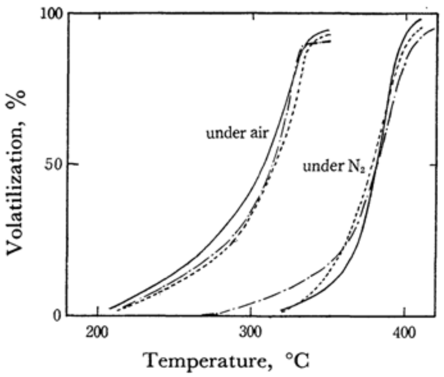

Fig. 10. The volatilization curves of polypropylene containing GMA-S.
——: Polypropylene
······: Polypropylene containing 3.9% GMA-S
·—·: Polypropylene containing 11.5% GMA-S

PFPC of the St-GMA-DVB system was stable up to 300°C. These differences in the thermal stability of the polymer composites may be attributed to the thermal stability of the PFPC used. The differences in the volatilization curves between under air and a nitrogen atmosphere may reasonably by attributed to the participation of oxygen on the degradation of the polymer composite.

Conclusion

The blending of a polymeric fine powder with crosslinkage was effective in improving the polypropylene dyeability and had no serious demerit concerning the other properties of the polypropylene composite. Therefore, the blending of the polymeric fine powder with crosslinkage as a mordant was proposed. The polymeric fine powder of the glycidyl methacrylate-divinyl benzene system was found to be the best. The problems of the dispersibility and the optimum quantity of the polymeric fine powder to be blended in polypropylene remain to be solved.

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