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APPENDICES

Appendix A Non-Reactive Compatibilization (Chapter IV)

For preparation of PS/NR graft copolymer, the gel or crosslinked structure of NR could occur via free radical reaction. During mixing, the screw speed affected to gel content as shown in Table A1 and related to Figure 4.1.

Table A1 Gel content of PS/NR blend with various screw speeds

Screw Speed (rpm)	Gel Content (wt%)
30	12.05 ± 1.09
35	9.66 ± 1.09
40	4.98 ± 0.95
45	1.91 ± 1.08

The influence of non-reactive compatibilizer (PS/NR) loading on mechanical properties of the compatibilized Nylon12/NR blend was also investigated as shown in Tables A2-A4 and related to Figures 4.5-4.7.

Table A2 Impact energy of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/NR] blends with various PS/NR contents

Materials	Impact Energy (J/m)
Neat Nylon 12	112.05 ± 11.34
Nylon12/NR	230.17 ± 18.64
[Nylon12/NR]/[PS/NR]	
5 phr	345.89 ± 18.52
10 phr	378.54 ± 17.69
15 phr	320.09 ± 16.54
20 phr	300.31 ± 16.58
25 phr	267.82 ± 13.64

Table A3 Tensile modulus of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/NR] blends with various PS/NR contents

Materials	Tensile Modulus (MPa)
Neat Nylon 12	1100.02 ± 10.24
Nylon12/NR	836.35 ± 12.39
[Nylon12/NR]/[PS/NR]	
5 phr	847.36 ± 13.09
10 phr	870.46 ± 14.21
15 phr	854.34 ± 11.30
20 phr	823.56 ± 14.97
25 phr	796.45 ± 13.65

Table A4 Tensile yield stress of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/NR] blends with various PS/NR contents

Materials	Tensile Yield Stress (MPa)
Neat Nylon 12	40.11 ±0.43
Nylon12/NR	21.91 ± 0.45
[Nylon12/NR]/[PS/NR]	
5 phr	22.63 ± 0.39
10 phr	23.04 ± 0.41
15 phr	21.96 ± 0.37
20 phr	20.99 ± 0.38
25 phr	20.45 ± 0.43

Appendix B Reactive Compatibilization: Preparation (Chapter V)

The toughness enhancement of polystyrene (PS) has been done by incorporating with natural rubber (NR) via reactive blending using dicumyl peroxide (DCP) as an initiator and maleic anhydride (MA) as a grafting modifier. The various parameters affecting the impact energy, i.e., an amount of maleic anhydride (3 and 5 wt%) and a different mixing procedures (one-step and two-step mixings) were investigated as shown in Table B1 and related to Figure 5.3.

Table B1 Impact energy of Neat PS, PS/NR blend and PS-NR-MA blends with various mixing procedures and maleic anhydride (MA) contents

Materials	Type of Mixing	Impact Energy (J/m)
PS	One-step	20.50 ± 2.00
PS/NR	One-step	44.61 ± 3.03
PS/NR/MA-3	One-step	56.74 ± 2.29
PS/NR/MA-5	One-step	54.78 ± 2.00
PS/MNR-3	Two-step	51.46 ± 2.30
PS/MNR-5	Two-step	49.93 ± 2.66

Appendix C Reactive Compatibilization: Rheological Properties (Chapter VI)

Figure C1 shows the effect of shear rate on the extrudate swell of the compatibilized Nylon12/NR blend at 7 phr of PS/MNR. This result was related to Figure 6.11.

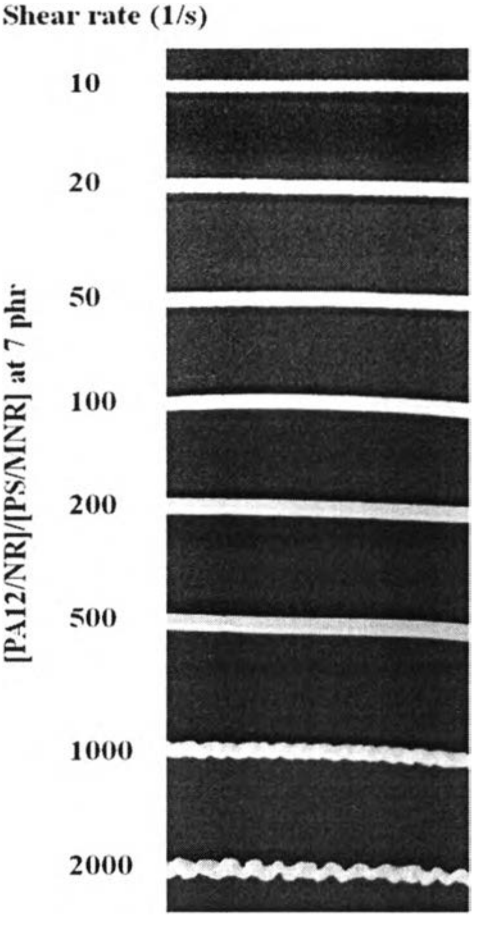

Figure C1 The extrudates of [Nylon12/NR]/[PS/MNR-3] blends at compatibilizer content of 7 phr and temperature of 210 °C with various shear rates.

Figure C2 demonstrates the influence of reactive compatibilizer (PS/MNR) content on the extrudate swell. This result was related to Figure 6.12.

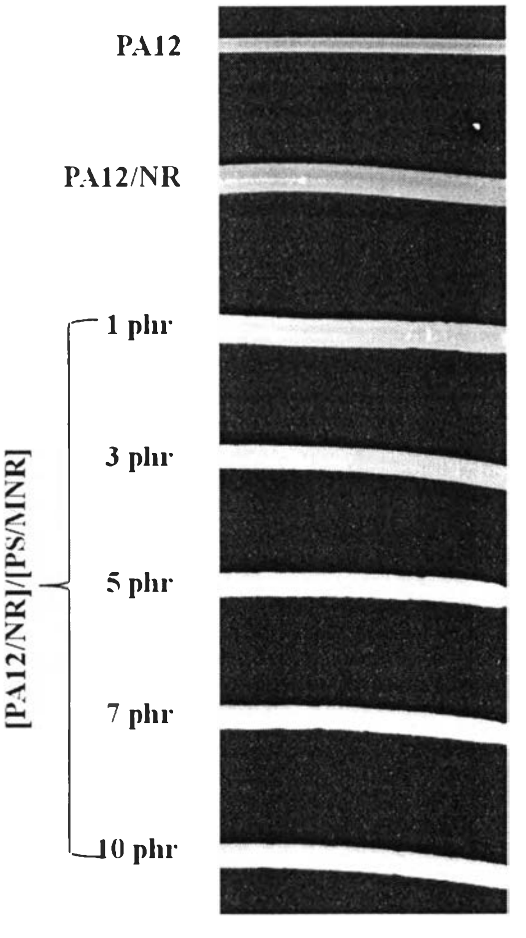

Figure C2 The extrudates of [Nylon12/NR]/[PS/MNR-3] blends with various compatibilizer contents at 210 °C and shear rate of 100 s^{-1}.

Appendix D Reactive Compatibilization: Thermal Properties, Phase Morphology and Mechanical Properties (Chapter VII)

Table D1 shows the influence of compatibilizer content (1-10 phr) and MA loading (3 and 5 wt%) on thermal properties of the compatibilized blends.

Table D1 Melting temperature (T_m), crystallization temperature (T_c) and degree of crystallinity of the blends

Materials	T_m (1st) (°C)	T_c (°C)	T_m (2nd) (°C)	ΔH_m (J/g)	%Xc
Neat Nylon12	179.1	149.5	177.8	52.1	21.2
Nylon12/NR	177.2	148.4	177.8	40.1	20.4
[Nylon12/NR]/[PS/NR]					
1 phr	179.7	149.1	177.4	39.8	20.5
3 phr	177.8	149.0	176.6	37.9	19.8
5 phr	179.8	148.0	178.2	37.3	20.0
7 phr	179.2	148.0	178.3	37.2	20.2
10 phr	178.0	148.7	177.4	36.3	20.2
[Nylon12/NR]/[PS/MNR-3]					
1 phr	176.5	148.3	177.2	39.3	20.2
3 phr	179.1	147.5	178.3	39.1	20.5
5 phr	177.6	148.4	177.6	38.7	20.7
7 phr	179.3	147.6	177.8	36.2	19.7
10 phr	179.0	148.7	177.9	34.8	19.5
[Nylon12/NR]/[PS/MNR-5]					
1 phr	178.5	148.8	177.6	48.0	24.7
3 phr	178.5	148.4	178.7	41.4	21.6
5 phr	178.9	148.4	178.0	38.3	20.5
7 phr	179.2	149.7	177.1	37.4	20.3
10 phr	179.0	148.9	177.3	37.2	20.7

Figures D1-D6 and Table D2 illustrate the influence of compatibilizer content (1-10 phr) and MA loading (3 and 5 wt%) on phase morphology and rubber particle size of the compatibilized blends.

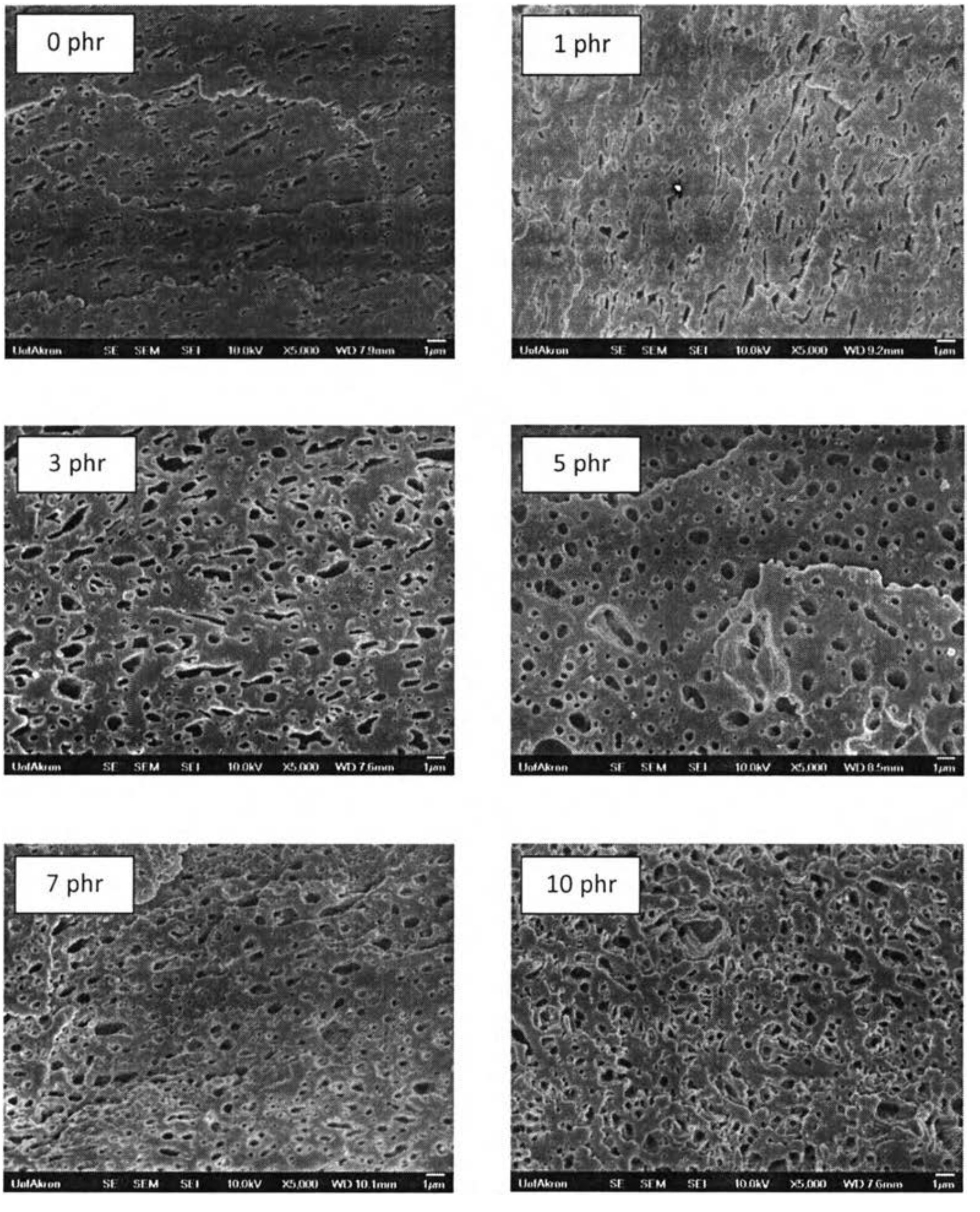

Figure D1 SEM micrographs (x5,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/NR content.

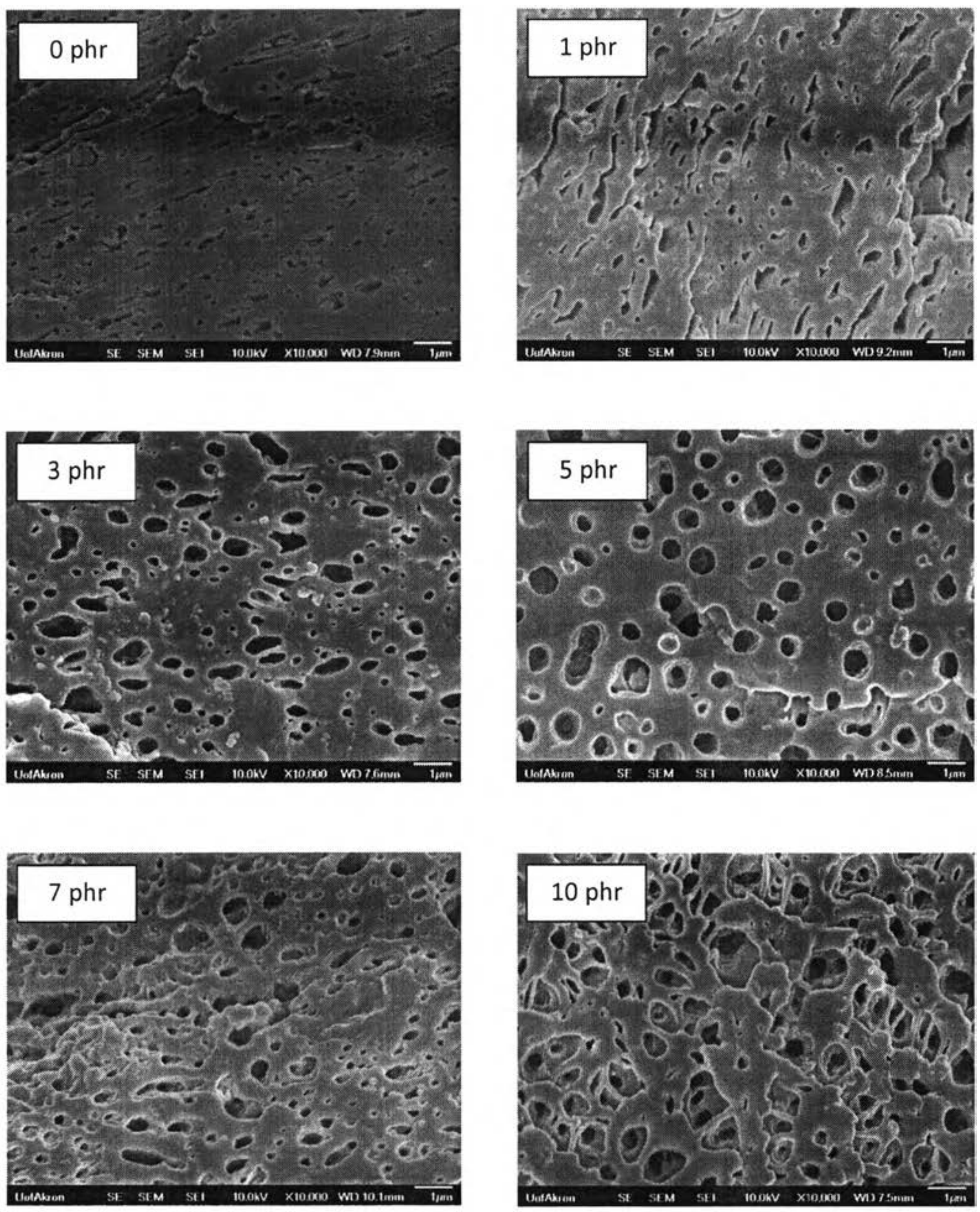

Figure D2 SEM micrographs (x10,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/NR content.

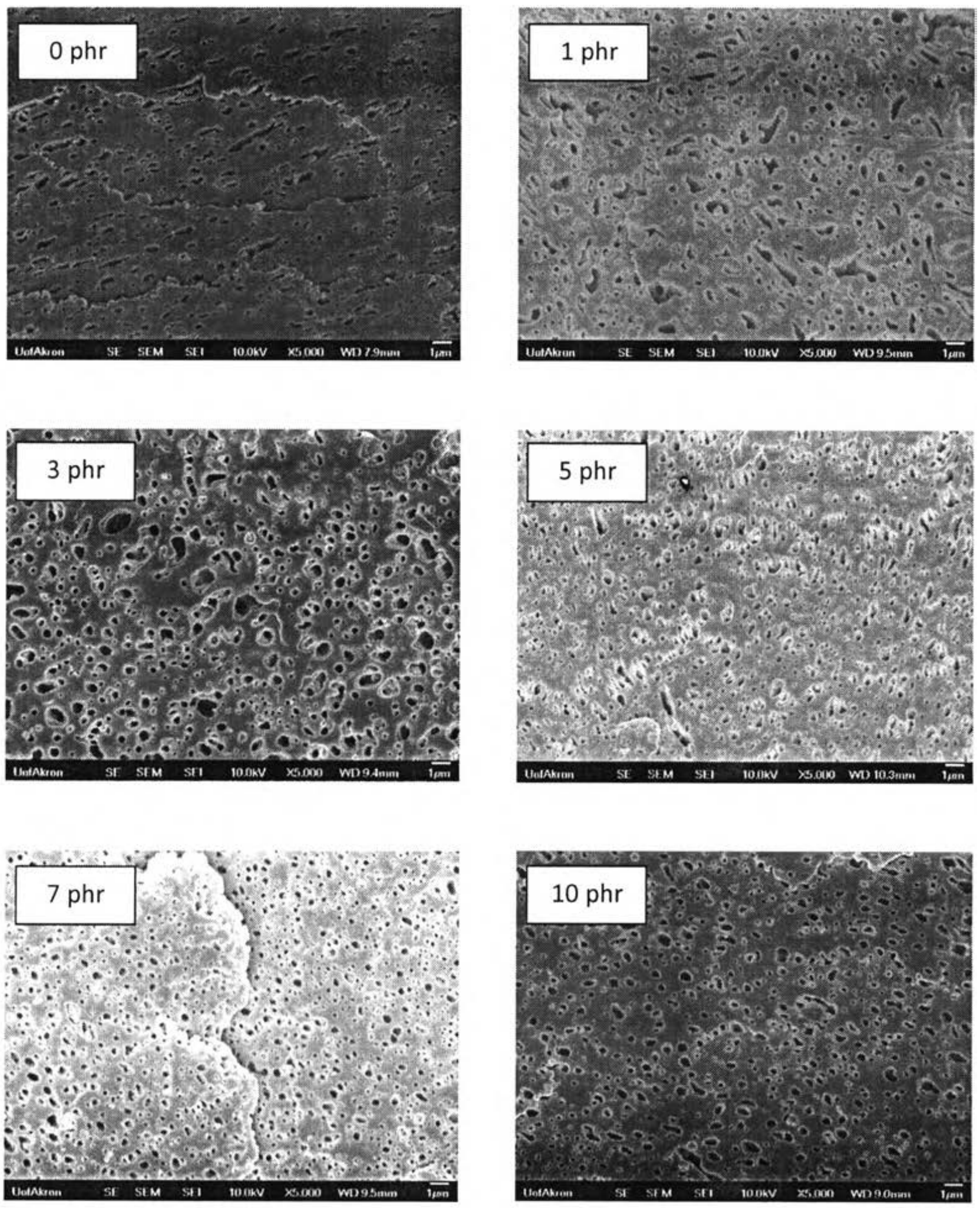

Figure D3 SEM micrographs (x5,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/MNR-3 content.

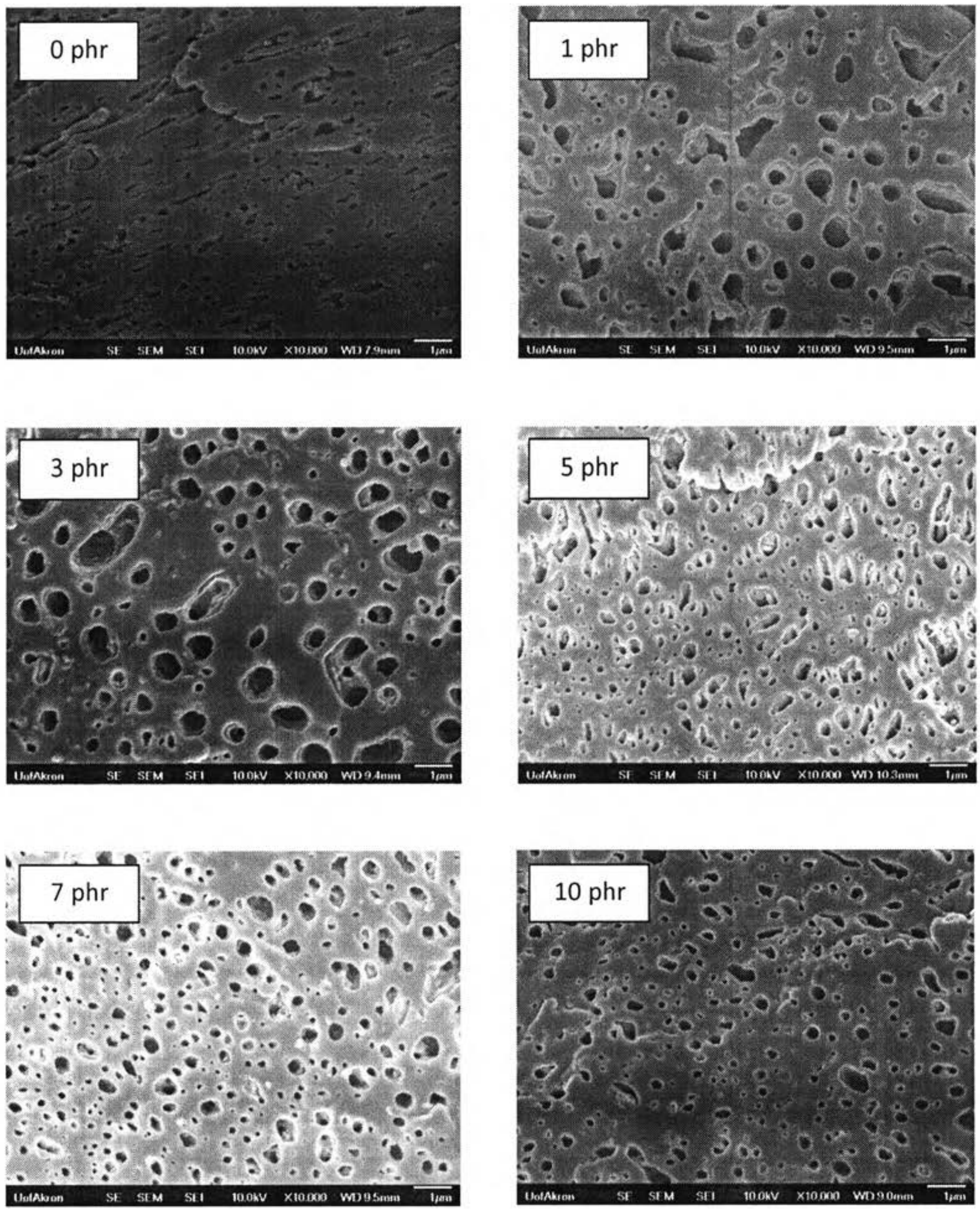

Figure D4 SEM micrographs (x10,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/MNR-3 content.

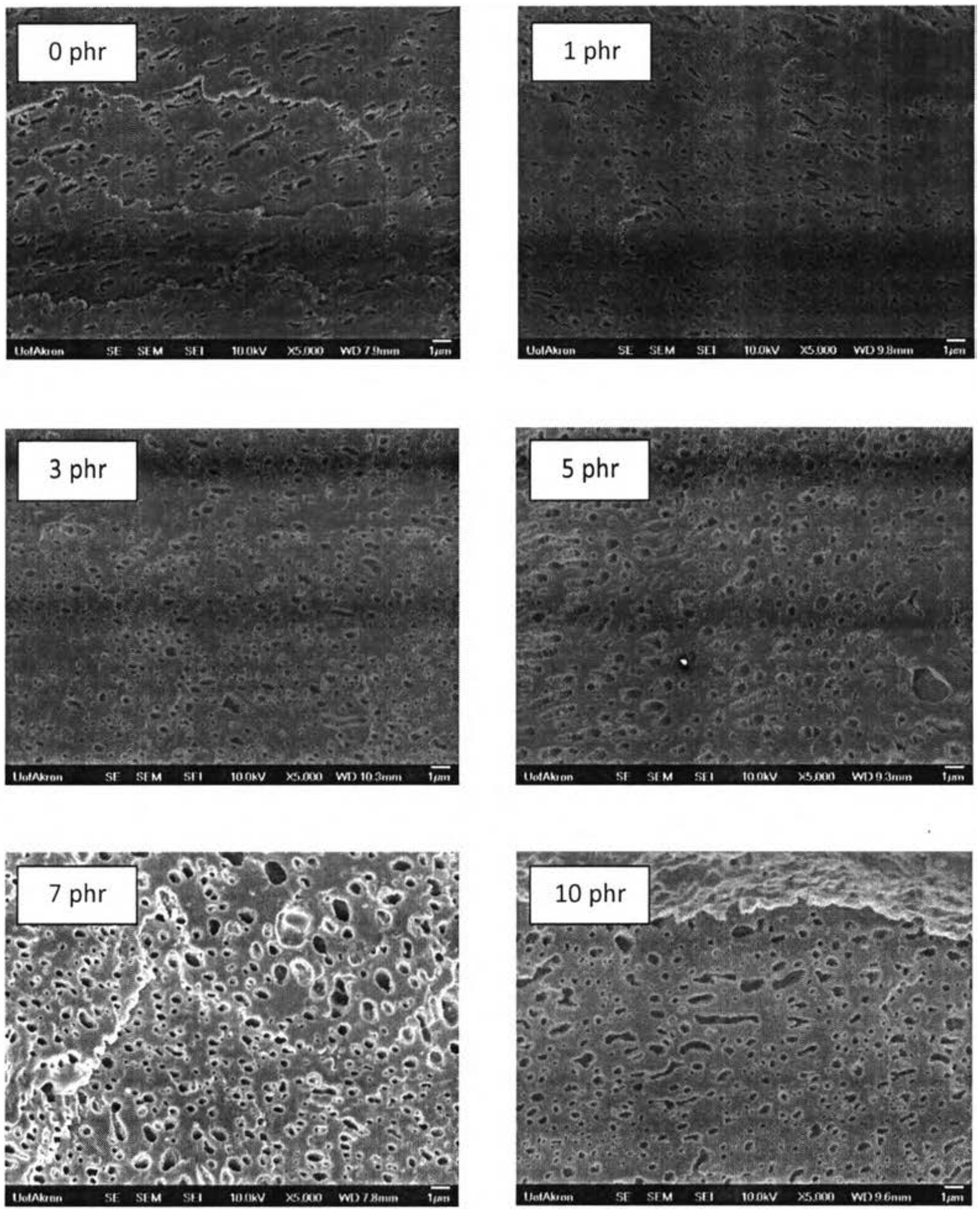

Figure D5 SEM micrographs (x5,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/MNR-5 content.

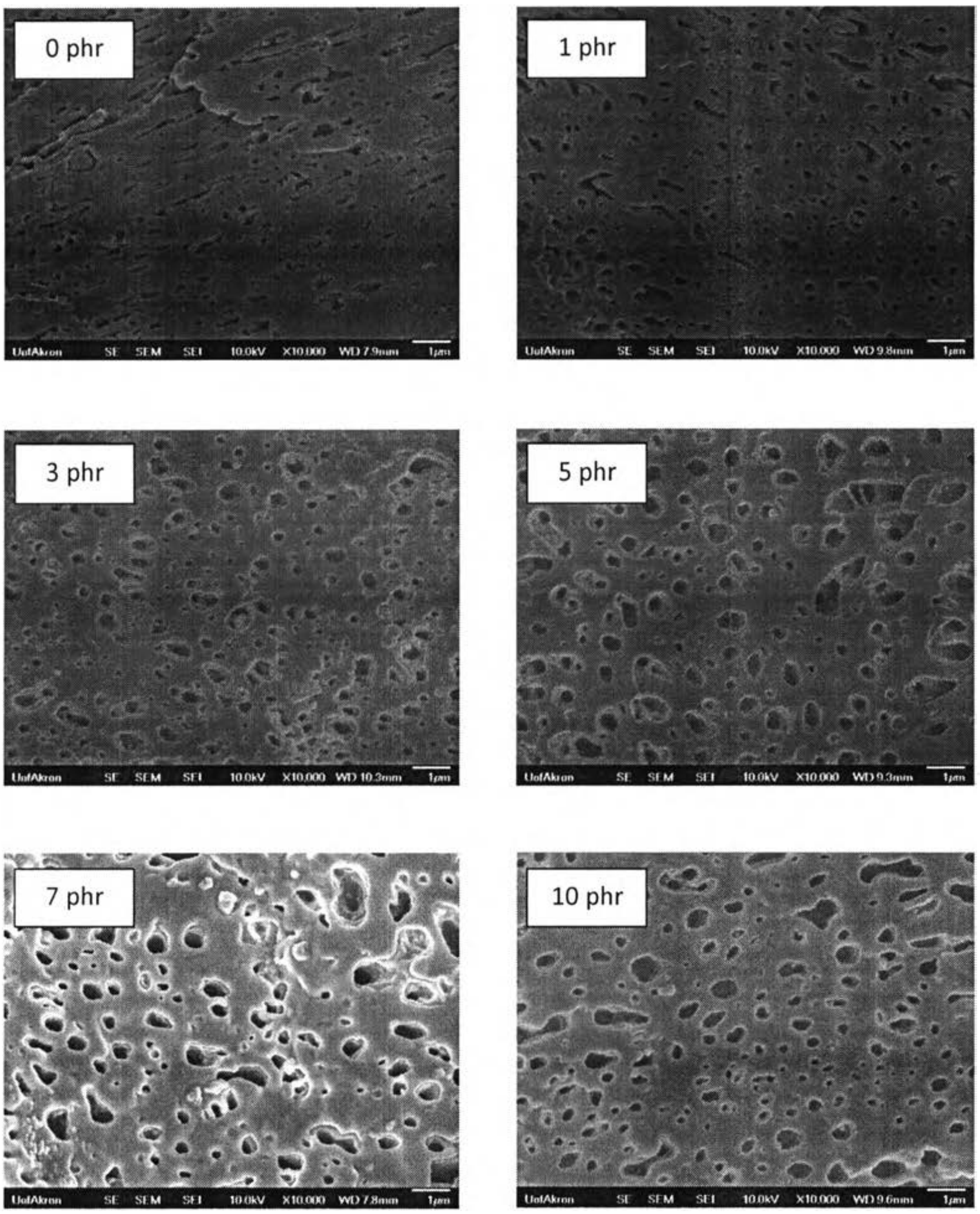

Figure D6 SEM micrographs (x10,000) of the cryofracture surfaces of the uncompatibilized blend and the compatibilized blends with various PS/MNR-5 content.

Table D2 Diameter of dispersed rubber phase of Nylon12/NR binary blend and [Nylon12/NR]/compatibilizer blends with various compatibilizer types and contents

Materials	Rubber Particle Diameter* (μm)
Nylon12/NR	0.72 ± 0.38
[Nylon12/NR]/[PS/NR]	
1 phr	0.68 ± 0.38
3 phr	0.57 ± 0.36
5 phr	0.47 ± 0.47
7 phr	0.46 ± 0.32
10 phr	0.44 ± 0.25
[Nylon12/NR]/[PS/MNR-3]	
1 phr	0.49 ± 0.33
3 phr	0.45 ± 0.25
5 phr	0.34 ± 0.17
7 phr	0.31 ± 0.17
10 phr	0.37 ± 0.21
[Nylon12/NR]/[PS/MNR-5]	
1 phr	0.54 ± 0.49
3 phr	0.38 ± 0.23
5 phr	0.37 ± 0.21
7 phr	0.42 ± 0.32
10 phr	0.41 ± 0.33

*The average diameter of about 100 rubber domains randomly selected from SEM micrographs

Tables D3-D9 show the influence of compatibilizer content (1-10 phr) and MA loading (3 and 5 wt%) on impact, tensile and flexural properties of the compatibilized blends.

Table D3 Impact energy of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/compatibilizer blends with various compatibilizer types and contents

Materials	Impact Energy (J/m)
Neat Nylon12	115.23 ± 9.12
Nylon12/NR	241.11 ± 17.15
[Nylon12/NR]/[PS/NR]	
1 phr	367.43 ± 25.03
3 phr	375.59 ± 23.46
5 phr	402.86 ± 26.71
7 phr	434.67 ± 23.46
10 phr	447.79 ± 21.63
[Nylon12/NR]/[PS/MNR-3]	
1 phr	421.46 ± 26.42
3 phr	458.86 ± 27.26
5 phr	481.74 ± 28.26
7 phr	503.98 ± 27.14
10 phr	493.46 ± 28.82
[Nylon12/NR]/[PS/MNR-5]	
1 phr	413.49 ± 24.84
3 phr	441.47 ± 21.63
5 phr	467.83 ± 24.52
7 phr	482.89 ± 24.81
10 phr	476.94 ± 26.09

Table D4 Tensile modulus of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/compatibilizer blends with various compatibilizer types and contents

Materials	Tensile Modulus (MPa)
Neat Nylon12	1243.28 ± 76.54
Nylon12/NR	845.26 ± 81.21
[Nylon12/NR]/[PS/NR]	
1 phr	851.25 ± 83.16
3 phr	869.71 ± 80.26
5 phr	875.77 ± 78.95
7 phr	894.49 ± 83.22
10 phr	920.36 ± 81.29
[Nylon12/NR]/[PS/MNR-3]	
1 phr	875.36 ± 79.54
3 phr	894.26 ± 74.26
5 phr	924.87 ± 65.24
7 phr	1194.26 ± 66.58
10 phr	987.26 ± 71.26
[Nylon12/NR]/[PS/MNR-5]	
1 phr	862.26 ± 81.33
3 phr	881.14 ± 86.67
5 phr	901.74 ± 82.27
7 phr	985.22 ± 76.69
10 phr	967.54 ± 76.25

Table D5 Tensile stress at yield of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/compatibilizer blends with various compatibilizer types and contents

Materials	Tensile Stress at Yield (MPa)
Neat Nylon12	47.48 ± 1.74
Nylon12/NR	39.71 ± 1.98
[Nylon12/NR]/[PS/NR]	
1 phr	38.25 ± 2.54
3 phr	34.71 ± 1.97
5 phr	33.77 ± 2.05
7 phr	34.81 ± 2.47
10 phr	33.01 ± 1.69
[Nylon12/NR]/[PS/MNR-3]	
1 phr	37.90 ± 2.03
3 phr	42.60 ± 1.86
5 phr	36.57 ± 1.67
7 phr	46.85 ± 1.59
10 phr	39.83 ± 1.87
[Nylon12/NR]/[PS/MNR-5]	
1 phr	35.43 ± 1.74
3 phr	35.00 ± 2.98
5 phr	37.50 ± 2.42
7 phr	37.03 ± 2.26
10 phr	38.26 ± 3.08

Table D6 Elongation at break of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/compatibilizer blends with various compatibilizer types and contents

Materials	Elongation at Break (%)
Neat Nylon12	72.64 ± 5.90
Nylon12/NR	84.70 ± 7.40
[Nylon12/NR]/[PS/NR]	
1 phr	81.36 ± 5.06
3 phr	92.58 ± 6.89
5 phr	104.33 ± 8.19
7 phr	106.98 ± 7.48
10 phr	115.68 ± 8.12
[Nylon12/NR]/[PS/MNR-3]	
1 phr	88.33 ± 6.85
3 phr	105.56 ± 5.71
5 phr	108.89 ± 6.19
7 phr	129.88 ± 5.55
10 phr	129.95 ± 7.09
[Nylon12/NR]/[PS/MNR-5]	
1 phr	96.25 ± 7.44
3 phr	99.89 ± 6.98
5 phr	105.35 ± 7.36
7 phr	115.97 ± 5.74
10 phr	106.18 ± 8.26

Table D7 Flexural modulus of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/MNR-3] with various compatibilizer contents

Materials	Flexural Modulus at 0.5%-1.0% (MPa)
Neat Nylon12	527.7 ± 35.2
Nylon12/NR	361.3 ± 31.3
[Nylon12/NR]/[PS/MNR-3]	
1 phr	421.9 ± 26.5
3 phr	428.1 ± 30.6
5 phr	434.4 ± 32.7
7 phr	440.3 ± 27.6
10 phr	438.7 ± 29.2

Table D8 Flexural stress of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/MNR-3] with various compatibilizer contents

Materials	Flexural Strength (MPa)	Flexural Stress at 5% Strain (MPa)	Flexural Stress at Break (MPa)
Neat Nylon12	38.70 ± 1.12	21.69 ± 1.14	35.24 ± 1.57
Nylon12/NR	14.33 ± 0.98	8.47 ± 1.58	12.10 ± 1.88
[Nylon12/NR]/[PS/MNR-3]			
1 phr	24.68 ± 2.01	13.70 ± 1.87	21.36 ± 0.97
3 phr	24.95 ± 1.45	14.07 ± 1.11	21.73 ± 1.14
5 phr	25.46 ± 1.95	14.66 ± 0.96	22.00 ± 1.19
7 phr	26.16 ± 1.53	15.02 ± 0.86	22.15 ± 1.85
10 phr	25.60 ± 1.22	14.78 ± 1.03	22.03 ± 2.00

Table D9 Flexural strain of Neat Nylon12, Nylon12/NR binary blend and [Nylon12/NR]/[PS/MNR-3] with various compatibilizer contents

Materials	Flexural Strain (%)
Neat Nylon12	10.97 ± 1.56
Nylon12/NR	12.80 ± 1.23
[Nylon12/NR]/[PS/MNR-3]	
1 phr	11.80 ± 1.91
3 phr	11.87 ± 2.01
5 phr	12.02 ± 1.34
7 phr	12.28 ± 2.33
10 phr	12.10 ± 2.19

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Publications:

1. Saengthaveep, S.; and Magaraphan, R. (2013). Natural rubber-toughened Nylon12 compatibilized by polystyrene/natural rubber blend. Advances in Polymer Technology, 32(3), 1-11.
2. Saengthaveep, S.; Jana S.; and Magaraphan, R. (2015). Flow and structure of compatibilized Nylon12/natural rubber blend with functional copolymer. Journal of Elastomers and Plastics, 1-26.
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Proceedings:

1. Saengthaveep, S.; and Magaraphan, R. (2009, February 24-27). Reactive extrusion of Nylon12/natural rubber compatibilized by *in situ* reactive PS/NR blend. Proceedings of Global Plastics Environmental Conference (GPEC), Florida, USA.
2. Saengthaveep, S.; and Magaraphan, R. (2011, May 10-14). Natural rubber-toughened polyamide12. Proceedings of the 27th Polymer Processing Society, Marrakech, Morocco.
3. Saengthaveep, S.; Jana S.; and Magaraphan, R. (2013, July 14-17). Natural rubber-toughened polystyrene: Effects of mixing procedure and maleic anhydride content on impact property and phase morphology. Proceedings of the 4th International Conference on Multi-Functional Materials and Structures (MFMS), Bangkok, Thailand.
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Presentations:

1. Saengthaveep, S.; and Magaraphan, R. (2009, February 24-27). Reactive extrusion of Nylon12/natural rubber compatibilized by *in situ* reactive PS/NR blend. Paper presented at Global Plastics Environmental Conference (GPEC), Florida, USA.
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