POLYMER BLENDS

AND THEIR RELEVANCE TO FIBER, TEXTILE AND CARPET RECYCLING

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CARPET WASTE

A four component system

- FACE FIBER - NYLON
- PRIMARY AND SECONDARY BACKING - POLYPROPYLENE
- ADHESIVE - SBR LATEX
- FILLER - $CaCO_3$

TEXTILE AND APPAREL WASTE

- PET, NYLON 6, NYLON 66, PE, PP, ELASTOMERIC FIBERS, COTTON, RAYON, WOOL, SILK
- Cotton, rayon, wool, and silk along with glass fibers can be used as reinforcing agents
- Elastomeric fibers as toughening agents?
- Melt blending and compatibilizing of other components

POLYMER RECYCLING

- DEPOLYMERIZATION
- MELT PROCESSING OF MIXED THERMOPLASTICS
- SEPARATION AND MELT PROCESSING OF THERMOPLASTICS
- COMPOSITES MANUFACTURING USING MIXED FIBROUS WASTE
- ALTERNATIVE APPLICATIONS OF FIBROUS WASTE WITHOUT MELT PROCESSING - e.g. non-wovens, geo-textiles etc.
- SOLID WASTE to ENERGY

MELT PROCESSING

- NYLON AND POLYPROPYLENE INCOMPATIBLE
- COMPATIBILIZERS CAN BE ADDED
- Appropriate particle size rubber can act as toughening agent - Can SBR?
- Fillers are commonly used in plastics processing - How about $CaCO_3$? Dust?
- Role of fiber finishes, dyes, pigments, anti-oxidants, stabilizers and other additives.

Agglomeration/Densification

- Thermoplastics such as PE, PP, PS, nylons, PET, polyurethane, PVC, ABS etc..
- Mixtures of these materials, films, fibers, foams etc...
- Convert into free flowing granules of high density
- Suitable for extrusion and injection molding
- Pullmann Pulverizers Co. Inc., 820 Bloomfiled Ave., Clifton NJ 07012, Tel (201)471-1450

Carpet Samples

SAMPLE	NYLON %	PP%	SBR & filler %
A	70	20	10
B	57	19	24
C	52	11	37

COMPATIBILIZERS and other additives

- PB3002 Maleic Anhydride Grafted Polypropylene
- Kraton 1901x A tri-block copolymer of polystyrene end blocks and poly(ethylene - butylene)midblocks grafted by 2% maleic anhydride.
- SEBS (styrene -ethylene/butylene -styrene block copolymer) and SIS (styrene -isoprene - styrene block copolymer)were used as toughening agents.

Experimental

- Carpet extruded on Haake TW-100 extruder
- Films compression molded
- Dog-bone shaped samples tested for mechanical properties
- Selected extruded samples were also injection molded and tested
- Morphology determined using SEM
- Thermal behavior using DSC

Extrusion Parameters

Temperature Zone 1 (°C)	Temperature Zone 2 (°C)	Temperature Zone 3 (°C)	Temperature Zone 4 (°C)	Screw Speed (rpm)
150	220	225	230	70/170
190	210	220	235	70/170
150	220	235	250	70/170
160	220	240	260	70/170

Preferred Experimental Conditions

- Double Pass Extrusion
- Molding at 500°C
- Screw speed 170 rpm
- Extrusion at 150,220,235, and 250°C
- 8 - 15% Kraton /other additives

Properties of Selected Samples

T. Chen, M. S. Thesis, "Recycling Carpet Waste by Reactive Extrusion", March 1996, Georgia Tech

Sample	Strength (KSI)	Strain to Failure (%)	Work of Rupture (lb/in^2)
A/PB3002 - 15%	7.0	8	275
A/Kraton 5%	5.8	12.6	460
A/Kraton - 15%	5.3	31	1160
A/Kraton - 7%/ SEBS - 8%	5.8	27	1100
B/Kraton - 8%/ SIS - 10%	3.7	32.8	970
C/Kraton - 8%/ SIS -10%	2.5	23.9	570
B/Kraton -5%/ nylon 66 10%	5.1	18.8	790
C/Kraton - 5%/ nylon 66 - 10%	4.1	18.4	865

Effect of Compatibilizers on the Melt Flow Index

	MFI (g/10 min)	
Compatibilizer /amount (%)	PB3002	Kraton
0	12.6	12.6
5	6.8	-
10	5.2	5.9
15	4.5	3.6

Effect of Kraton on the Thermal Behavior of Sample A

Kraton		0%	5%	10%	15%
Melting Temperature ˚C	PP	161	163	163	162
	Nylon6	214	215	214	214
	Nylon66	241	243	242	243
Crystallization Temperature ˚C	PP	110	95	89	81
	Nylon 6	190	190	190	190

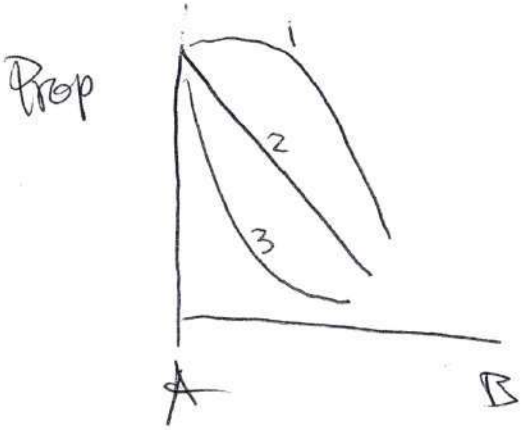
Effect of Rubber and Fillers

- Small particles < 1µm
- Carbon black
- $CaCO_3$
- Talc
- Titanium Dioxide
- Acrylonitrile butadiene styrene (ABS)
- Rubber modified PP

Discussion

- Carpet can be melt extruded.
- Addition of compatibilizers and toughening agents improves strain to failure.
- Foul odor at the melt processing temperature of nylon 66.
- Degradation of SBR during melt processing.
- If SBR can be broken into appropriate particle size during melt processing, then it can act as toughening agent. Can latex be chemically modified for this purpose?
- Few percent grafting of maleic anhydride on SBR before it is applied to carpet can convert SBR into compatibilizer.
- Selective decrosslinking of SBR at melt processing temperature?
- Calcium carbonate with controlled particle size can be an effective filler for the melt processed resin.
- New carpet construction with reduced number of compatible components.

Properties of Polymer Blends



- 1 > Rule of Mixtures
- 2 = Rule of Mixtures
- 3 < Rule of Mixtures

Miscible Polymers

- Can alter the melting point
- Change the crystallization kinetics

- If Tg decreases, then crystallization kinetics should increase as the addition of nylon 6 in bisphenol A polycarbonate increases the crystallization rate of polycarbonate.
- If Tg increases, then crystallization rate can significantly decrease, as for nylon 6 when PVC is added.
- Co-crystallization in polymer blends is rare.

Miscible Polymer Blends

poly(phenylene oxide) PPO/Polystyrene

- PPO Tg 210°C
- Polystyrene Tg 100°C
- Intermediate compositions offer a range of heat distortion temperatures

Nylon6/ Nylon66

Khanna and Turi, ACS Polymer Preprints, August 1984, p.98

- Random Copolymers in the presence of 1% triphenyl phosphite(TPP)
- Results in single melting transition rather than two melting transitions corresponding to nylon 6 and nylon 66
- Excellent Mechanical Properties

Nylon6/ Nylon66

Khanna and Turi, ACS Polymer Preprints, August 1984, p.98

Nylon6/ Nylon 66	% TPP Catalyst	Tensile Strength (KPSI)	Strain to Failure (%)	Tensile Modulus (KPSI)
100/0	0	10.6	340	171
0/100	0	11.4	315	212
80/20	1	12.0	355	116
60/40	1	13.5	355	134
40/60	1	12.9	370	147
20/80	1	13.3	375	167

Stabilizers used in Recycled Plastics

- Organic phosphites
- Phenolic anti-oxidants
- Hindered amine stabilizers
- Ultraviolet absorbers

- Ciba-Geigy Ltd., Additives Divsion CH-4002 Basle Switzerland
- Group Additives for Plastics Recycling, Ciba Additive Gmbh, D-64686 Lautertal, Germany

Mixed Plastics waste to Chemical Feed Stock in Germany

- BASF's Feed Stock Recycling Pilot Plant started in April 1994 in Ludwigshafen (Germany)
- 300,000 meteric tons per year of mixed plastics waste to be converted to liquid feed stocks by low pressure pyrolysis
- $175 million full scale recycling plant.
- BASF technology requires no presorting or cleaning the waste,keeping the costs low.
- Products are a mixtures of naptha, aromatics, and oils.
- Pat. Layman, Chemical and Engineering News, March 28, 1994, p. 19.

Carpet Waste in USA

- Approximately 3 billion lbs of old carpet removed in 1995.
- Over 99% of used carpet landfilled at a cost of approximately $75 million
- Old carpets represents only about 1% by weight of all municipal solid waste.
- Face yarn nylon6 or nylon66 ~40 oz per sq yd
- Primary and secondary backing ~8 oz per sq yd.
- Adhesive typically carboxylated styrene butadiene copolymer ~28 oz per sq yd. Filler (calcium carbonate is ~75% of the total weight of the adhesive).

Municipal Solid Waste

U.S. EPA Report PB90-215112, NTIS, Springfield VA, June 1990
as quoted in "Management of Polymer and Fiber Solid Waste (Part I)", Textile Research Institute, Report No. 37, July 1991

- ~ 200 million tons annually
- 40% of this waste is paper and paper board products
- 8% Plastics
- 2% Textiles
- ~25% paper and paper board products are recycled
- ~1% plastics and clothing/ footwear each recycled

Recent Books on Plastics Recycling

- R. J. Ehrig, editor, "Plastics Recycling", HanserPublishers, 1992.
- F. P. La Mantia, editor, "Recycling of Plastic Materials, ChemTec Publishing, 1993.
- G. D. Andrews and P. M. Subramanian, editors, "Emerging Technologies in Plastics Recycling", ACS Symposium Series 513, 1992
- C. P. Rader et al., editors, "Plastics, Rubber, and Paper Recycling: A Pragmatic Approach", ACS Symposium Series 609, 1995.

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