

Technical Insight of KURARAY LIQUID RUBBER

Silane modified LBR for TBR / Silica formulation

Elastomer R&D Department
Elastomer Division

kuraray

Agenda

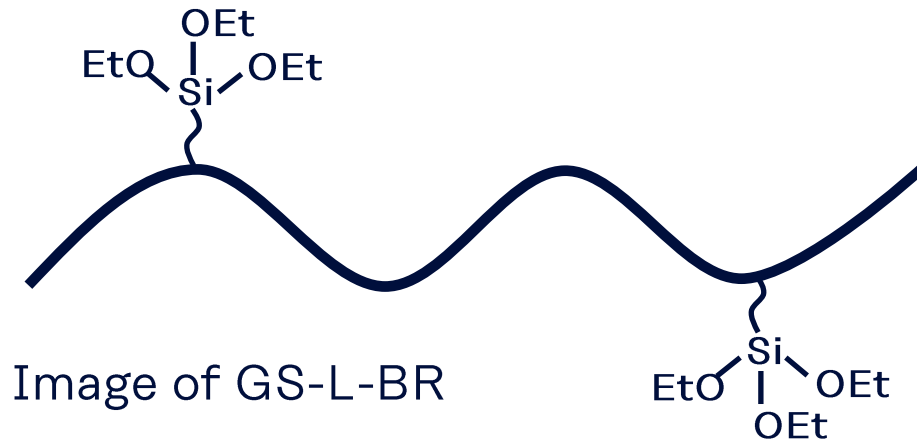
Our silane-modified LBR; GS-L-BR is the latest development of KURARAY LIQUID RUBBER grades.

1) Silane modified LBR (GS-L-BR)

2) Evaluation in TBR / Silica formulation

Silane modified LBR (GS-L-BR)

| Grade Name [Development code] | Structure | Functional Group | Mw | Tg (°C) | Number of functional group / chain | Viscosity at 38°C (Pa • s) |
|----------------------------------|-----------------------------|------------------|--------|---------|------------------------------------|----------------------------|
| GS-L-BR-188 [SB-006] | Polybutadiene /Graft silane | Triethoxysilane | 38,000 | -88 | 4 | 124 |



- High reactivity with silica
- Improve dispersibility of silica
- Crosslinkable with base rubber

Agenda

1) Silane modified LBR (GS-L-BR)

2) Evaluation in TBR / Silica formulation

Effect for reinforcing using GS-LR

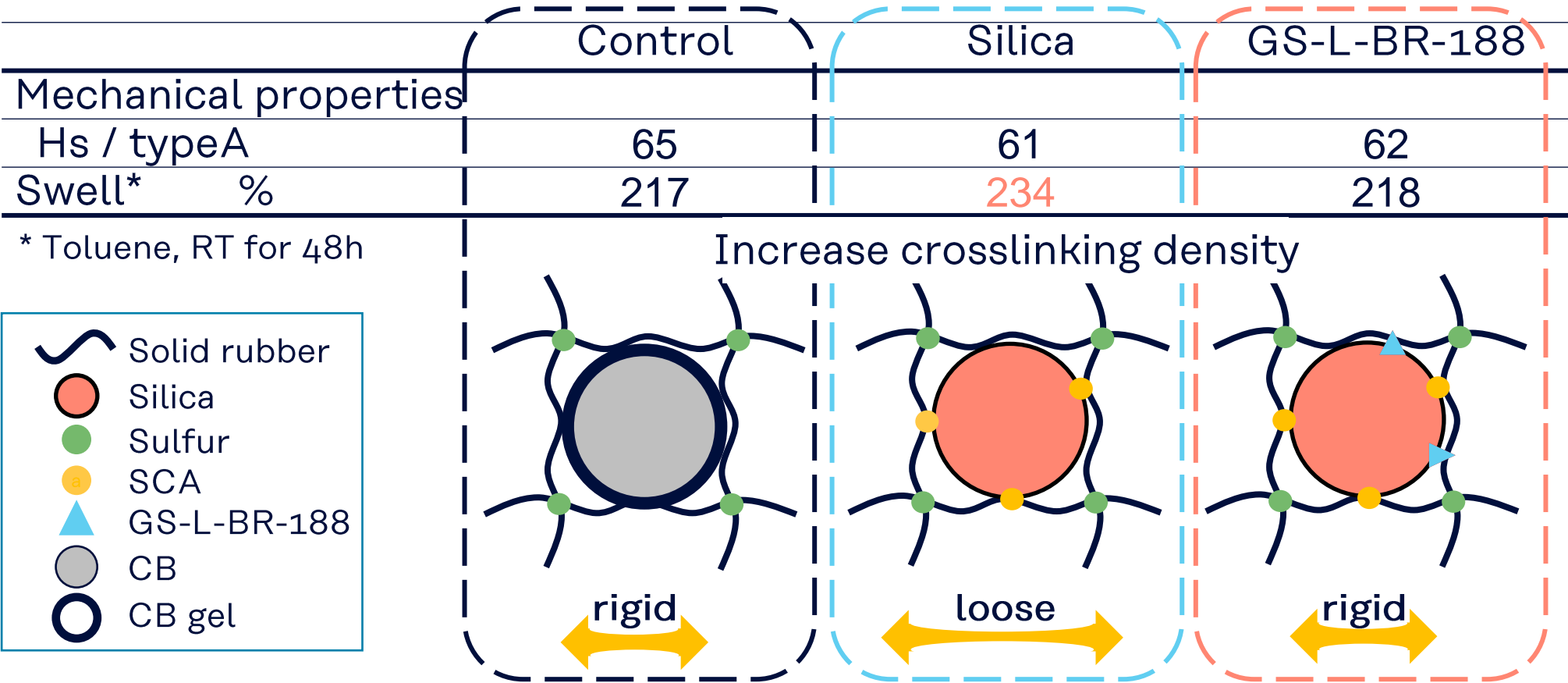
| Name | Control | Silica | GS-L-BR-188 |
|-------------|-------------------------------------|-----------------|-------------|
| NR | 80 | 80 | 80 |
| BR | 20 | 20 | 15 |
| CB | 55 | 13 | 13 |
| Silica | - | 42 | 42 |
| SCA | - | 4 | 4 |
| TDAE | 2 | 2 | 2 |
| GS-L-BR-188 | - | - | 5 |
| Chemicals | ZnO 3.0, Stearic acid 3.0, 6PPD 2.0 | | |
| OT-20* | 1.9 | 1.9 | 1.9 |
| Accelerator | NS 1.5 | DPG 0.5, CZ 1.6 | |

* OT-20: Sulfur/Oil=80/20

| Mixing Conditions | | |
|-------------------|-----|---------------------------------------|
| NP1 | sec | Banbury-type mixer* |
| | 0 | Solid rubber (60°C) |
| | 20 | CB, Silica, SCA, TDAE, LR, Chemicals |
| | 180 | Sweep |
| | 360 | Dump out (150-160°C) |
| NP2 | | Banbury-type mixer* |
| | 0 | 1 st mixed compound(90°C) |
| | 240 | Dump out (150-160°C) |
| FM | | Banbury-type mixer* |
| | 0 | Compound, Sulfur, Accelerators (50°C) |
| | 75 | Dump out (90-100°C) |

*MIXTRON® BB Mixer (by Kobe Steel, Ltd.)

Effect for reinforcing using GS-LR



- GS-L-BR-188 has strong reinforcing effect on silica and rubber.

Swell adjusted formulation

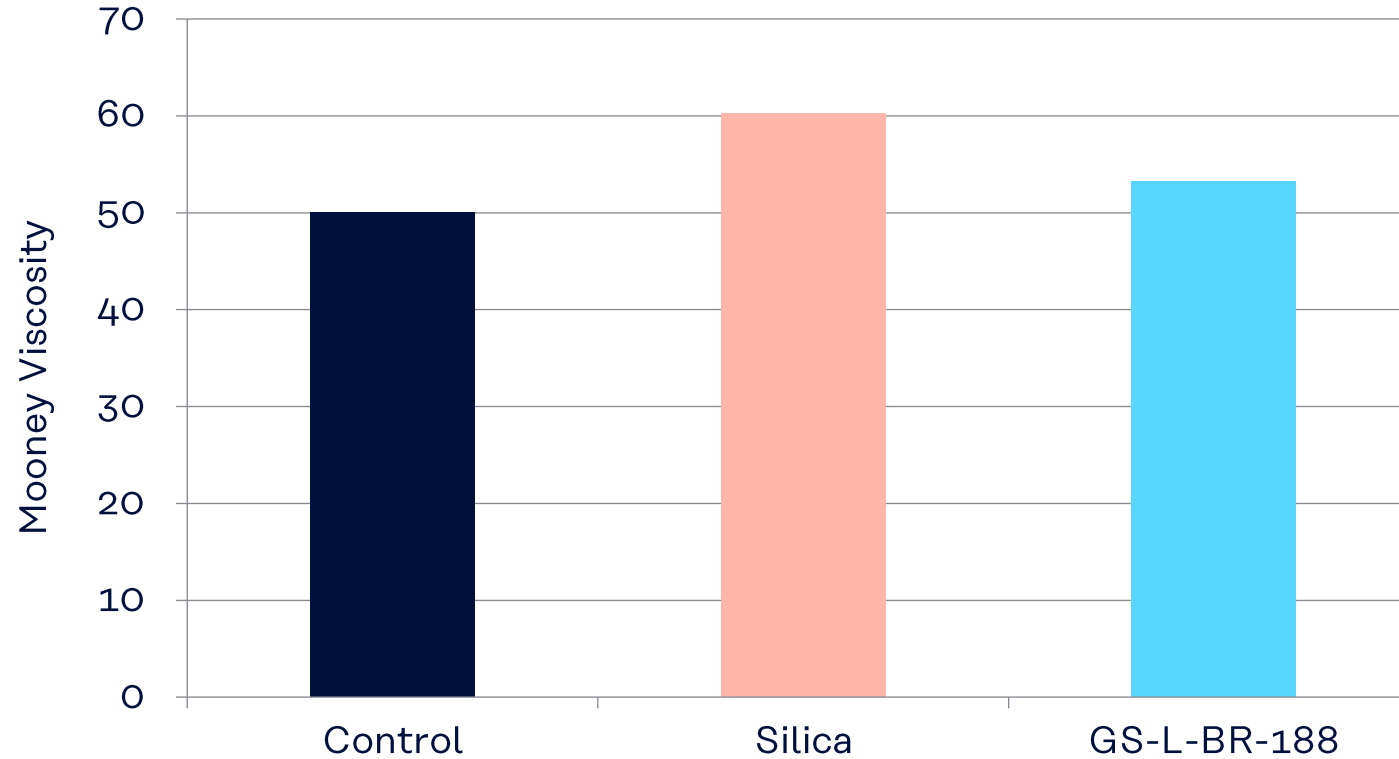
| | Control | Silica | GS-L-BR-188 |
|-----------------------|---------|--------|-------------|
| NR | 80 | 80 | 80 |
| BR | 20 | 20 | 15 |
| CB | 55 | 13 | 13 |
| Silica | - | 42 | 42 |
| SCA | - | 4 | 4 |
| TDAE | 2 | 2 | 2 |
| GS-L-BR-188 | - | - | 5 |
| OT-20 | 1.9 | 3.3 | 1.9 |
| Mechanical properties | | | |
| Swell / % | 217 | 216 | 218 |

- Swell ratio of silica formulation was adjusted to the control by adding sulfur.

Summary of properties

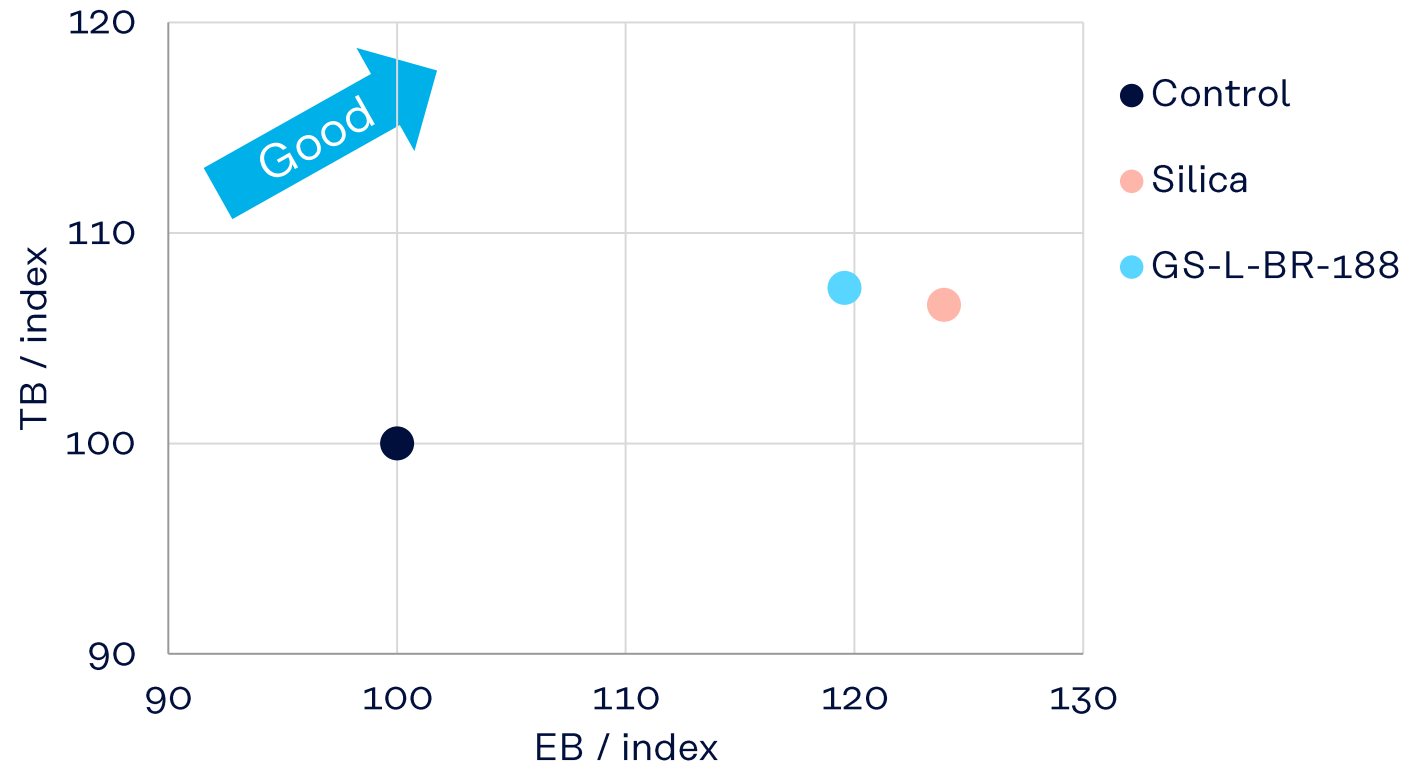
| | | | Control | Silica | GS-L-BR-188 |
|--|--------------------|-------|---------|--------|-------------|
| Mooney Viscosity (ML1+4, @130°C) | | | 50.0 | 60.3 | 53.2 |
| Mechanical Properties | | | | | |
| Hardness | Type A | | 65 | 63 | 62 |
| Swell | (%) | | 217 | 216 | 218 |
| EB | (%) | | 460 | 570 | 550 |
| TB | (MPa) | | 29.6 | 31.6 | 31.8 |
| M100 | (MPa) | | 3.59 | 2.91 | 3.13 |
| M300 | (MPa) | | 18.1 | 12.3 | 14.5 |
| Abrasion FPS 15% | (mm ³) | | 50.5 | 60.0 | 47.5 |
| DMA (Dynamic Mechanical Analysis) | | | | | |
| E' | 0°C | (MPa) | 8.39 | 6.27 | 5.87 |
| | 25°C | (MPa) | 7.40 | 5.62 | 5.21 |
| | 60°C | (MPa) | 6.66 | 5.33 | 4.88 |
| tanδ | 0°C | (-) | 0.225 | 0.175 | 0.178 |
| | 25°C | (-) | 0.174 | 0.124 | 0.127 |
| | 60°C | (-) | 0.136 | 0.089 | 0.092 |
| Payne effect (0.5%E'-5.0%E') | index | | 3.67 | 1.52 | 1.45 |

Mooney Viscosity



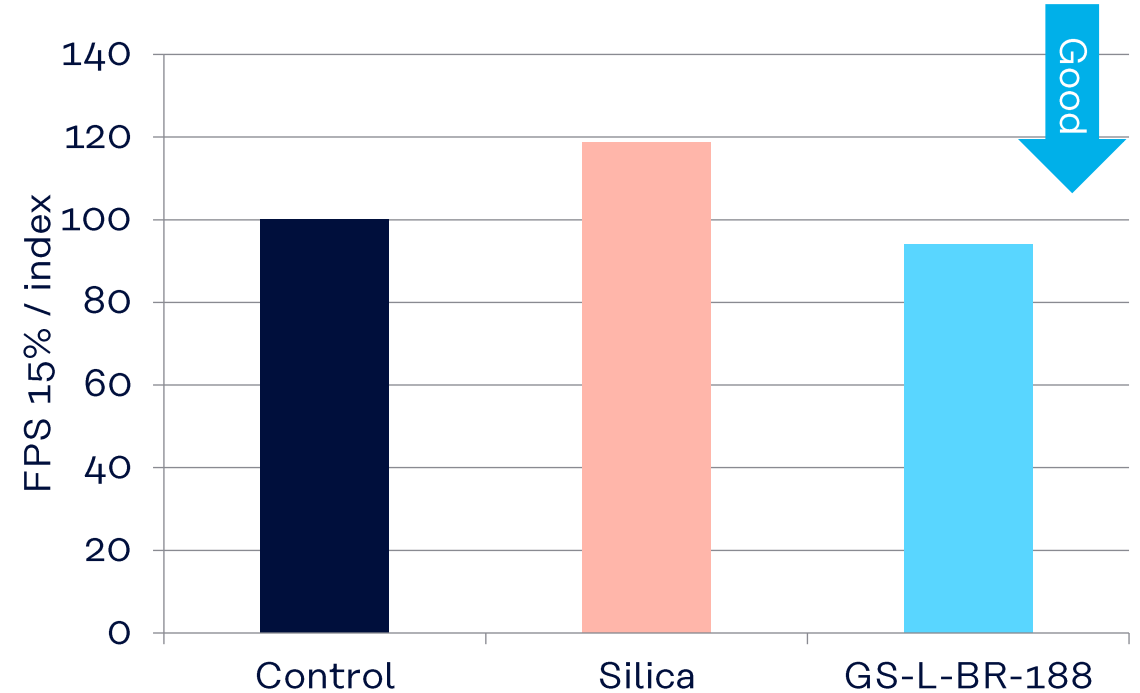
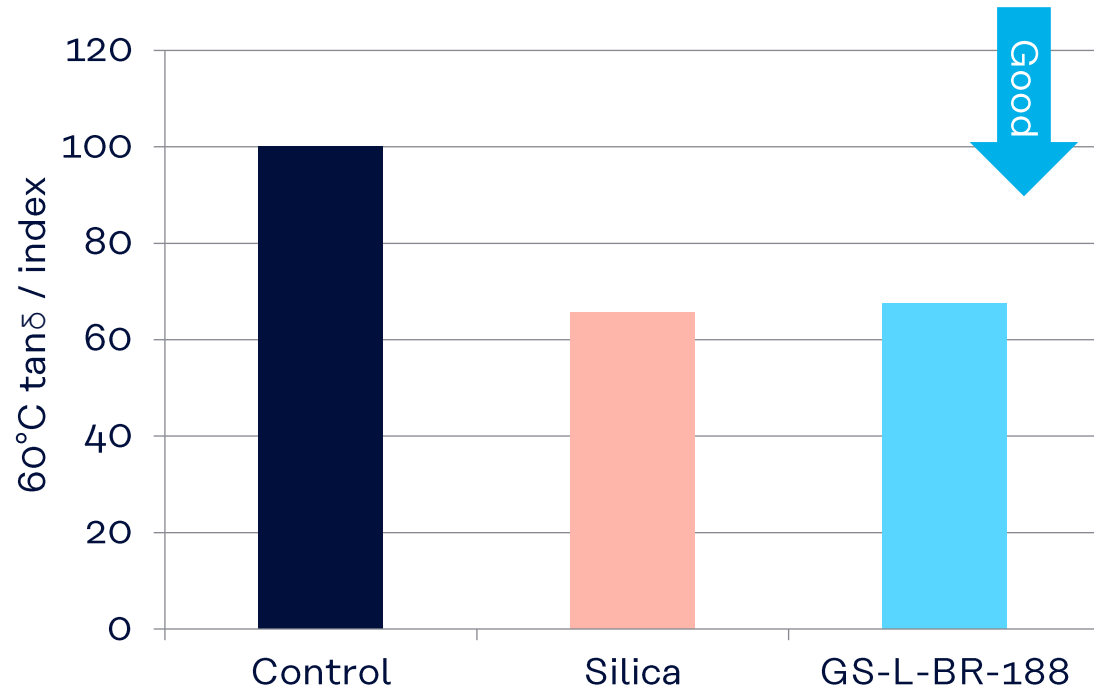
- GS-L-BR-188 exhibited lower Mooney viscosity than silica/silane formulation.

Tensile properties



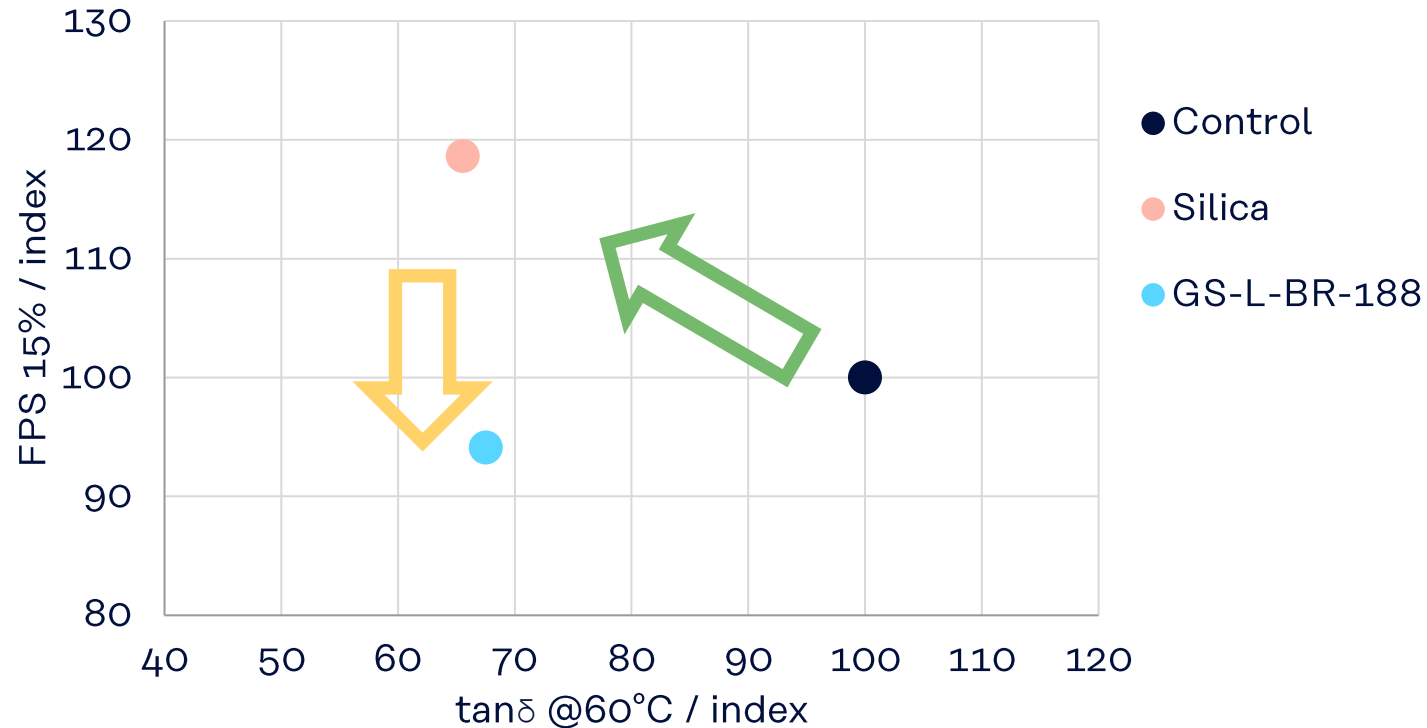
- TB and EB of GS-L-BR-188 were better than control, equivalent to silica/silane.

Rolling resistance (RR) and abrasion resistance



- GS-L-BR-188 improved RR and abrasion resistance of rubber compound.

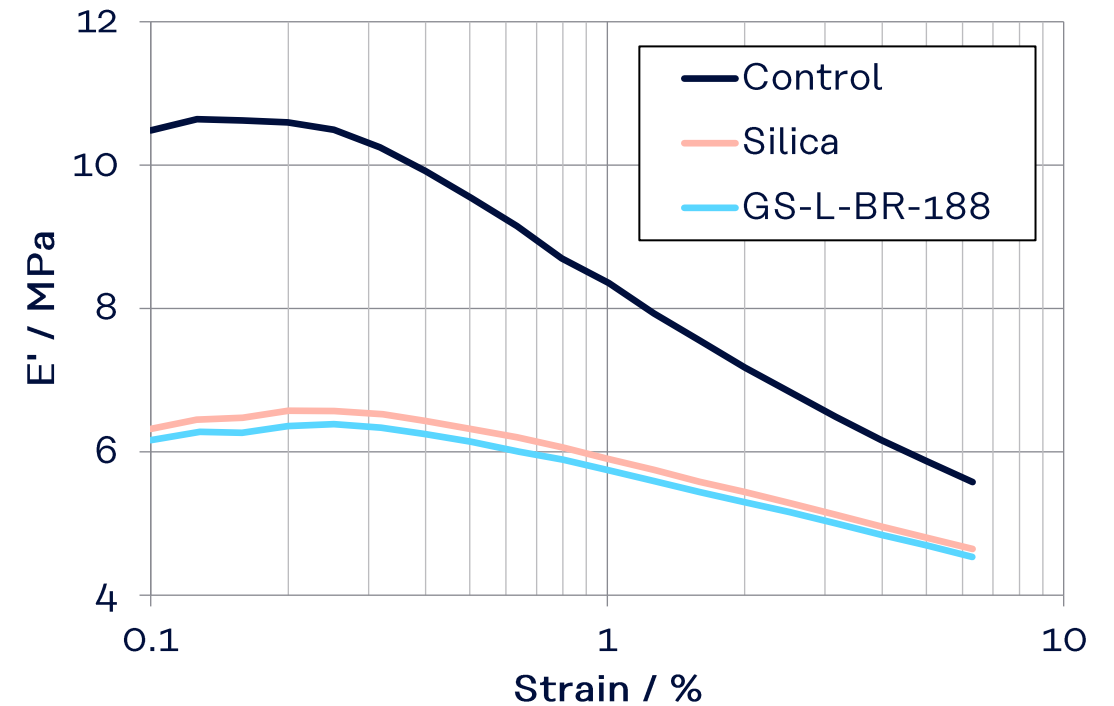
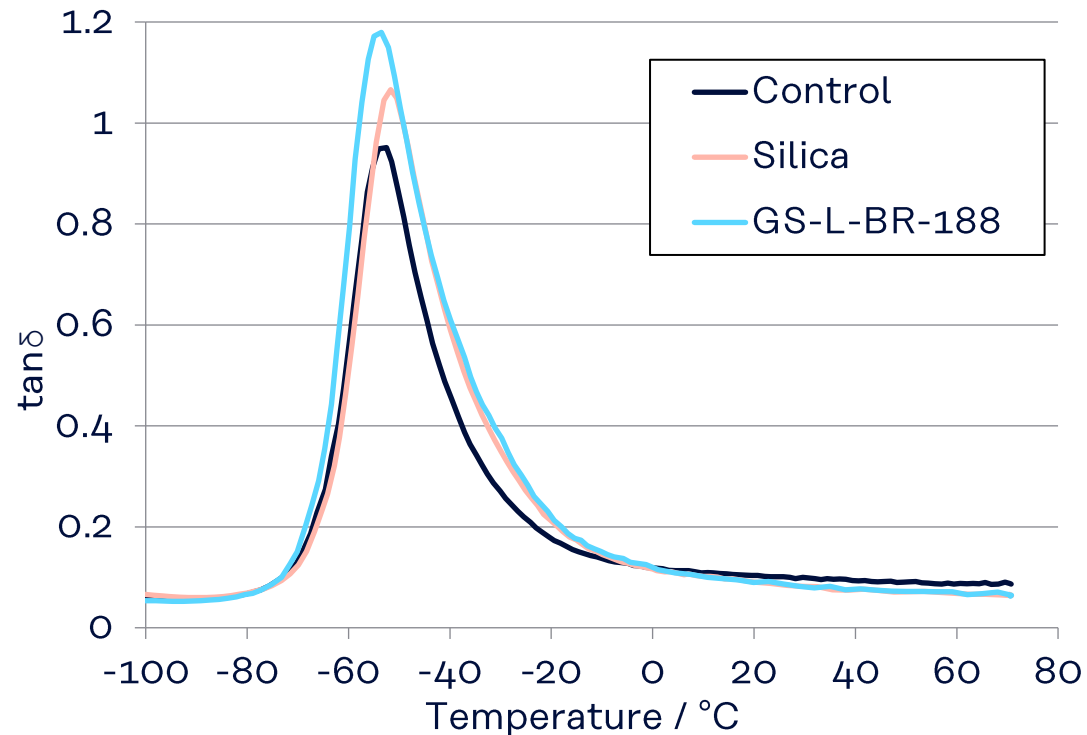
Balance between RR & abrasion resistance



- Silica formulation showed better RR, though worse abrasion resistance.
- GS-L-BR-188 greatly improved abrasion resistance as well as RR.

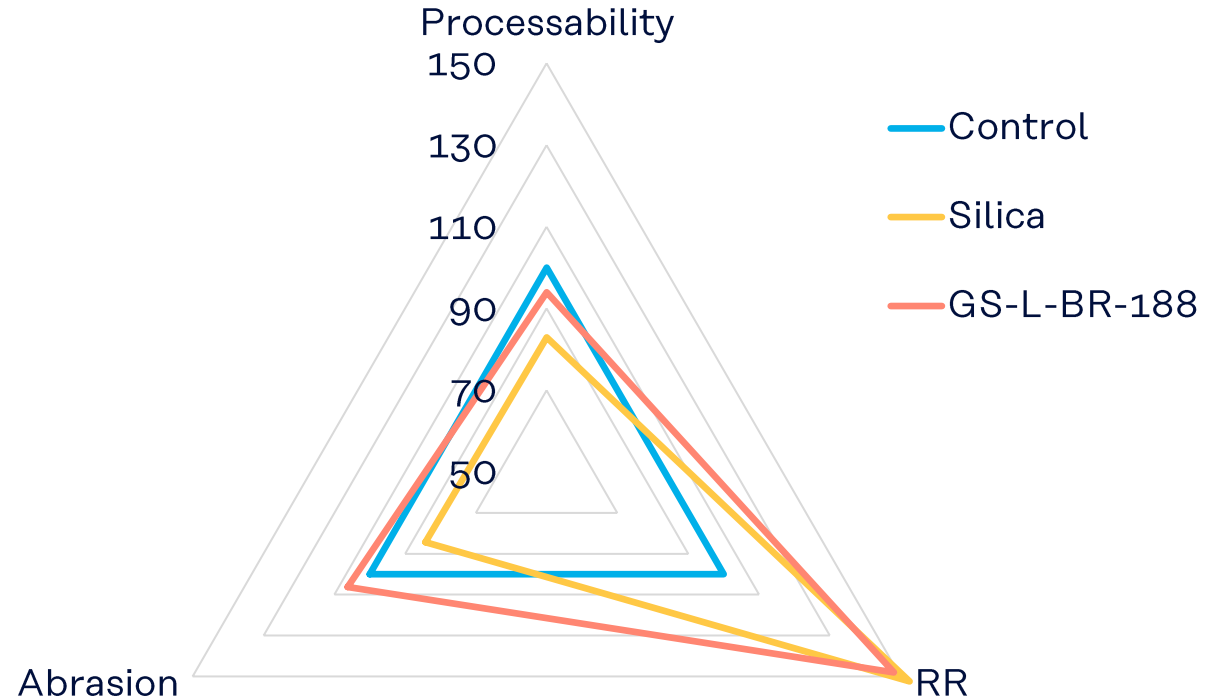
Dynamic Mechanical Analysis

Static strain 0.5%
Dynamic strain 0.1%
Frequency 10Hz



- GS-L-BR-188 exhibited the highest $\tan\delta$ peak top value and better Payne effect, which indicated better silica dispersion in rubber compound.

Test results



- Comparing the properties of swell-adjusted formulation, GS-L-BR-188 showed well balance between RR, abrasion and processability.

Summary

- **GS-L-BR**

- Improve silica dispersion
- Crosslinkable with base rubber
- Improve silica-polymer interaction

- **GS-L-BR-188 for TBR/silica formulation**

- Silica/silane in TBR formulation changes crosslinking density.
- GS-L-BR-188 has strong reinforcing effect on silica and rubber.
- GS-L-BR-188 showed well balance of RR, abrasion and processability.

Kuraray Co., Ltd.
Elastomer Division
Tokiwabashi Tower
2-6-4, Otemachi
Chiyoda-ku, Tokyo 100-0004, Japan

✉ elastomer@kuraray.com

→ www.kuraray.com

→ www.elastomer.kuraray.com

© Kuraray Co., Ltd. 2022

Precautions should be taken in handling and storage. Please refer to the appropriate Safety Data Sheet for further safety information. In using KURARAY LIQUID RUBBER, please confirm related laws and regulations, and examine its safety and suitability for the application.

For medical, health care and food contact applications, please contact your Kuraray representative for specific recommendations. Even so, users must conduct their own assessment, revisions, registrations as well rely in their own technical and legal judgment to establish the safety and efficacy of their compound and/or end product with KURARAY LIQUID RUBBER for any application. KURARAY LIQUID RUBBER should not be used in any devices or materials intended for implantation in the human body. Nothing contained herein constitutes a license to practice under any patent and it should not be construed as an inducement to infringe any patent and the user is advised to take appropriate steps to be sure that any proposed use of the product will not result in patent infringement.

kuraray

APPENDIX

Summary of properties

| | | | Control | Silica | GS-L-BR-188 |
|--|--------------------|-------|---------|--------|-------------|
| Mooney Viscosity (ML1+4, @130°C) | | | 50.0 | 60.3 | 53.2 |
| Mechanical Properties | | | | | |
| Hardness | Type A | | 65 | 61 | 62 |
| Swell | (%) | | 217 | 575 | 218 |
| EB | (%) | | 460 | 30.0 | 550 |
| TB | (MPa) | | 29.6 | 2.53 | 31.8 |
| M100 | (MPa) | | 3.59 | 11.8 | 3.13 |
| M300 | (MPa) | | 18.1 | 48.9 | 14.5 |
| Abrasion FPS 15% | (mm ³) | | 50.5 | 61 | 47.5 |
| DMA (Dynamic Mechanical Analysis) | | | | | |
| E' | 0°C | (MPa) | 8.39 | 6.43 | 5.87 |
| | 25°C | (MPa) | 7.40 | 5.70 | 5.21 |
| | 60°C | (MPa) | 6.66 | 5.33 | 4.88 |
| tanδ | 0°C | (-) | 0.225 | 0.193 | 0.178 |
| | 25°C | (-) | 0.174 | 0.139 | 0.127 |
| | 60°C | (-) | 0.136 | 0.102 | 0.092 |
| Payne effect (0.5%E'-5.0%E') | index | | 3.67 | 1.64 | 1.45 |
| Swell | (%) | | 217 | 234 | 218 |

Raw material

| Material | Product Name | Manufacturer | Note |
|-----------------------|------------------|---------------------------------|---|
| Natural Rubber | STR20 | Von Bundit Co., Ltd. | |
| Butadiene Rubber | JSR BR01 | JSR Corporation | Cis content: 95% Mooney Vis. @100°C: 45 |
| Silica | ULTRASIL® 9100GR | Evonik Industries AG | Specific surface area (N2) 235 m ² /g |
| Silane Coupling Agent | Si 69® | Evonik Industries AG | |
| Carbon black (CB) | DIABLACK™ I | Mitsubishi Chemical Corporation | ASTM N220 |
| TDAE | VIVATEC 500 | H&R GmbH Co. KGaA | |
| Insoluble sulfur | MUCRON OT-20 | SHIKOKU CHEMICALS CORPORATION | Sulfur/Oil = 80/20 |