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SBC & Elastomer Blends

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SBC Elastomer Blends

Improved properties while retaining excellent elastic recovery

Background & Application Needs

Stretch hood, stretch film, cling, and related flexible packaging applications rely on elastomeric materials that can be stretched and recover a meaningful portion of their original dimensions. Styroflex® performs well in these applications as a core component. The baseline high-elasticity styrene-butadiene copolymer provides excellent elastic recovery, but it can present practical challenges in production, processing, softness, tackiness, and cycle time that limit broader product acceptance.

Thus, an internal development route was explored based on blending commercially available styrene-butadiene copolymers to optimize these properties while maintaining the stretch recovery required for these applications. The objective was to improve stiffness, hardness, optical properties, impact performance, and processability without sacrificing the elastic recovery needed for stretch-oriented applications.

Ideal applications require a balance of elastic recovery, film or part clarity, manageable tack, and enough stiffness to improve handling and product robustness. A material that remains clear, tough, and easier to process could support stronger positioning in applications where elastic recovery and visual appearance matter. The work evaluated whether a compatible SBC modifier could shift the property balance. In practice, the most attractive blend window needs to retain adequate return after high elongation while improving stiffness-related properties and reducing haze versus the baseline highly elastomeric material.

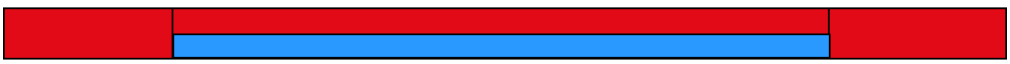

Figure 1: Example of linear triblock SBC elastomer structure with Styrene (red) and Butadiene (blue). The parallel lines in the middle represent statistical, quasi-statistical or random blocks. This is the structure for SE-1

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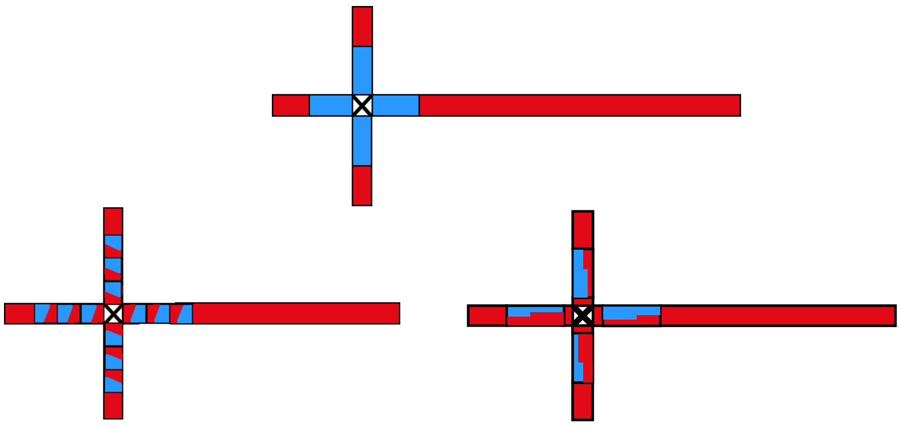

Figure 2: Examples of radial SBC architectures for thermoplastic elastomers. Styrene (red) and Butadiene (blue). Top is an example of straight block sequence from butadiene to styrene bottom left is tapered transition which is structure for SBC-1, and bottom right is statistical (random) block sequences with styrene and butadiene which is structure for SBC-2. Note: The 3 figures are simplified examples of radial SBC architectures that we investigated for use as blend partners with thermoplastic elastomers of type SE-1. The general principle:

- **Best properties can be expected when soft phases (those segments where butadiene and/or alternating or parallel styrene segments are present) are structurally similar to SE-1 soft phase with statistical, quasi-statistical or random blocks in the middle**
- **The star-shaped structure with one long and 3 short arms represent an approximately statistical average; species with more or less than 3 short blocks are statistically present, besides other structurally related species**
- **The "X" represents a so-called "coupling agent", being able to react with several "living" long or short arms**

Design and Testing

The evaluation compared elastomeric Styroflex® material with thermoplastic elastomer SBC materials of different block architectures. Styroflex® has a dispersed-hard-phase morphology, which enables excellent retention and recovery properties. SBC type materials can vary from dispersed-soft-phase to lamellar to gyroid morphologies, depending on polymer and block design. The two SBC modifiers have similar butadiene content (BD%) but differ in block design (tapered versus random) and morphology.

- SE-1 is a linear triblock copolymer elastomer from our Styroflex® family of products with styrene end blocks and a statistical butadiene and styrene middle block. Total butadiene content in the polymer is ~ 34%.

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- SBC-1 is a polymer having three tapered sequential Butadiene and Styrene soft blocks and Styrene hard blocks. Two different block length are produced and coupled to form a radial structure with lamellar morphology. Total butadiene content in the polymer is ~ 25%.
- SBC-2 is a polymer having two sequential random Butadiene and Styrene soft blocks and Styrene hard block. Two different block length are produced and coupled to form a radial structure that has gyroid morphology. Total butadiene content in the polymer is ~ 25%.

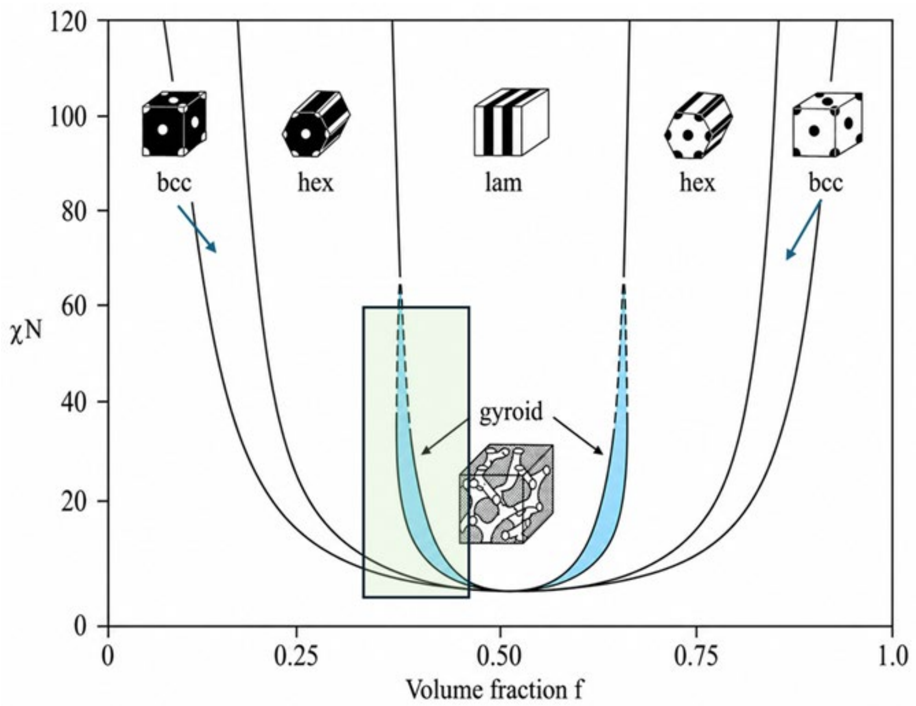

Figure 3: Morphology and design range of SB block copolymers, with the ideal elastic-recovery range highlighted. Figure adapted with permission from Matsen, M.W.; Bates, F.S. Unifying weak- and strong-segregation block copolymer theories. Macromolecules 1996, 29, 1091–1098. Copyright 1996 American Chemical Society.

The hypothesis was that co-continuous gyroid morphology would be the most promising morphology for mixing with continuous soft-phase Styroflex® elastomer because it is closest in soft-phase volume fraction. This architecture is thought to support compatibility between the components while raising stiffness and improving optical performance. Because this morphology has been observed in thermoplastic elastomers based on randomized styrene-butadiene blocks, SBC-2 was selected as the primary candidate for increasing stiffness while maintaining elastic recovery. A highly elastic lamellar-type SBC (SBC-1) was also evaluated to compare the effects of

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morphology and block design. If the approach was correct, it should maintain elastomer like properties for one type of SBC but not the other.

For material testing, tensile properties (stress at yield and strain at break) were measured using ASTM D638. Melt flow rate was measured using ASTM D1238 at 200 °C/5.0 kg. Haze and transmission were measured using ASTM D1003 on 3.2 mm, 4-in.-diameter injection-molded plaques. Gardner impact was measured using ASTM D5420 and is reported in in-lb. Shore D hardness was measured using ASTM D2240. Puncture force and energy were measured using ASTM D3763 and are reported in N and J, respectively. Elastic recovery was measured on 1 mm extruded sheet cut into 4 in. x 2 in. strips, stretched to 200% elongation, rested for 10 minutes, and remeasured.

Results and Discussion

After the materials were combined via compounding, specimens were prepared for property analysis. As expected, haze decreased relative to the baseline elastomer in measured SE-1 blends with both SBC modifiers. Stress at yield and Shore D hardness also increased in the blends, showing the benefit of adding a radial SBC to the elastomer. Strain at break decreased with SBC addition, reflecting the expected balance between stiffness and toughness. These results were expected and showed that both SBCs effectively increased the desired stiffness-related properties while demonstrating the associated property tradeoff. The results also showed that a wide property range could be achieved by adjusting the blend ratio. The critical question, however, was whether elastic recovery and elastomer-like behavior were maintained. All blend ratios are reported as SE-1/SBC modifier by weight.

Table 1: Initial Screening of SE-1/SBC-1 Blend

Metric	Unit	100/0	40/60	45/55	50/50
Elastomer Content	%	100	40	45	50
Melt flow rate	g/10 min	13	10	10	10
Gardner impact	in-lb	109	137	122	129
Stress at yield	psi	404	1237	1152	1057
Strain at break	%	>490	425	435	440
Shore D hardness	D scale	54	74	71	71
Haze	%	54	33	37	29

Table 2: Initial Screening of SE-1/SBC-2 Blend

Metric	Unit	100/0	40/60	45/55	50/50
Elastomer Content	%	100	40	45	50
Melt flow rate	g/10 min	13	10	10	10
Gardner impact	in-lb	109	117	111	114
Stress at yield	psi	404	952	860	825

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Metric	Unit	100/0	40/60	45/55	50/50
Strain at break	%	>490	392	400	420
Shore D hardness	D scale	54	68	66	62
Haze	%	54	19	23	24

In Figure 4, the tensile curves are compared against standard Styroflex® and elastomeric materials. The key feature is not total elongation but the absence of a yield peak. Elastomers should have little to no yield, indicating primarily elastic deformation rather than plastic deformation. In tensile curves of elastomers, no yield is observed and the material continues to stretch and strain-harden until failure. The SE-1/SBC-2 blends showed almost no yield, while the SE-1/SBC-1 blends showed a prominent yield point. The SE-1/SBC-2 blends retained the desired tensile performance, while the SE-1/SBC-1 blends did not. The tensile results indicate that randomized blocks are needed for better mixing with SE-1 because the blends should have little to no tensile yield to maintain elastomeric behavior. These results also indicate that gyroid, random-soft-phase SBCs blend better with SE-1 and retain elastic properties more effectively than lamellar, tapered/blocky-soft-phase SBCs.

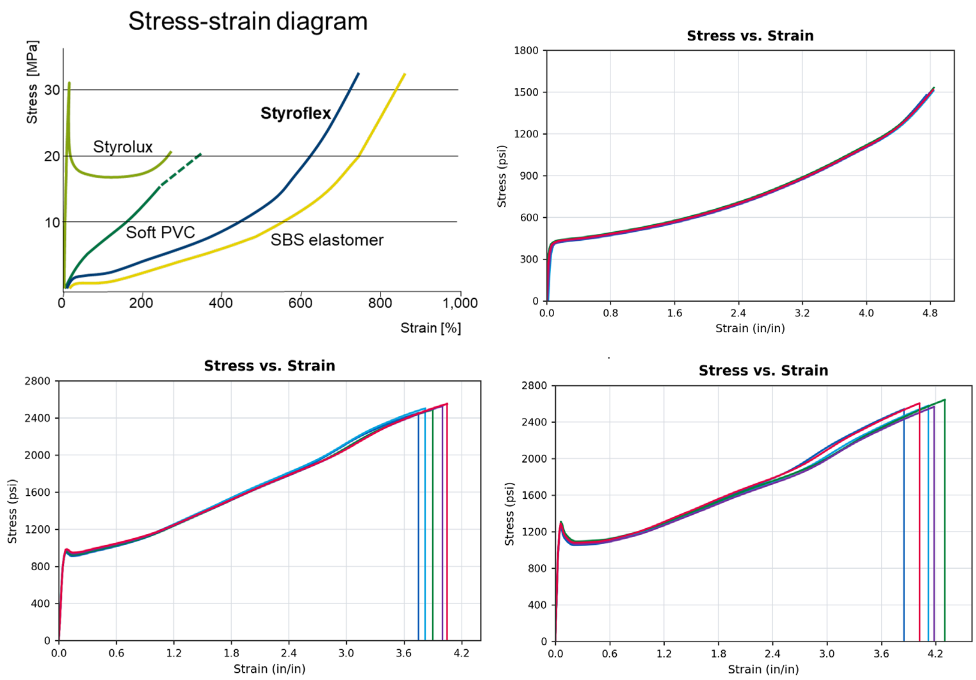

Figure 4: Typical tensile behavior for rubber materials (top left), SE-1 (top right), SE-1/SBC-2 40/60 (bottom left), and SE-1/SBC-1 40/60 (bottom right).

Although tensile behavior is an indicator of elastic recovery, the recovery performance of the blends needed to be validated directly. In Figure 5, elastic recovery was analyzed using extruded film samples for the corresponding blends. SE-1 showed strong elastic recovery (88%) after stretching to 200% elongation. In contrast, the SBC-2 control showed low recovery relative to SE-1. This result shows that little to no plastic deformation and a continuous soft phase are important for effective elastic recovery. Below 35% SE-1 loading, recovery improved only marginally and the blends still behaved more like the thermoplastic elastomer SBC-2. Recovery increased sharply between 35/65 and 45/55, with the highest measured return at 45/55.

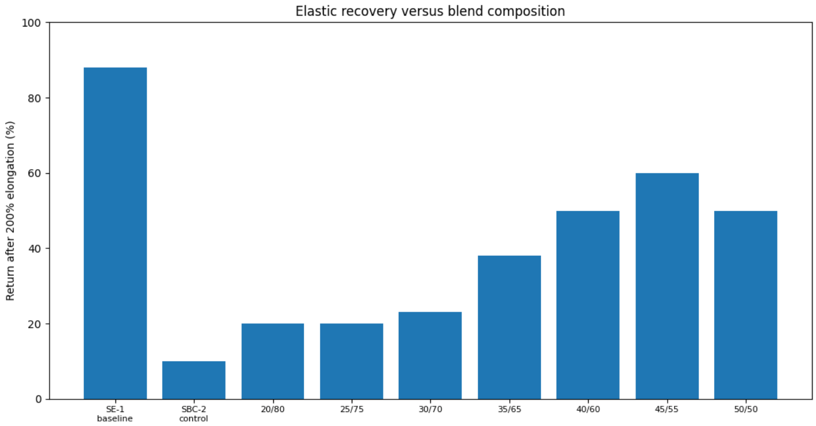

Figure 5: Elastic recovery after stretching to 200% elongation.

Table 3: Full Analysis of SE-1 & SBC-2 Blends

Metric	Unit	100/0	20/80	25/75	30/70	35/65	40/60	45/55	50/50
Elastomer Content	%	100	20	25	30	35	40	45	50
Melt flow rate	g/10 min	13	12	11	11	11	10	10	10
Gardner impact	in-lb	109	132	126	126	122	117	111	114
Force puncture	N	1719	1699	2122	2078	2090	2083	2049	2037
Energy puncture	J	121	67	76	80	85	87	91	96
Stress at yield	psi	404	1410	1237	1123	1051	952	860	825
Strain at break	%	>490	310	341	359	397	392	400	420
Shore D hardness	D scale	54	75	73	72	70	68	66	62
Haze	%	54	16	17	21	23	19	23	24
Elastic recovery 200% elongation	% return	88	20	20	23	38	50	60	50

Conclusions

Overall, the results show that blending SE-1 with an appropriate SBC can increase stiffness, hardness, impact performance, and clarity while preserving useful elastic behavior. SBC-2 was the stronger candidate because its random butadiene blocks and gyroid morphology were more compatible with SE-1, maintaining low-yield tensile behavior and better elastic recovery. The SE-1/SBC-2 blends showed the most promising balance at approximately 40/60 to 50/50 blend ratio, where recovery increased substantially to around 70% of the value seen for the SE-1 starting resin. These results demonstrate the ability and flexibility these blends are able to offer for applications where elastic recovery is critical, with increase need of stiffness, toughness, clarity, and improved handling.