Synthesis and Properties of High Oil-Absorptive Network Polymer 4-*tert*-Butylstyrene–SBR–Divinylbenzene

MEI HUA ZHOU,[a] **CHANG-SIK HA,**[b] **WON-JEI CHO**[b]

[a] College of Environmental Science and Engineering, Dong Hua University, Shanghai 200051, People's Republic of China

[b] Department of Polymer Science and Engineering, Pusan National University, Pusan 609-735, South Korea

ABSTRACT: 4-*tert*-Butylstyrene–SBR–divinylbenzene (PBSD) was prepared by the graft crosslinking polymerization of 4-*tert*-butylstyrene (tBS) and divinylbenzene (DVB) onto unvulcanized SBR in the solution process using BPO as an initiator. The effects of reaction conditions, such as, solvent amount, SBR content, mol ratio of DVB to tBS, initiator concentration, reaction temperature, and reaction time on conversion, grafting efficiency, and gel fraction were examined. In present reaction system, a solvent amount 15.0 mL/g is the threshold of the gelation process. The oil absorbency was evaluated by the ASTM (F726-81) method. The swelling rates, light resistance, and tensile strength of PBSD were investigated. It was found that the tensile strength is considerably better than that of 4-*tert*-butylstyrene–EPDM–divinylbenzene polymer (PBED). The highest oil absorbency of crosslinked PBSD was 57.76 g/g, and the largest swelling kinetic constant was 102.09×10^{-2} h^{-1}. © 2001 John Wiley & Sons, Inc. J Appl Polym Sci 81: 1277–1285, 2001

Key words: 4-*tert*-butylstyrene–SBR–divinylbenzene polymer; oil-absorptive network; swelling rate; light resistance; tensile strength

INTRODUCTION

Crosslinked polymers are important in chemical research and practice, owing to the wide range of applications they find. Water treatment, chromatographic techniques, biomedical and biochemical applications, solid-phase organic synthesis, enzyme immobilization, soil conditioning, solvent and ion separations, and various other areas are using crosslinked polymers as the principal substrate. Crosslinking is responsible for the three-dimensional network structure that characterizes these materials. Elasticity and swelling properties are attributed to the presence of physical or chemical crosslinks within polymer chains. Among them, alkylacrylate and aromatic polymers have been attracting much attentions of scientific and applied research groups.[1–6] Because hydrophobic network polymers can absorb nonpolar solvents, abroad they are used as absorbents of oil or some organic solvents spilled on water in the field of environment.

It has been known that vulcanized styrene–butadiene rubber (SBR) has excellent tensile strength, tear resistance, and abrasion resistance. In this work, the graft terpolymer, tBS–SBR–DVB (PBSD) was prepared by the graft polymerization of 4-*tert*-butylstyrene (tBS) and divinylbenzene (DVB) onto unvulcanized SBR in the solution process using benzoyl peroxide (BPO) as an initiator. The synthesized PBSD was extracted by tetrahydrofuran (THF) and separated

Table I   Graft Crosslinking Polymerization Conditions Used in the Study

Condition	Description						
SBR (wt %)[a]	100	80	60	50	40	30	20
DVB/tBS (mol ratio)	0.0	0.05	0.10	0.20	0.30		
Initiator (wt %)[a]	0.5	1.0	2.5	5.0	10.0		
Time (h)	24	48	72	96			
Temperature (°C)	60	70	80	90			
Solvent amount (mL/g)	5.0	7.5	10.0	12.5	15.0	20.0	

[a] The concentration was based on the total weights containing monomers and SBR.

into gel and sol. The structure of crosslinked PBSD and sol PBSD were identified by infrared (IR) spectroscopy. The effects of various synthesis parameters, such as solvent amount, SBR content, mol ratio of DVB to tBS, initiator concentration, reaction time, and temperature, on total conversion, grafting efficiency, and gel fraction were investigated. The oil absorbency was evaluated by the ASTM (F726-81) method.[7] The swelling rates, light resistance, and tensile strength of PBSD were investigated.

EXPERIMENTAL

Materials

4-*tert*-Butylstyrene (tBS; Aldrich Chem., Milwaukee, WI) and divinylbenzene (DVB; Fluka) were purified by standard procedures. Benzoyl peroxide (BPO; Aldrich Chem) was crystallized from methanol. Styrene-butadiene rubber (SBR; bound styrene 23.5 mol %; M_n 95,000; M_w 520,000) was used as received from Kosyn Co. Methanol, THF, dioxane, toluene, acetone, and MEK (methyl ethyl ketone) were distilled prior to use.

Synthesis of PBSD

A given amount of SBR was dissolved in certain volume of toluene in a flask equipped with a modified Hopkins cooler, thermometer, and nitrogen gas inlet. A mixture of tBS and DVB at a given mol ratio was mixed in toluene, and the solution was introduced into SBR solution with a required amount BPO based on total weights containing monomers and SBR. The reactions were carried out under various experimental conditions, as shown in Table I.

The obtained product was precipitated in excess methanol with stirring. The precipitate was collected by filtration and then dried in a vacuum

oven until a constant weight. The product was further extracted by THF in a Soxhlet extractor for 1 day with a coarse-grade thimble. The sol-free materials were gels including gel PBSD, gel Poly-(tBS-*co*-DVB) and gel PDVB, but for infinite network polymer, only gel PBSD existed. The synthesized sol PBSD was isolated from soluble mixtures of several homopolymers, copolymers, and nongrafted SBR, such as Poly(*tert*-butylstyrene) (PtBS), Poly(divinylbenzene) (PDVB), Poly(tBS-*co*-DVB), Poly(SBR-*g*-tBS) and Poly(SBR-*g*-DVB) by using dioxane, MEK and acetone-to-toluene (50/50% by volume) cosolvent. Figure 1 shows the scheme of isolation procedure. The total conversion, grafting efficiency, and gel fraction were estimated using the following equations[8]:
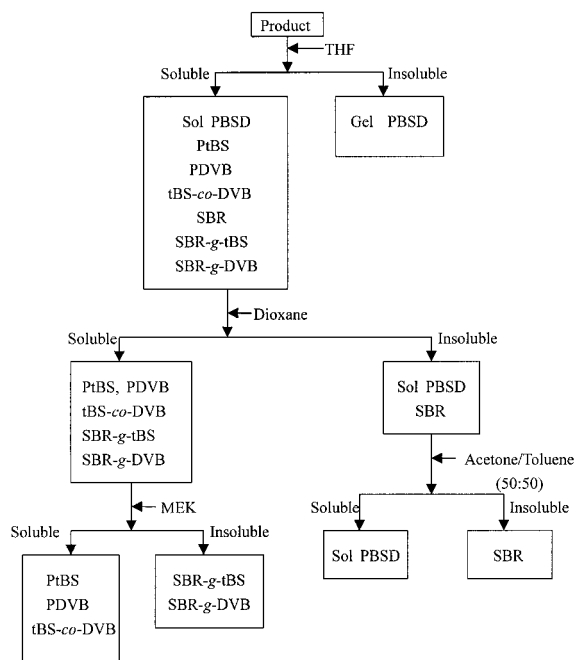

Figure 1   Block diagram of isolation procedure for PBSD.

Total conversion (%)

$$= \frac{\text{Total weight of polymer formed}}{\text{Weight of monomers and SBR}} \times 100 \quad (1)$$

Grafting efficiency (%)

$$= \frac{\text{Weight of polymer in grafts}}{\text{Total weight of polymer formed}} \times 100 \quad (2)$$

Gel fraction (%)

$$= \frac{\text{Weight of dried gel after extraction}}{\text{Total weight of polymer before extraction}}$$
$$\times 100 \quad (3)$$

Measurements

Infrared Spectroscopy (IR)

The infrared spectroscopy of graft terpolymer was recorded on a Perkin-Elmer 1330 spectroscopy.

Oil Absorption Test

The oil absorbency of crosslinked polymers obtained from graft crosslinking polymerization was determined by ASTM (F726-81): 0.1 g polymer was put in a stainless steel mesh ($4 \times 4 \times 2$ cm) that had been immersed in oil solution (crude oil diluted with toluene, 10% oil) and weighed beforehand. The sample and the mesh were together picked up from oil, drained for 20 s, tapped with filter paper to remove excess oil from the bottom of the mesh, and then weighed on a balance. The oil absorbency was calculated by following formula:

Oil absorbency (g oil/g sample)

$$= \frac{\text{Weight of absorbed oil in sample}}{\text{Weight of sample before oil-absorption}} \times 100$$
$$(4)$$

For the study of the kinetics of oil absorption, the above measurements repeated from time to time. For the determination of maximum oil absorbency, the test was allowed to stand for 7 days.

Kinetics of Swelling

According to Yao and Zhou,[9] the swelling rate of the crosslinked polymers can be described by the following experimental equation:

$$\frac{dQ}{dt} = K(Q_{\max} - Q) \quad (5)$$

where $Q_{\max}$ is the maximum oil absorbency; Q is the characteristic oil absorbency; and K is the swelling kinetic constant.

Integration from (5) gives

$$-\ln(Q_{\max} - Q) = Kt + C \quad (6)$$

where t is the characteristic swelling time, and C is the integration constant. As a consequence of $t = 0$, $Q = 0$, and $-\ln Q_{\max} = C$, therefore,

$$\ln \frac{Q_{\max}}{Q_{\max} - Q} = Kt \quad (7)$$

For an example, the characteristic swelling time is defined at $Q = 0.632 \, Q_{\max}$.[10]

Light Resistance

The light resistance was determined using a Fade-o-Meter (Atlas, at 60°C and 65% relative humidity) and color difference meter (NP-101 DP). The film specimens were cast from THF solutions (ca. 3 wt %) on a nonyellowing urethane-coated hiding paper. The films were slowly dried at room temperature and then kept under vacuum until they reached constant weight. The cross sectional area of the films was 3×5 cm^2, and thickness was 35 μm. The color difference (ΔE) of the samples after exposing to UV was calculated using the Hunter-Schofield equation.[11]

Tensile Properties

The tensile tests were carried out using an Instron Tensile Tester (Model 4204). The samples were prepared following the procedure of ASTM D638-84. The crosshead speed was 5 mm/min, and the initial gauge length was adjusted at 25 mm.

RESULTS AND DISCUSSION

Characterization

The structure of the synthesized graft terpolymer PBSD was indicated by IR spectra, as shown in Figure 2. The characteristic absorption bands of PBSD appeared at 3020 cm^{-1} (stretching vibration of aromatic C—H bond), 2900 cm^{-1} (stretch-
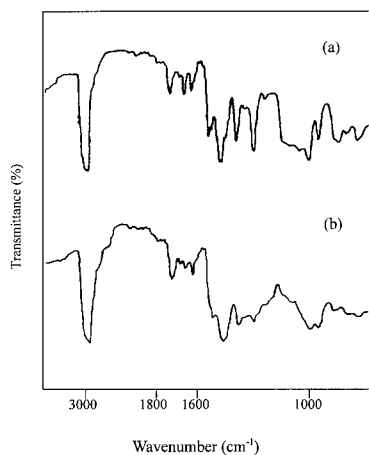
Figure 2 FTIR spectra of uncrosslinked PBSD (a) and crosslinked PBSD (b).

ing vibration of aliphatic C—H bond), 1465 cm^{-1} (CH$_2$; scissoring), 1380 cm^{-1} (CH$_3$; bending), and 900–790 cm^{-1} (aromatic C—H bond; out-of-plane vibration), respectively. The peak height of vinyl stretching vibration at 1640 cm^{-1} in the sol PBSD was higher than that in the crosslinked PBSD.

Effect of Reaction Conditions

Effect of Solvent Amount

The effects of solvent amount on graft crosslinking polymerization are shown in Table II. The products were carried out in 0.05 mol ratio of DVB to tBS with 50 wt % SBR and BPO 2.5 wt % at 70°C for 48 h, and the solvent amount was added based on the total weight of SBR, DVB, and tBS. As Table II shows, the conversion, the grafting efficiency, and the gel fraction of the polymer decreased with increase in the amount of solvent monotonously. The gel fraction fell down to zero after the value of solvent amount increased to 15.0 mL/g. These results can be explained by the concentration of polymeric solution.[12,13] Toluene is a good solvent for the polymerization system; 15.0 mL/g for this system may be a critical value. More than that, the polymeric solution becomes dilute and SBR macromolecules are separated for a long distance by solvent and curl-like cloud. Only monomers tBS and DVB can move to them and polymerize with them or further crosslink with them. As a result, it is easy to form intramolecular crosslinking or intramolecular cyclization. Thus, microgels may be produced at this system (microgel can pass through the coarse-grade thimble during the extraction of THF). When sol-

vent amount decreases, the polymeric solution becomes more and more viscous and the SBR macromolecules extend enough so that they can touch each other or entangle together. The monomers diffuse and react among the macromolecules. It has more possibility to form intermolecular crosslinking with prepolymer.[14–16] The following reactions were adopted 5.0 mL/g to be sure of the crosslinked polymer. In addition, the high viscosity of reaction system appears to be in favor of graft polymerization.

Effect of SBR Content

The effect of SBR content on graft crosslinking polymerization is shown in Table II. The products were carried out SBR content 100, 80, 60, 50, 40, 30, and 20 wt % in feed, respectively. As SBR content decreased, the conversion decreased a little at first and then increased, but the grafting efficiency and the gel fraction decreased with decreasing SBR monotonously. When SBR content decreased from 100 wt % to 80 wt %, the viscosity of reaction mass decreased obviously and the conversion decreased also. With a further decrease in SBR weight percentage, however, the monomer weight percentage increased and the molar number of monomers became larger and larger, and as a result, the conversion increased. On the other hand, it seems that the lower the concentration of unvulcanized SBR, the fewer the active centers,[17,18] and thus, the higher degrees of homopolymer of PtBS and copolymer P(tBS-co-DVB) are produced. Moreover, the grafting efficiency and the gel fraction at the same reaction system had similar values listed in columns III and IV in Table II. This phenomenon can be explained that almost all double bonds in the solution are opened and further react at very high conversion and a very low solvent amount. It turns out to be a lump of three-dimensional network, and therefore, the grafting efficiency and the gel fraction represent an identical result in the manner. At low conversion, however, the value of the gel fraction is usually smaller than that of the grafting efficiency.

Effect of Molar Ratio

Table II shows the influence of the molar ratio, DVB to tBS, on the graft crosslinking polymerization. The reactions were performed in solvent amount 5.0 mL/g with SBR 50 wt % and BPO 2.5 wt % at 70°C for 48 h. As Table II shows, the

Table II   Effects of Graft Crosslinking Polymerization Conditions on Conversion, Grafting Efficiency, and Gel Fraction

Changing Condition	Conversion (%)	Grafting Efficiency (%)	Gel Fraction (%)
Solvent amount (mL/g)			
5.0	94.97	88.58	88.38
7.5	89.22	87.30	82.45
10.0	86.93	86.82	81.67
12.5	85.32	86.51	80.99
15.0	84.49	74.15	66.34
17.5	81.91	72.03	0.00
20.0	80.09	70.63	0.00
SBR (wt %)			
100	96.59	98.51	97.61
80	92.05	96.94	94.45
60	92.37	92.83	89.20
50	94.97	88.58	88.38
40	97.14	87.15	86.74
30	98.20	85.05	85.05
20	98.59	83.86	83.23
[DVB/tBS] (mol ratio)			
0.00	94.66	85.97	85.83
0.05	94.97	88.58	88.38
0.10	95.59	89.04	89.04
0.20	96.65	93.12	93.12
0.30	97.62	94.12	94.12
Initiator (wt %)			
0.5	73.29	91.90	78.46
1.0	83.86	90.33	83.92
2.5	94.97	88.58	88.38
5.0	96.05	88.02	87.98
10.0	99.50	87.64	87.64
Temperature (°C)			
60	87.52	86.37	84.91
70	94.97	88.58	88.38
80	91.10	93.01	92.39
90	85.22	89.73	88.90
Reaction time (h)			
24	86.33	91.06	90.60
48	94.97	88.58	88.38
72	95.02	89.76	89.69
96	95.14	91.23	91.21

Besides changing conditions, the others were [DVB]/[tBS]: 0.05; solvent amount: 5.0 mL/g; SBR content: 50 wt %; BPO concentration: 2.5 wt %; reaction temperature: 70°C; reaction time: 48 h.

conversion, the grafting efficiency, and the gel fraction increased monotonously with increasing the molar ratio in the feed. The conversion increased a little, allover 94.5%, and the values of the grafting efficiency and the gel fraction in one system were very close. The reason is as that of the SBR content. Otherwise, DVB has two double bonds, so the higher DVB level makes graft polymerization and chemical crosslinking easier.[19] It

is known that the lower the degree of crosslinking, the more the gel swells,[20] so that the rest of the experiments adopted a low molar ratio of DVB to tBS.

Effect of Initiator Concentration

Table II also shows the effect of initiator concentration on the graft crosslinking polymerization.

The conversion increased with increasing initiator concentration. It can easily be understood that more initiator will give more active centers. The grafting efficiency, however, decreased with increasing the initiator. This is expected, because the homopolymer is formed more readily than the graft polymer as the initiator concentration increases.[21] The gel fraction was increased up to 2.5% with increasing the initiator concentration, and then decreased a little. The reason may be explained by the fact that the few active centers exist mainly on the SBR chains to form graft polymer or microgel in lower initiator concentrations. At too high are initiator content, however, the gel fraction has a similar result of the grafting efficiency; the homopolymer is formed more readily than the graft polymer.

Effect of Reaction Temperature

The effect of reaction temperature on the graft crosslinking polymerization is shown in Table II also. The reactions were carried out at 60, 70, 80, and 90°C, keeping other factors constant. Upon increasing the temperature, the conversion had a maximum value at 70°C, but the graft efficiency and the gel fraction passed through a maximum at 80°C, respectively. The grafting efficiency depends on the number of active sites available. The increase in temperature is expected to increase the rate of grafting. With an increase in temperature, however, the rates of copolymerization and homopolymerization also increase.[22,23] As a result, the grafting efficiency increases initially, but on further increase in temperature graftinging efficiency decreases. A similar observation was made by Porejko et al.[24] for the grafting of maleic

Figure 4   Oil absorbency of crosslinked PBSD with different solvent amount vs. oil immersion time.

anhydride onto low-density polyethylene. The gel fraction has as similar explanation as for the grafting efficiency. The reason why the conversion decreases with further increasing temperature, however, is not clear.

Effect of Reaction Time

In Table II, the influence of reaction time on graft crosslinking polymerization is also listed. The conversion increased with reaction time up to 48 h and then leveled off. With an increase in reaction time, the radicals hold on more time for reaction; as a result, an increase in conversion was observed. After some time all the initiator is used up,[23,25,26] and no further change in conversion is observed with an increase in reaction time. On the other hand, the grafting efficiency and the gel fraction had minimums at 48 h, listed in Table II. With an increase in reaction time, a decrease in grafting efficiency and gel fraction may be
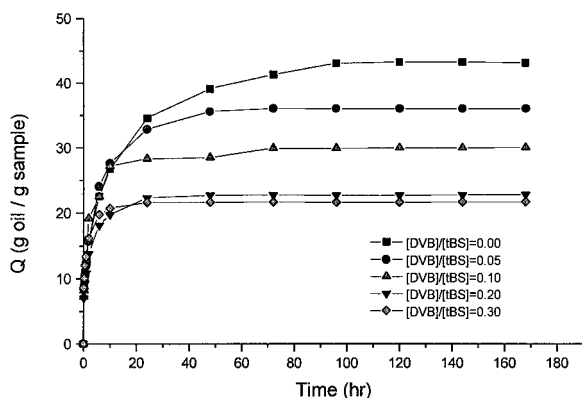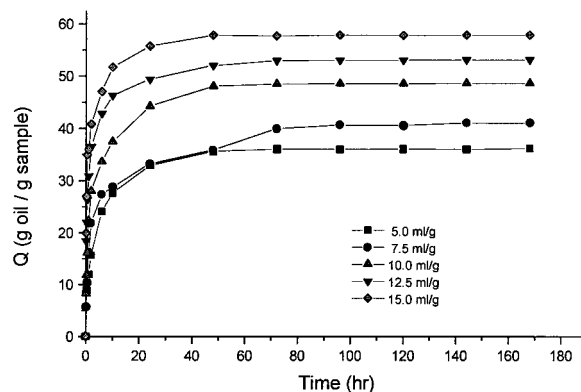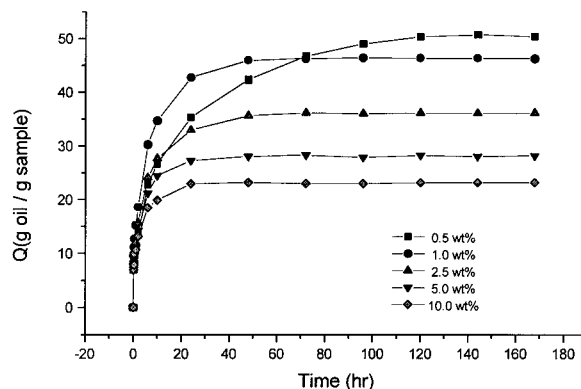

Figure 3   Oil absorbency of crosslinked PBSD with different mol ratio of DVB to tBS as a function of oil immersion time.

Figure 5   Oil absorbency of crosslinked PBSD with various initiator concentration vs. oil immersion time.

Table III   Absorption Characteristics of PBSD in Oil Solution

Sample	Q_{max} (g/g)	t_{max} (h)	Q (g/g)	t (h)	$K \times 10^2$ (h^{-1})
Solvent amount (mL/g)					
5.0	36.05	72	22.87	5.39	18.54
7.5	48.44	72	31.61	5.22	20.25
10.0	50.96	48	32.21	4.31	23.19
12.5	52.96	48	34.50	2.33	45.23
15.0	57.76	48	35.18	0.92	102.09
SBR content (%)					
100	29.74	96	18.80	7.03	14.23
80	36.19	96	22.87	10.02	9.98
60	36.85	72	23.43	7.71	12.97
50	37.05	72	22.78	5.39	18.54
40	34.80	72	21.99	8.47	11.80
30	34.78	72	21.98	8.28	12.07
20	31.06	72	19.63	10.00	10.00
[DVB]/[tBS] (mol ratio)					
0.00	43.19	96	27.30	11.17	8.95
0.05	36.05	72	22.87	5.39	18.54
0.10	29.88	72	18.88	3.84	26.02
0.20	22.70	48	14.35	2.52	39.69
0.30	21.61	24	13.66	1.13	88.49
Initiator concentration (%)					
0.5	50.25	120	31.76	18.33	5.45
1.0	45.65	96	28.85	5.51	18.14
2.5	36.05	72	22.87	5.39	18.54
5.0	28.22	72	17.84	4.05	24.70
10.0	23.16	48	14.64	3.13	31.95
Reaction temperature (°C)					
60	41.03	120	25.93	36.39	2.75
70	36.05	72	22.87	5.39	18.54
80	33.88	96	21.41	15.48	6.46
90	36.51	96	23.07	11.61	8.61
Reaction time (h)					
24	39.71	120	25.10	8.15	12.27
48	36.05	72	22.87	5.39	18.54
72	32.40	96	20.48	8.00	12.50
96	32.81	96	20.74	4.22	23.70

The other reaction conditions were SBR content 50%, [DVB]/[tBS] mol ratio 0.05, solvent amount 5.0 mL/g, initiator concentration 2.5%, reaction time 48 h, and reaction temperature 70°C besides changed condition.

caused by the formation of homopolymers and copolymers. After 48 h, however, the viscosity of the reaction mass rises along the reaction path and it is favorable to graft polymerization as well as crosslinking.

Oil Absorbency

Figure 3 shows oil absorbencies of a series of PBSD xerogels at a given mol ratio of DVB to tBS as a function of oil immersion time. The samples were produced with a solvent amount: 5.0 mL/g; SBR content: 50 wt %; BPO concentration: 2.5 wt %; reaction temperature: 70°C; reaction time: 48 h.

Figure 4 shows oil absorbencies of a series of PBSD xerogels at given solvent amounts vs. oil immersion time. The products were from [DVB]/[tBS]: 0.05; SBR content: 50 wt %; BPO concentration: 2.5 wt %; reaction temperature: 70°C; and reaction time: 48 h.

Figure 5 shows oil absorbencies of a series of PBSD xerogels at given initiator concentrations vs. oil immersion time. The specimens were obtained from [DVB]/[tBS]: 0.05; solvent amount:

5.0 mL/g; SBR content: 50 wt %; reaction temperature: 70°C; reaction time: 48 h.

All of discussions about these results were included in the following section.

Swelling Kinetics

Table III shows absorption characteristics of crosslinked PBSD in an oil–toluene solution. As Table III listed, besides changed condition, the other conditions were SBR content 50 wt %, [DVB]/[tBS] mol ratio 0.05, solvent amount 5.0 mL/g, BPO 2.5 wt %, reaction time 48 h and reaction temperature 70°C. It is known from Table III that pure SBR (100% SBR content) could crosslink itself, but its maximum oil absorbency, Q_{max}, was the lowest of all tests concerning SBR content. Swelling kinetic constant, K, of pure SBR was the second largest among them. When the SBR content was 50 wt %, the crosslinked PBSD had the highest values of K as well as Q_{max}. The swelling kinetics may be depended not only on the surfaces of the polymer but also on the number and the volume of the pores in the polymer. The polymer produced from 50 wt % of SBR may have suitable structure for oil absorption.

As the mol ratio of DVB to tBS increased, the values of Q_{max} decreased, but the value of K increased. This result may be explained by the fact that the more DVB content, the stiffer the crosslinked polymer is, and the smaller the cavities produce. At the same time, the smaller cavities will provide larger absorption surfaces, which give higher swelling rate of the polymeric network, namely, larger value of K.

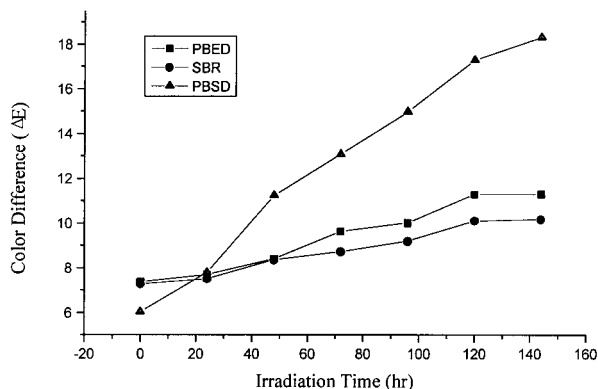By increasing solvent amount, both of Q_{max} and K increased monotonously. The responsibil-

Table IV   Comparison of the Tensile Properties of Cured SBR, PBSD,[a] and PBED[b]

Material	Tensile Strength kg/cm^2	Elongation at Break (%)
Cured SBR	280	440
PBSD	79	410
PBED	35	112

[a] PBSD synthesized from graft polymerization of DVB and tBS onto SBR: [DVB]/[tBS] = 0.05; solvent amount: 5.0 mL/g; reaction time: 48 h; reaction temp.: 70°C; BPO: 2.5 wt %.
[b] PBED produced from graft polymerization of DVB and tBS onto EPDM: [DVB]/[tBS] = 0.05; solvent amount: 5.0 mL/g; reaction time: 48 h; reaction temp.: 70°C; BPO: 2.5 wt %.

ity may be that during the polymerization much more solvent is wrapped in the polymeric network to form huge volume of cavities, which will catch a large quantity of oil in the oil-absorption test. After drying the gel material from THF extraction, the swelling cavity shrinks, and many wrinkles will be produced, which support large surfaces on the xerogel, so that the swelling rate is high. The highest Q_{max} and K were 57.76 g (oil)/g (polymer) and $102.09 \times 10^{-2}\,h^{-1}$, respectively, at a solvent amount of 15.0 mL/g after being immersed in oil solution for 48 h.

The value of Q_{max} decreased with increasing initiator concentration, but the value of K increased. The reason is similar to mol ratio of DVB to tBS.

The influences of reaction temperature and the time on absorption process were listed in Table III also. The values of Q_{max} decreased with increasing reaction temperature or reaction time in general. For the values of the swelling kinetic constant, however, there were not obvious regularity from them.

Light Difference

The light resistance was semiquantitatively expressed in terms of ΔE with the National Bureau of Standards Unit. The smaller ΔE means better light resistance. Figure 6 shows the light resistance of 4-*tert*-butylstyrene–EPDM–divinylbenzene (PBED),[27] SBR, and 4-*tert*-butylstyrene–SBR–divinylbenzene (PBSD), where EPDM is an ethylene–propylene–diene terpolymer. PBSD synthesized in this work does not show better light resistance than does SBR or PBED, due to the photoconductive properties of many double bonds in the chain.

Figure 6   Plot of color difference vs. irradiation time for various samples (by Fade-o-Meter).

Tensile Properties

Table IV shows the tensile properties of SBR, PBSD, and PBED. The tensile strength and the elongation at break of PBSD were not as large as that of SBR, but larger than that of PBED at the same reaction conditions. This means that the tensile properties of the terpolymer can be improved by SBR instead of EPDM.

CONCLUSION

High oil-absorbent Poly(4-*tert*-butylstyrene–SBR–divinylbenzene) (PBSD) was synthesized from 4-*tert*-butylstyrene and divinylbenzene onto SBR using benzoyl peroxide as an initiator by a solution polymerization technique. The effects of the solvent amount, SBR content, mol ratio of DVB to tBS, initiator concentration, reaction temperature, and reaction time were studied in the graft crosslinking polymerization.

The oil absorption tests of various crosslinked polymers were investigated. The important results were summarized as follows.

1. Oil absorbency was dependent not only on the stiffness of the polymeric network, but also on the surface areas of the polymer. So that, the more DVB content or initiator, the lower the oil absorbency, but the higher the rate of absorption.
2. Solvent amount was an important factor impacting on gel fraction. In the present reaction system, 15.0 mL/g is the threshold of gelation process.
3. The polymer, which was produced from solvent amount 15.0 mL/g, SBR content 50 wt %, initiator concentration 2.5 wt % and mol ratio of DVB to tBS 0.05 at 70°C for 48 h, has the highest oil absorbency 57.76 g/g and the largest swelling kinetic constant 102.09×10^{-2} h^{-1}.
4. The light resistance of PBSD was poorer than that of SBR or PBED.
5. The tensile strength and the elongation at break of PBSD were larger than that of PBED at the same reaction conditions.

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