No.RRL10-021

Technical Insight of KURARAY LIQUID RUBBER

# GS-L-BR for Winter tire and All season tire (2)

Elastomer R&D Department
Elastomer Division

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# Agenda

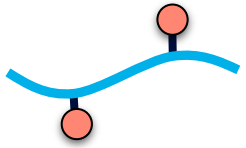
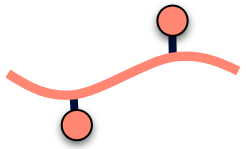
**Our silane-modified LBR; GS-L-BR is the latest development of KURARAY LIQUID RUBBER grades.**

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

2) Evaluation in winter tire formulation

3) Formulation adjustment

# Silane modified LBR (GS-L-BR)

| Grade Name [Development Code] | Structure | Mw | Tg (°C) | Number of functional groups / chain | Viscosity at 38°C (Pa • s) |
|---|---|---|---|---|---|
| GS-L-BR-114* [SB-005] | Polybutadiene  | 6,000 | -50 | 2 | 6 |
| [SB-018*] | Polybutadiene  | 6,500 | -84 | 2 | 2 |

*All polymers are in development stage.

# Formulation & Mixing Conditions

| | Control | Formulation |
|---|---|---|
| S-SBR | 40 | 40 |
| NR | 30 | 30 |
| BR | 30 | 30 |
| TDAE | 30 | 10 |
| Liquid Rubber | - | 20 |
| CB | 10 | 10 |
| Silica | 80 | 80 |
| SCA | 6.4 | 6.4 |
| ZnO | 2.0 | 2.0 |
| Stearic acid | 2.0 | 2.0 |
| Anti oxidant 6PPD | 2.0 | 2.0 |
| Wax | 1.0 | 1.0 |
| OT-20 | 2.75 | 2.75 |
| Accelerator DPG | 0.2 | 0.2 |
| Accelerator CBS | 1.6 | 1.6 |

| 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 | 1st 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) |

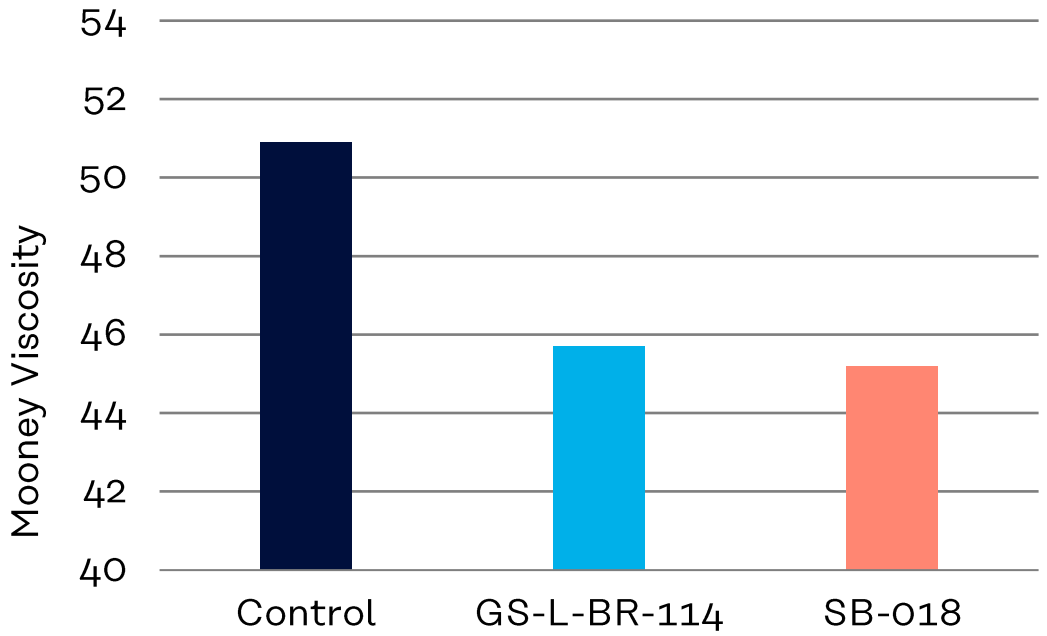
*MIXTRON® BB Mixer (by Kobe Steel, Ltd.)

# Summary of Properties

| | | | Control | GS-L-BR-114 | SB-018 |
|---|---|---|---|---|---|
| Mooney Viscosity (ML1+4, @130°C) | | | 51 | 46 | 45 |
| Curelastometer (t90, 160°C) | | (min) | 19 | 29 | 26 |
| Mechanical properties | | | | | |
| Hs | | Type A | 65 | 68 | 66 |
| EB | | (%) | 626 | 554 | 590 |
| TB | | (MPa) | 20.7 | 19.8 | 20.4 |
| M100 | | (MPa) | 1.94 | 2.39 | 2.17 |
| M300 | | (MPa) | 8.14 | 9.15 | 8.89 |
| Viscoelasticity (10% to 2%, -50 to +70°C) | | | | | |
| E' | -20°C | (MPa) | 17.1 | 25.3 | 15.2 |
| | 0°C | (MPa) | 8.99 | 12.41 | 9.15 |
| | 60°C | (MPa) | 4.63 | 5.69 | 5.18 |
| tanδ | -20°C | (-) | 0.694 | 0.65 | 0.544 |
| | 0°C | (-) | 0.445 | 0.445 | 0.344 |
| | 60°C | (-) | 0.225 | 0.201 | 0.175 |
| Abrasion resistance FPS , 5% | | index | 100 | 115 | 119 |
| Friction coefficient | | | | | |
| Wet | 20°C | index | 100 | 104 | 97 |
| Ice | -10°C | index | 100 | 88 | 105 |

# Processability

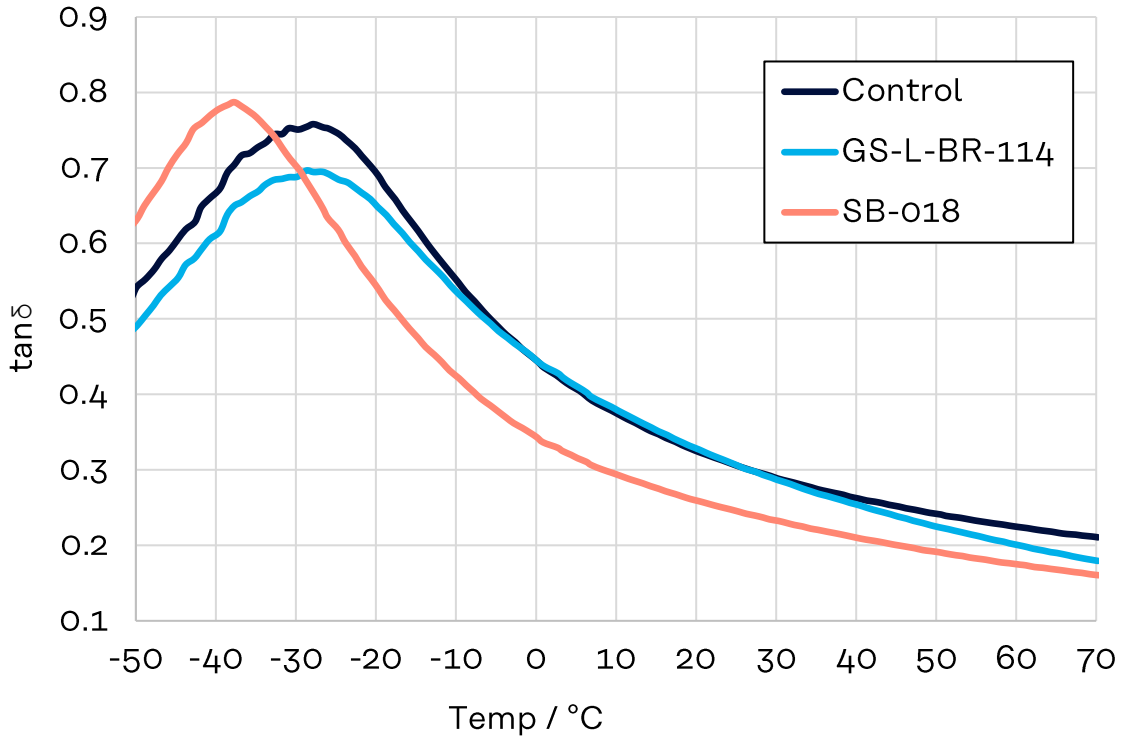
| | GS-L-BR-114 | SB-018 |
|---|---|---|
| Melt Viscosity @38°C (Pa • s) | 6 | 2 |

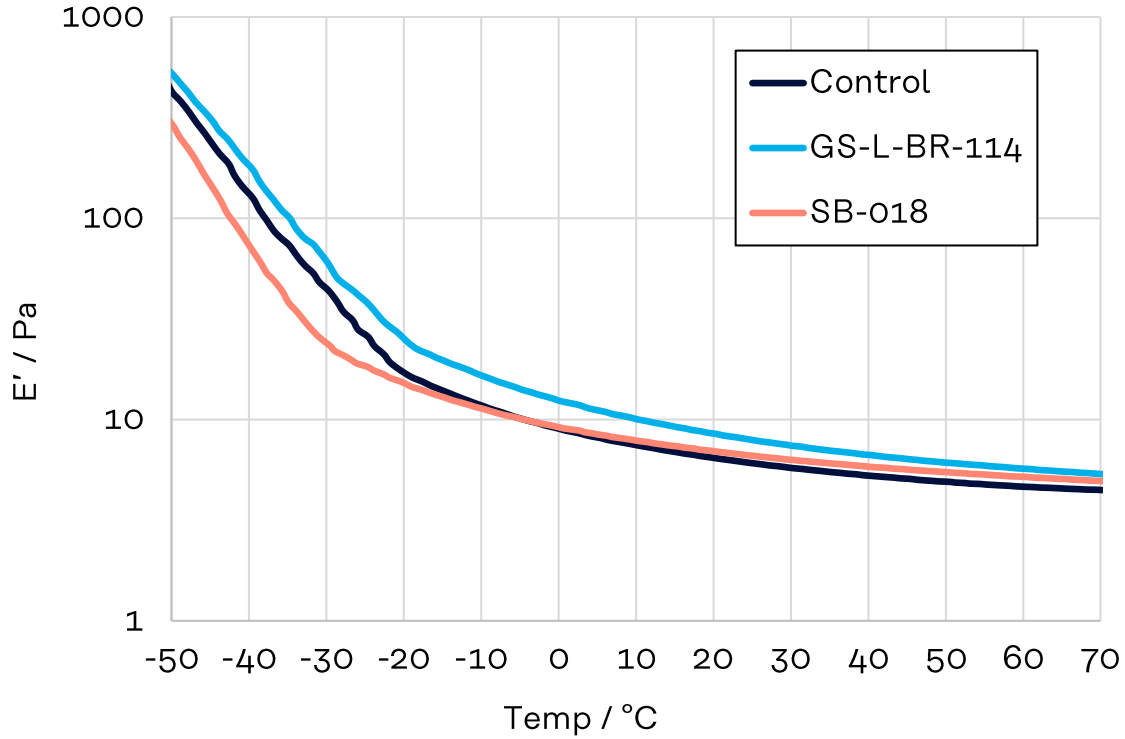



GS-L-BR-114 & SB-018

- Easy to handle due to low viscosity.
- Oil replacement of GS-LR results in a decrease in Mooney viscosity.

# Change in viscoelasticity with liquid rubber



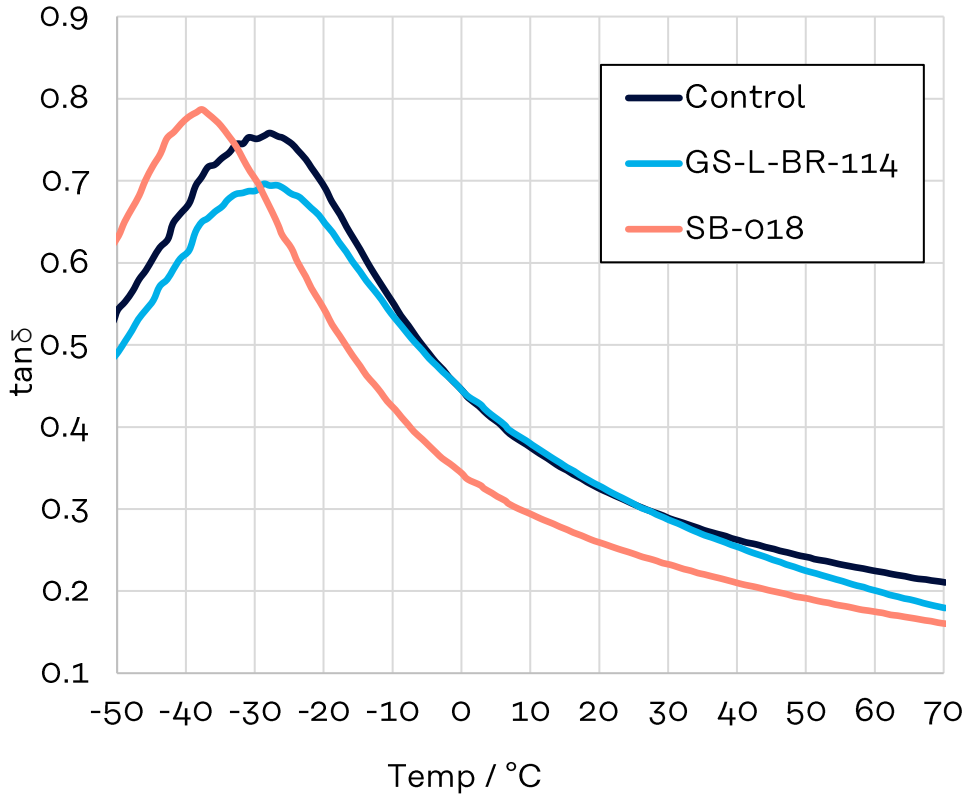

## GS-L-BR-114 (High Tg)

- Lowering the tanδ at 60°C while maintaining the tanδ at 0°C.

## SB-018 (Low Tg)

- Sharpening tanδ and moving to lower temperatures.
- Decrease in elastic modulus at low temperatures.

# Effect of changes in viscoelasticity on physical properties



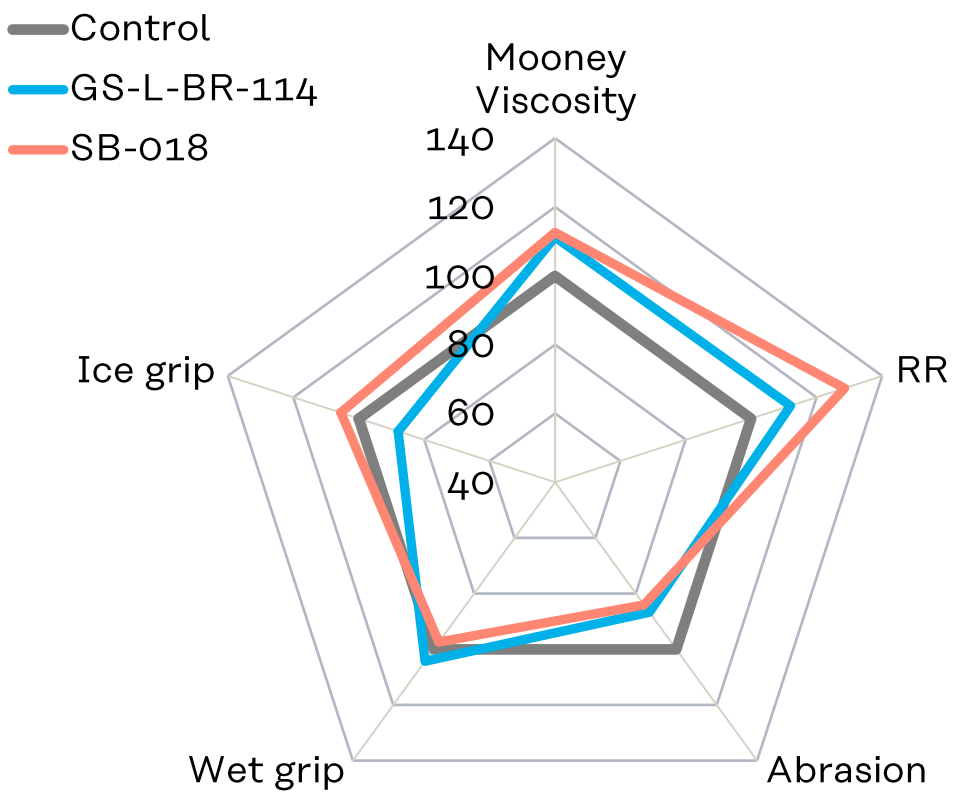

(normalized value to TDAE)

| | GS-L-BR-114 | SB-018 |
|---|---|---|
| E'@-20°C | 148 | 89 |
| Ice μ | 89 | 105 |
| tanδ@0°C | 104 | 77 |
| Wet μ | 103 | 97 |
| tanδ@60°C | 87 | 78 |

## Improvement effect

- GS-L-BR-114 improves RR without reducing wet grip.
- SB-018 improves RR without reducing Ice & wet grip.

# Test results




## GS-L-BR-114 & SB-018

- Easy to handle due to low viscosity.
- Improve processability

## Improvement effect of GS-L-BR-114

- Rolling resistance
- Wet grip
  - Suitable for all-season tire.

## Improvement effect of SB-018

- Rolling resistance
- Ice grip
  - Suitable for winter tire.

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# Raw material

| Material | Product Name | Manufacturer | Note |
|---|---|---|---|
| Styrene-butadiene rubber | JSR HPR355 | JSR Corporation | Styrene content: 27%<br>Mooney Vis. @100°C: 44<br>Tg: -24°C |
| Natural Rubber | STR20 | Von Bundit Co., Ltd. | |
| Butadiene Rubber | JSR BR01 | JSR Corporation | Cis content: 95%<br>Mooney Vis. @100°C: 45 |
| Carbon black | DIABLACK™ I | Mitsubishi Chemical Corporation | ASTM N220 |
| Silica | ULTRASIL® 7000GR | Evonik Industries AG | Specific surface area (N2)<br>175 $m^2/g$ |
| Silane Coupling Agent | Si 75® | Evonik Industries AG | |
| TDAE | VIVATEC 500 | H&R GmbH Co. KGaA | |
| Insoluble sulfur | MUCRON OT-20 | SHIKOKU CHEMICALS CORPORATION | Sulfur/Oil = 80/20 |