Eastoflex Amorphous Polyolefins as Elastomer Extenders in Hot-Melt Adhesive and Sealant Formulations

Styrenic block copolymers are used as elastomer bases in a variety of hot-melt applications. These include pressure-sensitive tapes and labels, nonwoven assemblies, sealants, and other applications. Included among these elastomers are block copolymers such as styrene-isoprene-styrene (SIS), styrene-ethylene-butylene-styrene (SEBS), and styrene-butadiene-styrene (SBS). These materials are sold under trademarks such as *Kraton*, *Europrene*, *Vector*, and *Stereon*.

Several *Eastoflex* amorphous polyolefins (APOs) from Eastman Chemical Company have been found to be effective extenders for these block copolymers. Their relatively low selling price can result in lower raw material costs when the APO is used to replace a portion of the elastomer in the formulation.

An extensive study has been made by Eastman's Adhesives and Sealants Raw Materials Laboratory to determine the effects on physical and adhesive properties when APOs are substituted for up to 50% of the styrenic block copolymer in a typical hot-melt pressure-sensitive adhesive formulation. The APOs studied included amorphous polypropylene homopolymers and amorphous propylene-ethylene copolymers. Representative block copolymers of SIS, SEBS, and SBS were studied.

Compatibility was examined by thermal aging and by electron microscopy. Other properties examined included tensile strength; elongation; adhesive and static shear bond strength at elevated and ambient temperatures; and pressure-sensitive tack, bond strength, and holding power. All testing was performed in accordance with PSTC and ASTM standards.

Tables 1 through 3 show the formulations tested and the resulting physical and pressure-sensitive properties. The SEBS-block copolymer exhibited the greatest compatibility with APOs, followed by the SIS type. As shown in Table 3, the SBS type was found to be the least compatible.

Tables 4 through 6 show typical starting-point formulations for a pressure-sensitive adhesive, a disposable diaper elastic-attachment adhesive, and a hot-melt sealant, which were APO-modified. Also shown are test results for each of these formulations.

Table 1 APO Substitution for SEBS Block Copolymer in Hot-Melt Adhesive Formulations

Ingredient, %							
Kraton G-1652 (SEBS)	20	18	15	10	18	15	10
Eastoflex P1023 (APP)	—	2	5	10	—	—	—
Eastoflex E1060 (APE)	—	—	—	—	2	5	10
Shellflex 371[a]	20	20	20	20	20	20	20
Eastotac H-100R	59.50	59.50	59.50	59.50	59.50	59.50	59.50
Irganox 1010[b]	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Cyanox 1212[c]	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Physical Properties							
Viscosity @ 177°C	1,805	1,325	1,000	498	1,680	1,230	700
RBSP, °C	91	91	83	82	92	92	83
Tensile strength, psi	132	107	97	41	116	74	32
Elongation, %	597	641	694	742	656	747	678
High-temperature peel—kraft paper, °C	54	49	49	33	46	46	44
High-temperature shear—kraft paper, °C	68	63	53	57	57	58	57
Molten stability, 100 h[d]	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Pressure-Sensitive Properties							
Static shear strength, h	47.5	>300	>300	>300	>300	>300	>300
Probe tack, g	<10	<10	<10	<10	<10	<10	<10
180° peel (PSTC-1), g	572	528	535	185	715	693	162

[a] *Shell Chemical Company*
[b] *Ciba-Geigy Corporation*
[c] *American Cyanamid*
[d] *Pass = No phase separation* *Fail = Phase separation*

Table 2 APO Substitution for SIS Block Copolymer in Hot-Melt Adhesive Formulations

Ingredient, %							
Kraton D-1107 (SIS)	20	18	15	10	18	15	10
Eastoflex P1023 (APP)	—	2	5	10	—	—	—
Eastoflex E1060 (APE)	—	—	—	—	2	5	10
Shellflex 371	20	20	20	20	20	20	20
Eastotac H-100R	59.50	59.50	59.50	59.50	59.50	59.50	59.50
Irganox 1010	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Cyanox 1212	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Physical Properties							
Viscosity @ 177°C	950	1,555	1,100	500	1,050	500	800
RBSP, °C	91	87	86	85	84	75	87
Tensile strength, psi	20	29	28	23	19	10	18
Elongation, %	1,500	1,650	1,750	1,650	1,700	1,850	1,650
High-temperature peel—kraft paper, °C	41	36	34	43	37	38	32
High-temperature shear—kraft paper, °C	68	60	55	52	59	53	54
Molten stability, 100 h[a]	Pass	Pass	Pass	Fail	Pass	Pass	Fail
Pressure-Sensitive Properties							
Static shear strength, h	89	280	78	24	97	3	38
Probe tack, g	500	200	360	300	540	130	20
180° peel (PSTC-1), g	1,400	2,500	2,100	1,950	1,475	1,220	1,450

[a]*Pass = No phase separation* *Fail = Phase separation*

Table 3 APO Substitution for SBS Block Copolymer in Hot-Melt Adhesive Formulations

Ingredient, %			
Stereon 840A (SBS)	20	18	18
Eastoflex P1023 (APP)	—	2	—
Eastoflex E1060 (APE)	—	—	2
Shellflex 371	20	20	20
Zonatac 105L[a]	59.50	59.50	59.50
Irganox 1010	0.15	0.15	0.15
Cyanox 1212	0.35	0.35	0.35
Physical Properties			
Viscosity @ 177°C	683	913	1,045
RBSP, °C	79	78	73
Tensile strength, psi	35	32	30
Elongation, %	973	1,127	1,159
High-temperature peel—kraft paper, °C	46	49	40
High-temperature shear—kraft paper, °C	57	59	44
Molten stability, 100 h[b]	Pass	Pass	Pass
Pressure-Sensitive Properties			
Static shear strength, h	>300	>300	>300
Probe tack, g	112	208	230
180° peel (PSTC-1), g	158	1,763	2,312

[a] *Arizona Chemical*
[b] *Pass = No phase separation* *Fail = Phase separation*

Pressure-Sensitive Adhesives

SIS is the most commonly used styrenic block copolymer in pressure-sensitive adhesives (PSAs). The largest application for PSAs is self-sticking tapes and labels. Important properties include tack, peel adhesion, and holding power. Table 4 illustrates substitution of an amorphous polyolefin for 29% of the *Kraton* D-1107 in a typical PSA formulation.

Table 4 Adhesive Properties of APO-Modified PSA Formulations

	Composition, % by Weight	
Ingredient	**Control**	**Amorphous Polyolefin**
Kraton D-1107 (SIS)	35.0	25.0
Eastotac H-100E	50.0	50.0
Shellflex 371	5.5	5.5
Wingtack 10[a]	9.0	9.0
Irganox 1010	0.5	0.5
Eastoflex E1060 (APE)	—	10.0
Test Results		
Probe tack, g	1,289	702
Quick tack, psi		
Stainless steel	6.8	4.4
High-density polyethylene	4.5	3.5
180° peel adhesion, psi		
Stainless steel	6.5	8.1
High-density polyethylene	5.5	6.4
Low-density polyethylene	4.7	6.0
Polypropylene	6.3	8.0
Room-temperature hold power, h	>175	>175

[a]*Goodyear Tire & Rubber Company*

Polyken probe tack of these compounds was measured. Quick tack to stainless steel and high-density polyethylene (HDPE) was determined according to PSTC-5. Peel adhesion at a 180° angle was measured according to PSTC-1 on stainless steel, high- and low-density polyethylene, and polypropylene. Room temperature hold power was determined in accordance with PSTC-7 using a 1,000 g/in.^{2} load.

The APO-modified formulation exhibited higher peel strength on all substrates compared with the control formulation. No significant differences in holding power were detected between the APO-modified adhesives and the control.

All samples exceeded 175 hours under shear load of 1,000 g/in.^{2} with no slippage. These results indicate that APO can replace approximately one-third of the SIS block copolymer and yield a functional PSA.

Disposable Diaper Elastic-Attachment Adhesives

The manufacture of disposable diapers is a major use for adhesives based on SEBS block copolymers. A diaper-construction adhesive is used to bond polyethylene (PE) film and polypropylene (PP) film to each other and to nonwoven materials. Elastic-attachment adhesives are used to bond elastic bands in the diaper to PE or PP liner film.

These adhesives must provide high creep resistance, good adhesion to polyolefin films, and a low application temperature to reduce distortion of thin thermoplastic films. Table 5 illustrates use of an APO in a diaper elastic-attachment adhesive. Replacement of 50% of the SEBS base with *Eastoflex* P1023 APO resulted in better T-peel adhesion with no reduction in creep resistance.

Table 5 ***Eastoflex* P1023 in a Diaper Adhesive Formulation**

		Composition, % by Weight	
Ingredient		**Control**	**APO-Modified Adhesive**
Kraton G-1652 (SEBS)		20.00	10.00
Eastotac H-130L		59.85	59.85
Shellflex 371		20.00	20.00
Eastoflex P1023 (APP)		—	10.00
Irganox 1010		0.15	0.15
Test Results			
T-peel adhesion, psi		0.05	0.11
Creep resistance,[a]	Passed	12	12
	Failed	0	0

[a] *Twelve test specimens, 8 h @ 100°F*

Sealants

In hot-melt sealant formulations, the elastomer must act as a water barrier in addition to providing strength and adhesion. Use of an APO modifier in an SEBS elastomer base exhibited better adhesion, improved water resistance, and reduced mixing time and energy. Table 6 summarizes APO-modified sealant formulations along with test results.

Based on these results, an APO-modified SEBS sealant formulation offers a number of potential benefits compared with an unmodified grade. First, the APO portion is less costly than the block copolymer that it replaces. In addition, the APO-modified sealant tolerated higher filler loadings than the unmodified version. Further, the APO modification showed improved adhesion to metal, both before and after water immersion. Finally, mixing time and energy were reduced by virtue of the APO modification, and resistance to water and ultraviolet light was improved. More information on the use of APOs in sealant formulations is contained in Eastman Publication WA-12.

Table 6 **Partial Replacement of *Kraton* SEBS Block Copolymer With *Eastoflex* APO in a Hot-Melt Sealant Formulation**

	Composition, % by Weight		
Ingredient	**Control**	**A**	**B**
Kraton G-1652 (SEBS)	20.0	10.0	10.0
Eastotac H-130E	20.0	20.0	20.0
Indopol H-300[a]	30.0	30.0	30.0
$CaCO_3$	17.5	17.5	17.5
TiO_2	6.0	6.0	6.0
ZnO	6.0	6.0	6.0
Irganox 1010	0.5	0.5	0.5
Eastoflex P1023 (APP)	—	10.0	—
Eastoflex E1060 (APE)	—	—	10.0
Test Results			
Needle penetration, dmm	32	39	43
Initial peel adhesion,[b] g/mm	196	363	250
Standard deviation	36	36	71
Fail mode	Adhesive	Cohesive	Cohesive
12-Day water immersion, g/mm	179	375	161
Standard deviation	36	89	54
Fail mode	Adhesive	Cohesive	Cohesive

[a] *Amoco Chemical*
[b] *Peel adhesion average of six tests*

Conclusion

Replacing part of a styrenic block copolymer base in a hot-melt adhesive formulation with an APO can result in several benefits depending on the block copolymer, APO type, and APO level selected. These benefits include:

- Lower raw material cost
- Improved pressure-sensitive holding power
- Increased adhesive flexibility and elongation
- Reduced viscosity
- Improved adhesive rheology (viscosity versus shear rate)
- Improved adhesion to olefin films
- Reduced mixing time and energy
- Improved resistance to water and ultraviolet light

EASTMAN

NORTH AMERICA

Eastman Chemical Company
Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations (1) 423-229-2000
Fax: (1) 423-229-1673

http://www.eastman.com

LATIN AMERICA

Eastman Chemical Latin America, Inc.
2333 Ponce de Leon Blvd.
Suite R-20
Coral Gables, FL 33134 U.S.A.

Telephone: (1) 305-461-8240
Fax: (1) 305-461-8254

EUROPE / MIDDLE EAST / AFRICA

Eastman Chemical, Europe,
Middle East, and Africa Ltd.
Tobias Asserlaan 5
2517 KC The Hague
NETHERLANDS

Telephone: (31) 70 370 1711
Fax: (31) 70 370 1704

ASIA PACIFIC

Eastman Chemical Japan Ltd.
Yebisu Garden Place Tower, 32F
4-20-3 Ebisu
Shibuya-ku, Tokyo 150 JAPAN

Telephone: (81) 3-5424-1551
Fax: (81) 3-5424-1590

Eastman Chemical Asia Pacific Pte. Ltd.
#05-04 Winsland House
3 Killiney Road
Singapore 239519 SINGAPORE

Telephone: (65) 738-4877
Fax: (65) 732-4930

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