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(2001 5 4 , 2001 10 30)

Structural Changes of Homopolymer Polypropylene Foam with Molecular Weights and Rheological Properties : (1) In Batch Process

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(Received May 4, 2001; accepted October 30, 2001)

: (PP) 가 가 , 가
 PP () () 가 (G'), (G"), 가 가
 Mrad 가 , PP 3.2

ABSTRACT : The effects of molecular weights and rheological properties of polypropylene (PP), on its foam structures in batch process were investigated. The effects of crosslinking process were also considered in this study. The rheological properties of polypropylene, such as storage modulus(G'), loss modulus(G''), zero shear viscosity(η_0), and relaxation time(λ), increased with the increase of molecular weights, and these increases in rheological properties directly affected the stability improvements of the PP foam. The increase of crosslinked PP's gel content stopped at the irradiation dose of 3.2 Mrad. The development of foam structures was more enhanced as the irradiation dose increased up to 3.2 Mrad. When the irradiation dose exceeded 3.2 Mrad, however, it negatively affected the structural development of the foam by diminishing gel contents of the foaming material, which resulted in instability of the foam structure.

Keywords : polypropylene, foam, irradiation crosslinking, molecular weight.

(PP) 가가 (PE) , (PS)
 , PE PS PP PE

1 PP melt strength가 , PP

2 , PP melt strength 가 , PE 가 ,²⁻⁶ 가 7.8 가 “high melt strength” PP 가 (branched) PP 가 , 가 melt strength (melt elasticity) 가 PP PP 가 (MI)가 PP GPC(gel permeation chromatography) parallel plate capillary 가 가 PP SEM(scanning electron microscopy) , PP PP 가 (MI)가 6

Table 1. Molecular Weight Characteristics of PP Used in This Study

sample	MI (g/10min)	T _m	M _n	M _w	M _z	M _w /M _n	M _z /M _w
SH-1	1.1	162.65	108700	469500	1236000	4.32	2.63
SH-2	1.0	164.72	114200	469100	1324000	4.11	2.82
SH-3	1.8	164.74	86460	444100	1507000	5.14	3.39
SH-4	3.1	164.15	72360	357100	1118000	4.94	3.13
SH-5	5.5	162.60	59740	295800	845300	4.95	2.85
SH-6	7.5	162.04	58190	264100	748500	4.54	2.83

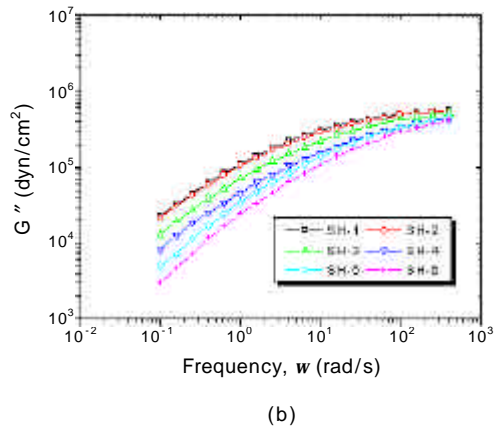
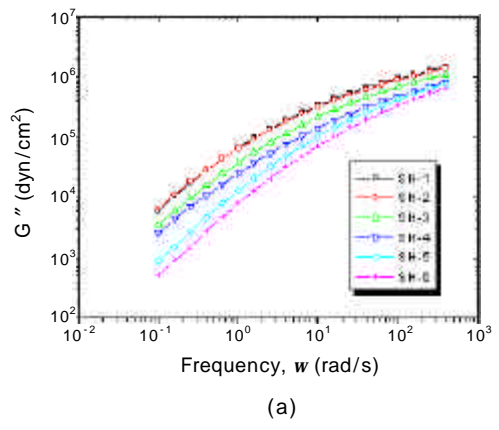


Figure 1. (a) Storage modulus(G') of the PP as a function of frequency at 190 and (b) Loss modulus(G'') of the PP as a function of frequency at 190

Table 1 GPC 가 가 parallel plate capillary (G'),

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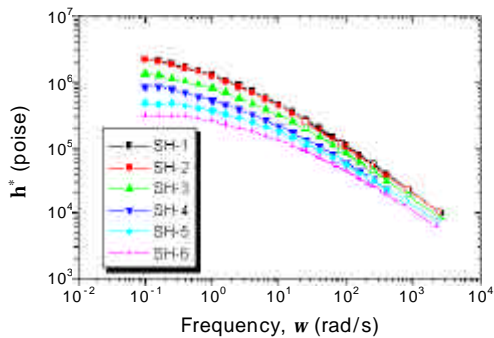


Figure 2. Complex shear viscosities of the PP as a function of frequency at 190 .

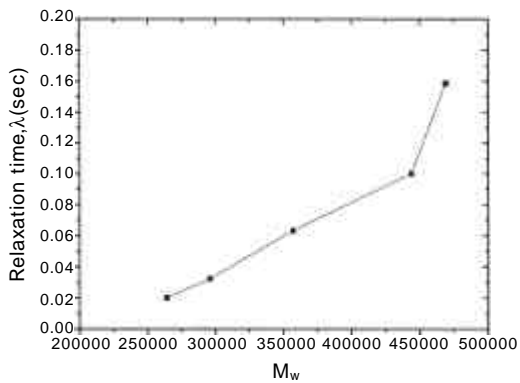


Figure 3. Relaxation time () versus molecular weight (M_w).

Table 2. Physical Properties of Carbon Dioxide¹⁰

properties	carbon dioxide
molecular weight	44.01
critical temp.()	30.98
critical pressure(MPa)	7.42
critical volume(cm^3/mol)	94
melting point ()	- 56.58

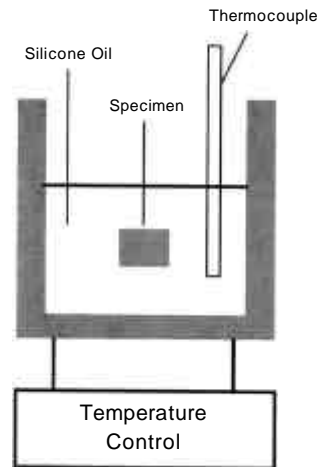


Figure 4. Schematic diagram of foaming apparatus.

(G ") ()
 Figure 1 2 . Parallel plate
 RDS-II(Rheometric Scientific Inc.)
 25 mm 1.8 mm
 , 190
 0.1 500 s^{-1} , 10%
 capillary (Instron 4467)
 190
 16.24 1624 s^{-1}
 Macosko Dealy, Wissbrun G ' G "
 G ' G "
 =1 9,10

,
 가
 , 가 , 가
 Figure 3 가
 CO₂
 가 , 5 7 wt%
 Table 2 CO₂
 CO₂ 가
 42 MPa
 12,13,14
 (SUS 304)
 K thermocouple
 가

: (1)

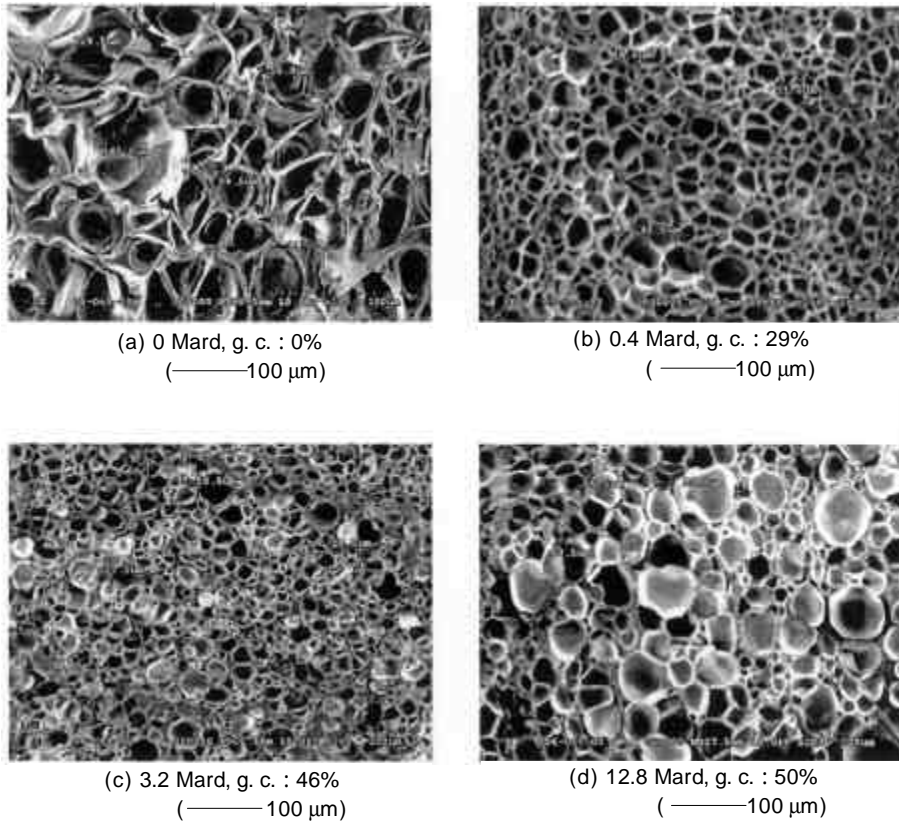


Figure 6. SEM microphotographs of SH - 1 foamed at 200 MPa . Foaming time : (a) 30 sec and (b), (c), (d) 60 sec.
* g. c is the abbreviation of gel content.

PP
6.4 Mrad
가
가
20.8 MPa
CO₂
, 200
,
1)
0.4 Mrad
Figure 6 8 a) b) mm 가
, 가
, Figure 6 469500 , Figure
7 444100, Figure 8 264100 ,
SH - 1 Figure 6 29%
0.4 Mrad 50 mm
, 3.2 Mrad 46%
, 30 mm
, 12.8 Mrad
3.2 Mrad 70
,
PP 가
,
가 SH -

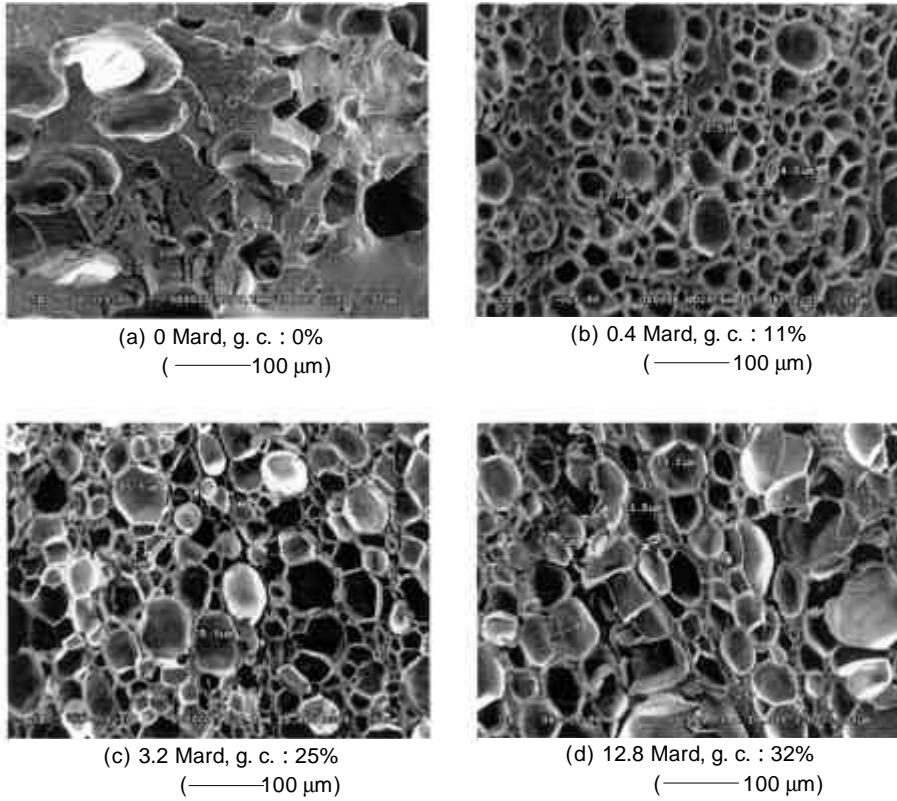


Figure 7. SEM microphotographs of SH - 3 foamed at 200 °C. Foaming time : (a) 30 sec and (b), (c), (d) 60 sec.

3 가 SH - 6
 (Figure 7 8).
 12.8 Mrad 가

10 29%
 SH - 1, SH - 3, SH - 4 29%
 470000
 SH - 1 10 40 mm
 , 450000 SH - 3 20 80 mm
 SH - 3 M_w/M_n M_z/M_w 5.14 3.39

, CPD Figure 9
 1.6 3.2 Mrad

. Figure 11 12%
 SH - 3, SH - 5, SH - 6
 12%

가
 2)

M_n M_w 가
 M_w/M_n M_z/M_w

가
 . Figure

: (1)

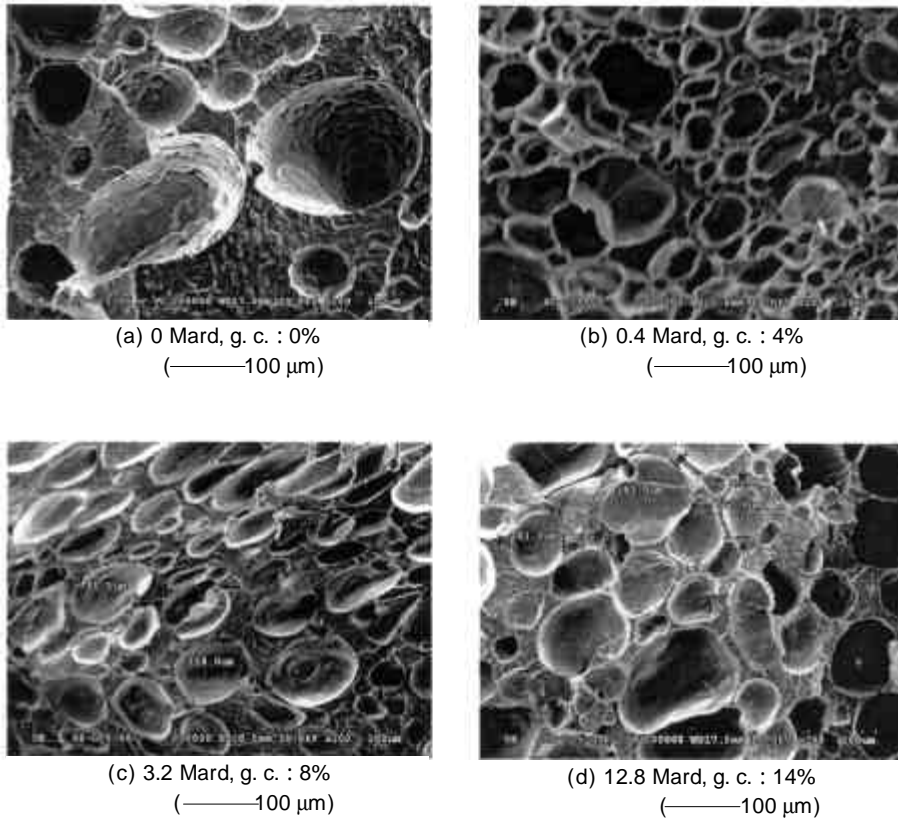


Figure 8. SEM micrographs of SH - 6 foamed at 200 °C. Foaming time : (a) 30 sec and (b), (c), (d) 60 sec.

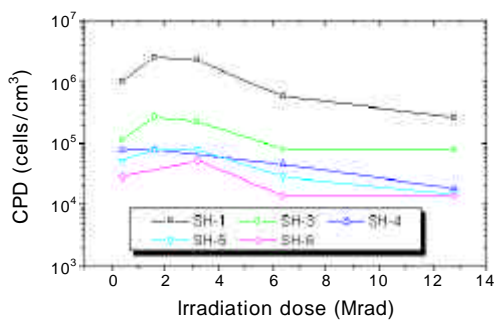
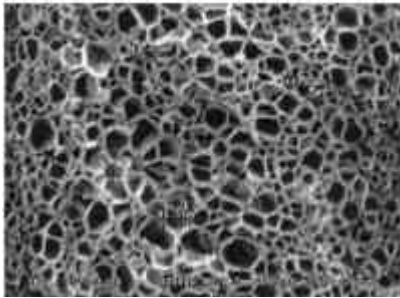


Figure 9. Cell population density(CPD) of the foams by the batch process (foaming temperature 200 °C ; foaming time 60 sec).

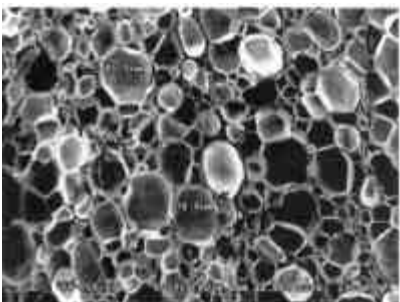
Table 3. Density and CPD Changes with Increase of Foaming Time

sample	30 sec		60 sec	
	density (g/cm ³)	CPD (cells/ cm ³)	density (g/ cm ³)	CPD (cells/ cm ³)
SH - 1	0.3847	5.36 × 10 ⁸	0.4019	2.25 × 10 ⁸
SH - 3	0.3538	4.19 × 10 ⁸	0.4025	2.26 × 10 ⁷
SH - 5	0.3981	1.92 × 10 ⁸	0.3787	8.0 × 10 ⁶
SH - 6	0.3383	1.85 × 10 ⁷	0.3645	5.2 × 10 ⁶

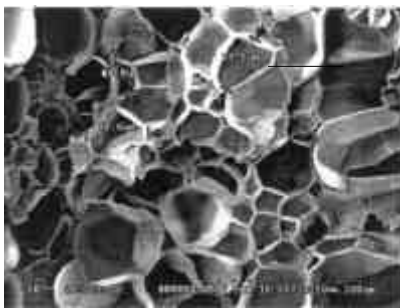
Figure 1 3 G ' , G " , 0 가 가 , 가 0 가 , 가 , G ' , G " 가



(a) SH - 1 (M_w : 469500), 0.4 Mrad
(——100 μ m)

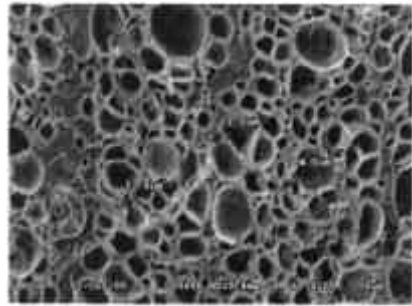


(b) SH - 3 (M_w : 444100), 3.2 Mrad
(——100 μ m)

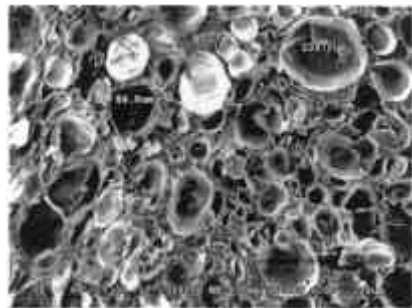


(c) SH - 4 (M_w : 357100), 6.4 Mrad
(——100 μ m)

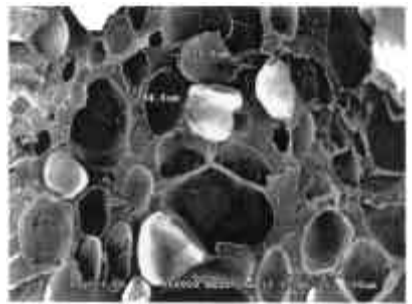
Figure 10. SEM micrographs of the foams with the gel content of 30%.



(a) SH - 3 (M_w : 444100), 0.4 Mrad
(——100 μ m)



(b) SH - 5 (M_w : 295800), 3.2 Mrad
(——100 μ m)



(c) SH - 6 (M_w : 264100), 6.4 Mrad
(——100 μ m)

Figure 11. SEM micrographs of the foams at the gel content of 12% approximately.

3)

40 mm
 M_w 가 470000 , 0.16 s
 가 .

60 , 30
 (CPD) Table 3
 , Figure 12

가 PP 가
 (, M_w 400000) 가
 가 가
 가
 가 (G'),
 (G"), (o)
 가
 가
 가 3.2 Mrad
 가
 , 3.2 Mrad
 40 mm
 PP M_w 450000
 , 0.16 s

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