Technical Insights of KURARAY LIQUID RUBBER

# Liquid Farnesene Rubber in Tire Formulation

Elastomer R&D Department
Elastomer Division

kuraray

Technical Insights of KURARAY LIQUID RUBBER

# New Bio-based Liquid Polymer in Various Formulations

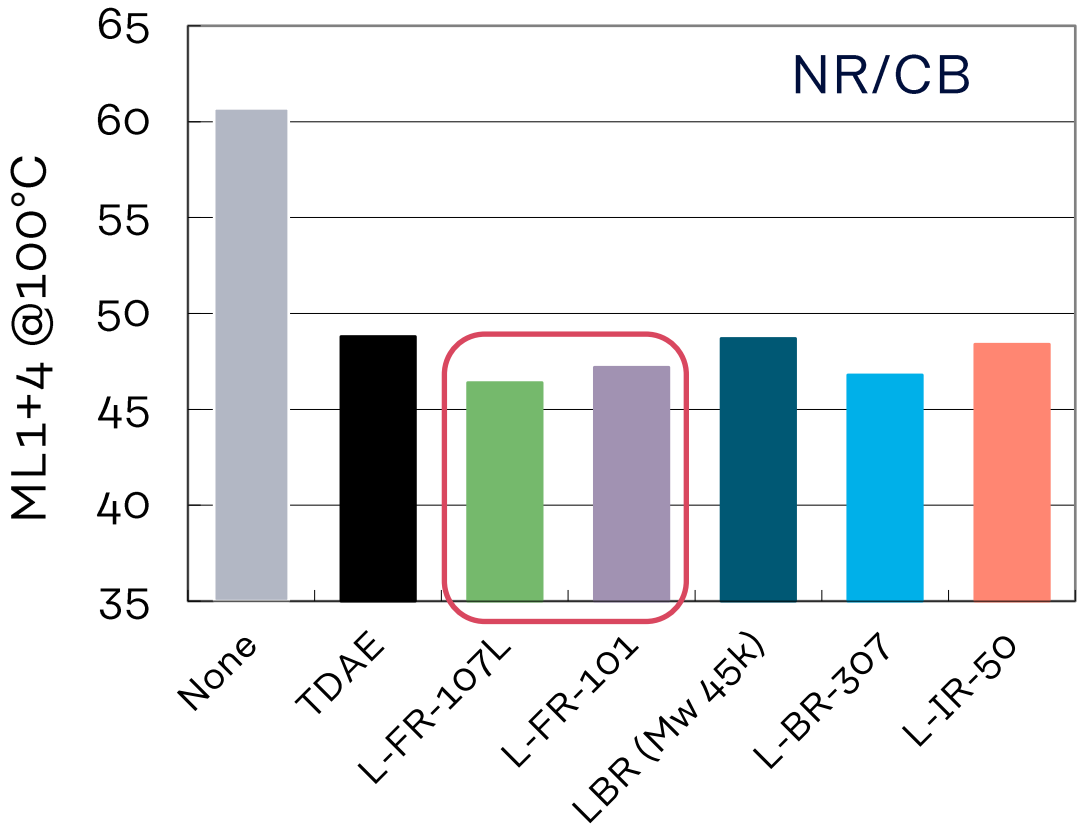
Elastomer R&D Department
Elastomer Division

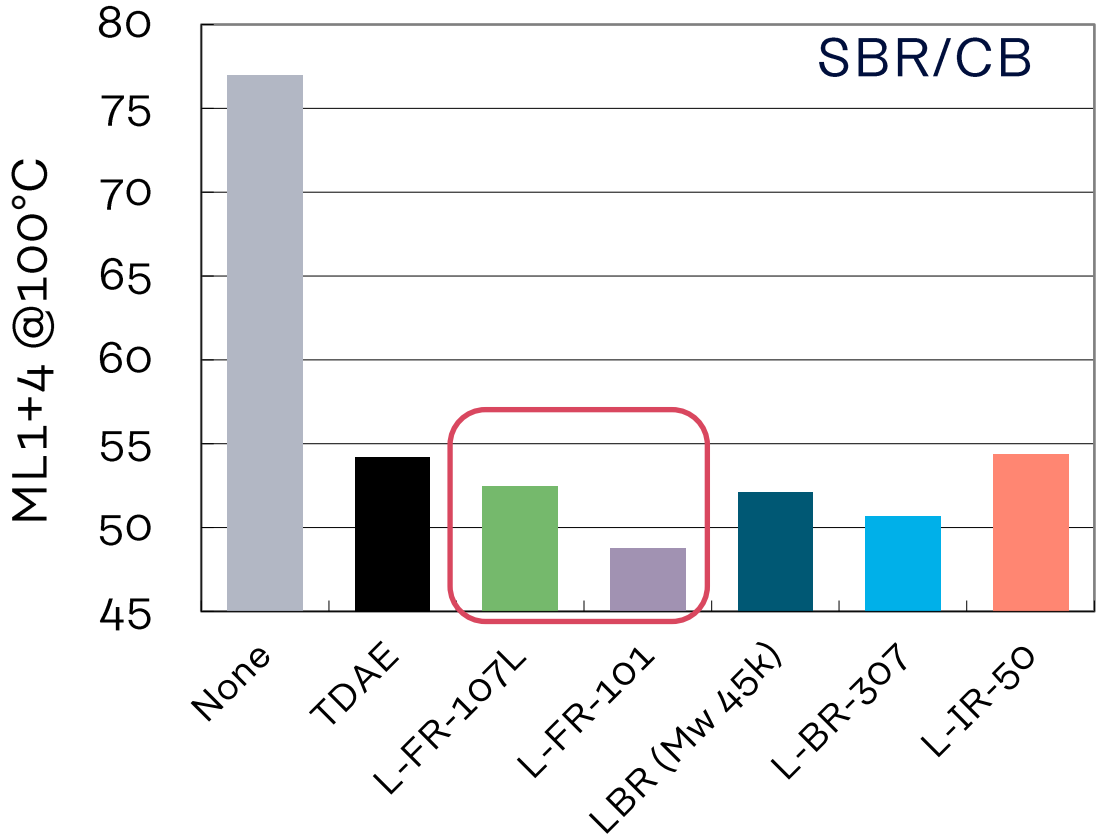
kuraray

# Test Formulation

- NR/ CB/ Plasticizer = 100/ 50/ 10
- SBR/ CB/ Plasticizer = 100/ 50/ 10
- SBR/ CB/ Silica/ Plasticizer = 100/ 25/ 25/ 10
- SBR/ Silica/ Plasticizer = 100/ 50/ 10

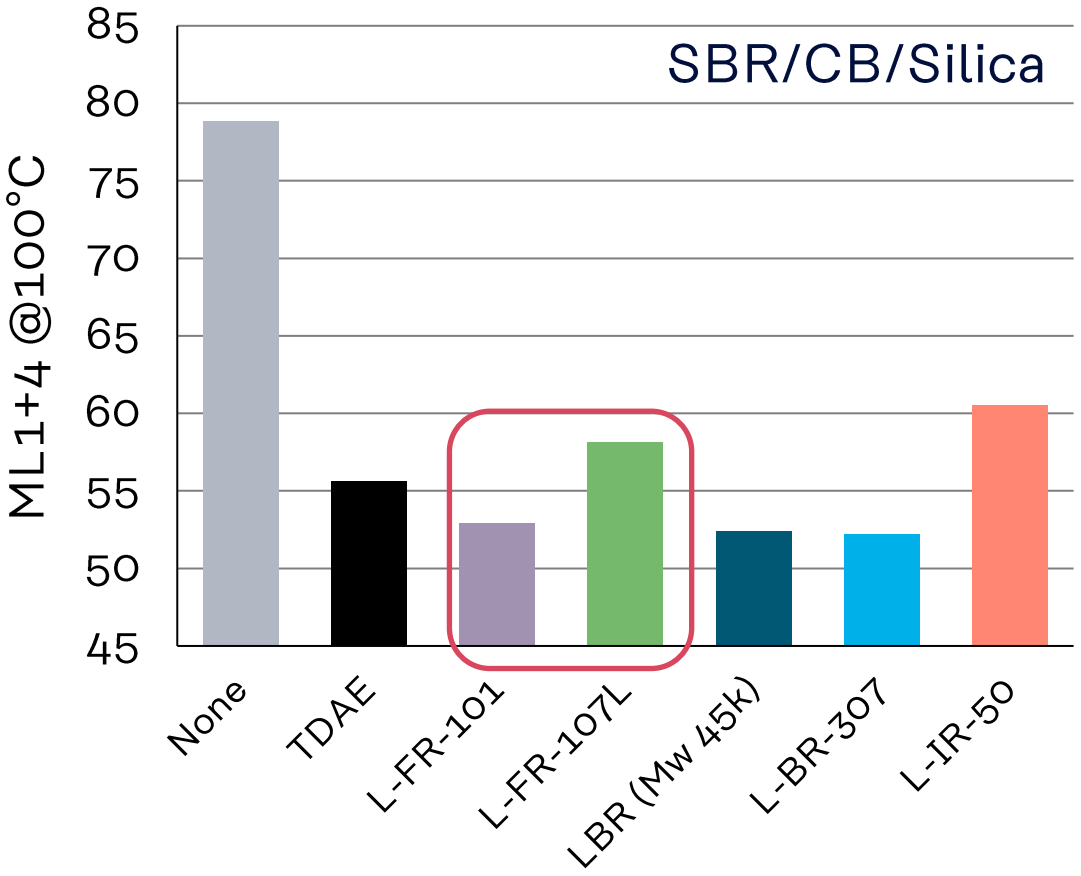
# Mooney Viscosity 1

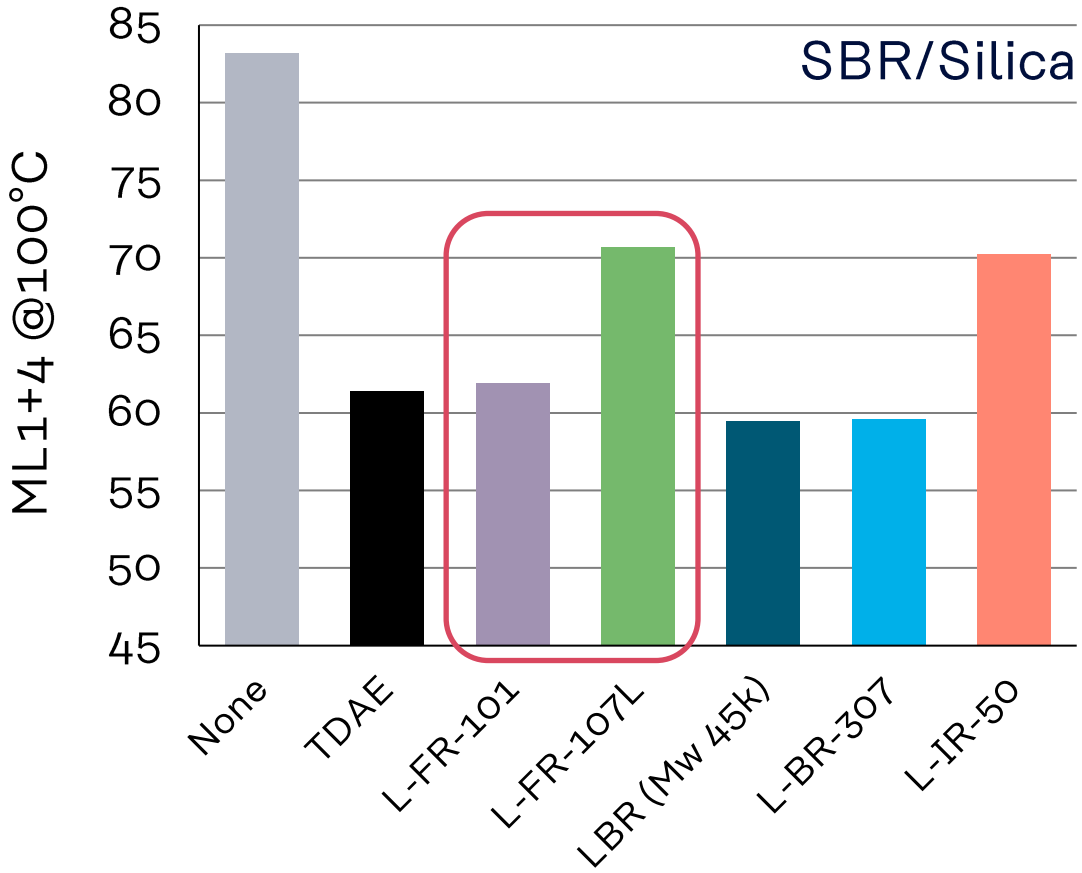



Better Plasticizing Effect

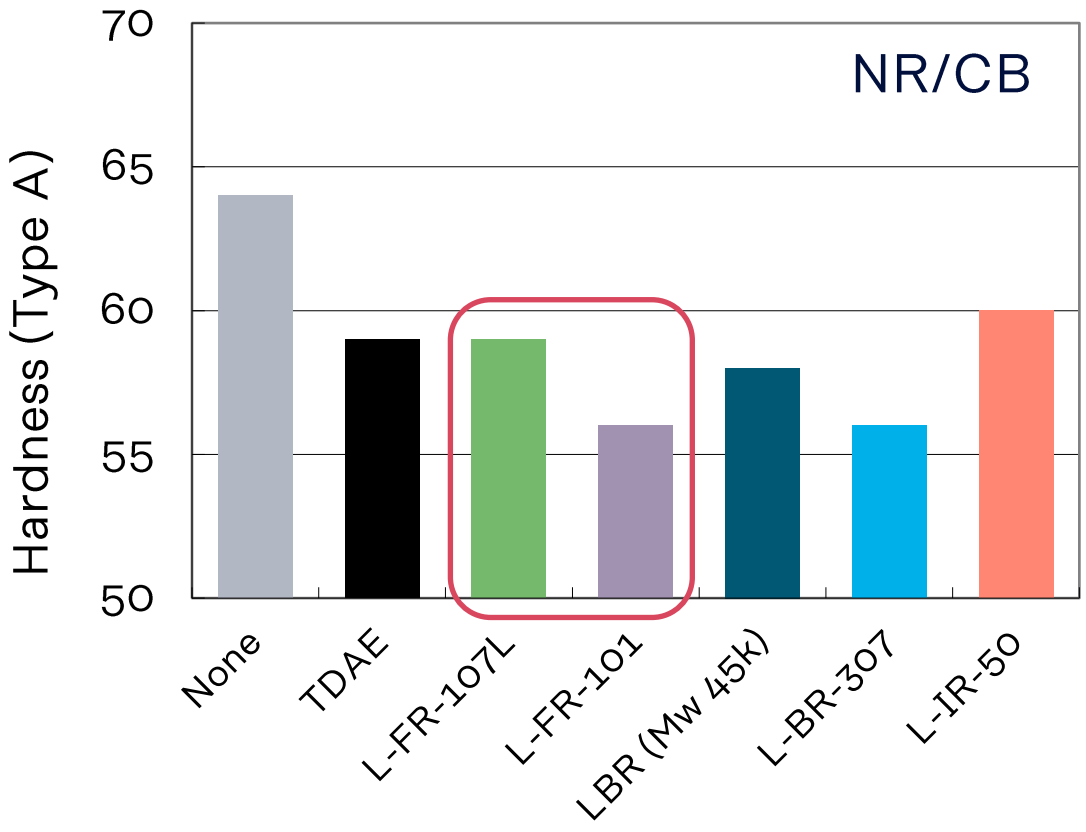
# Mooney Viscosity 2

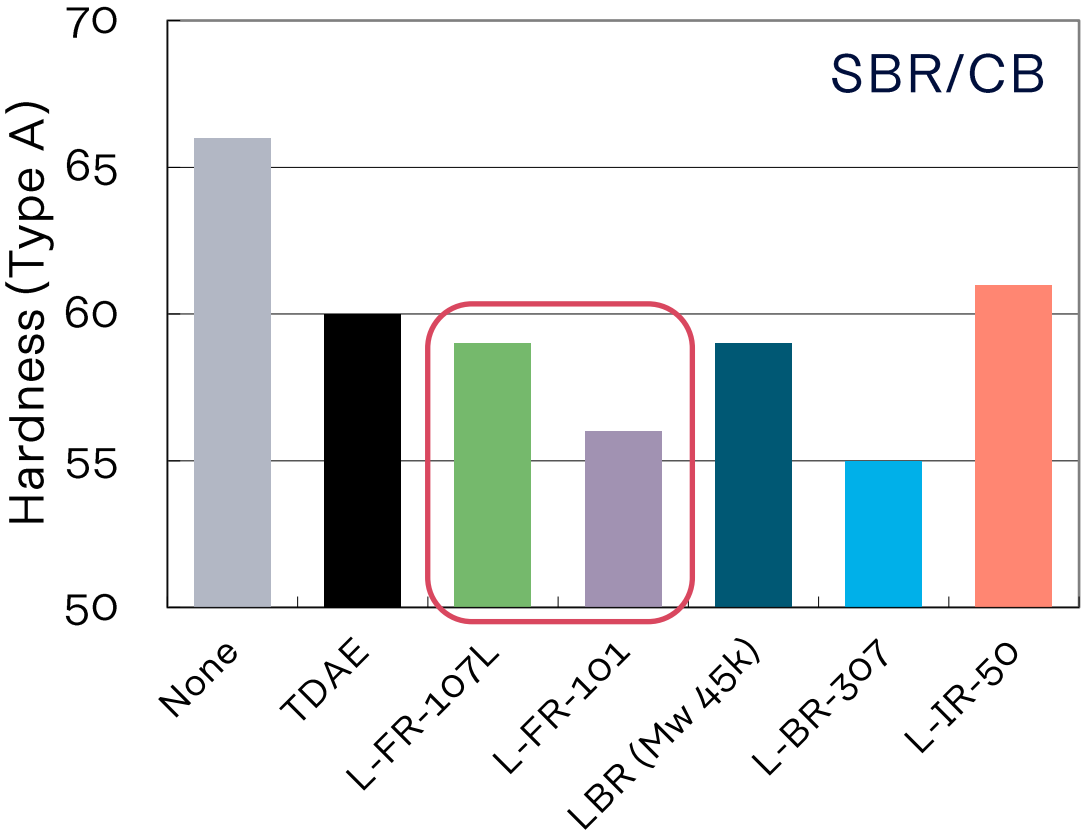


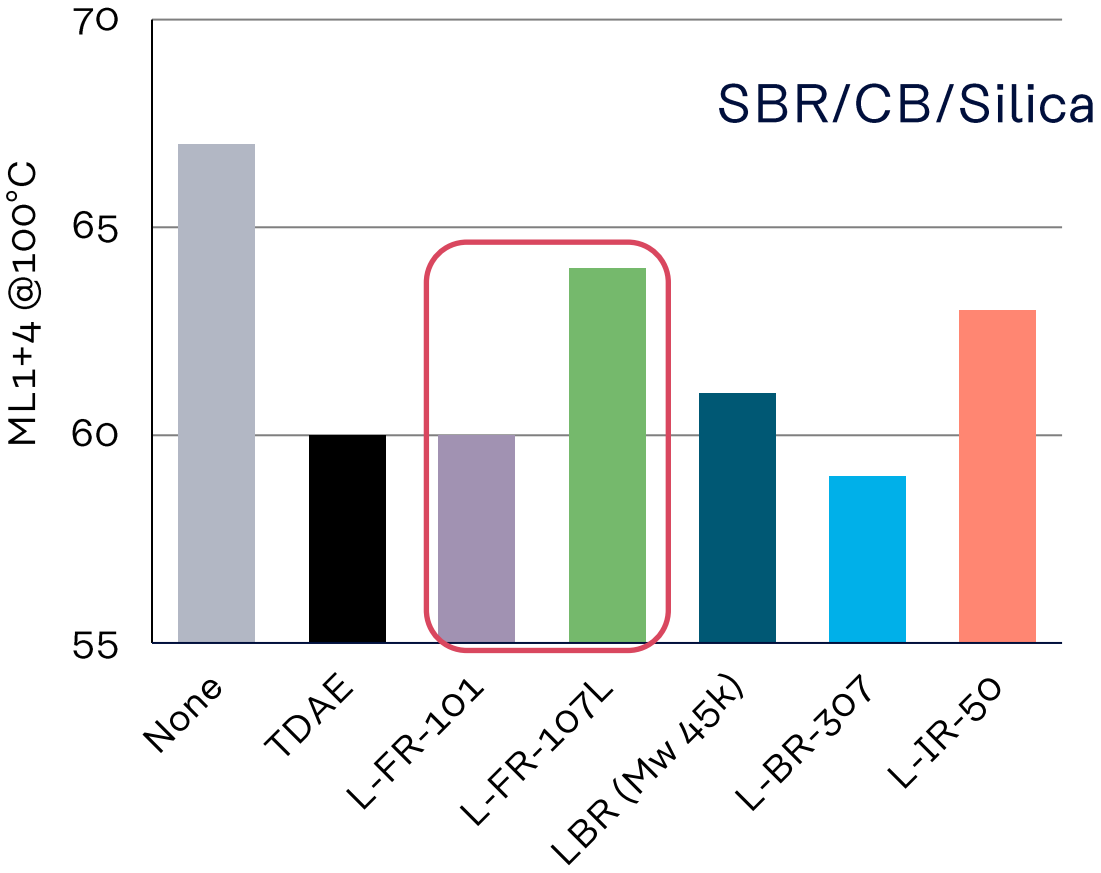

Good Plasticizing Effect

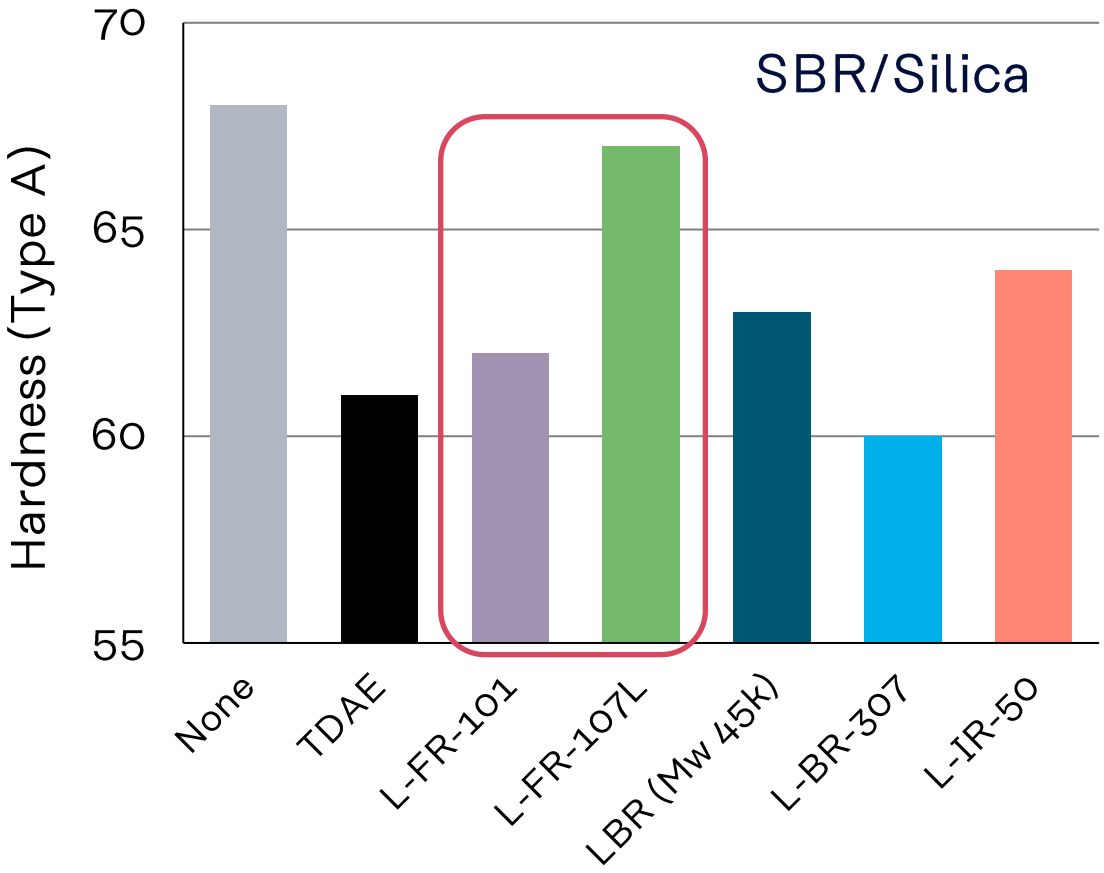
# Hardness (Type A) 1



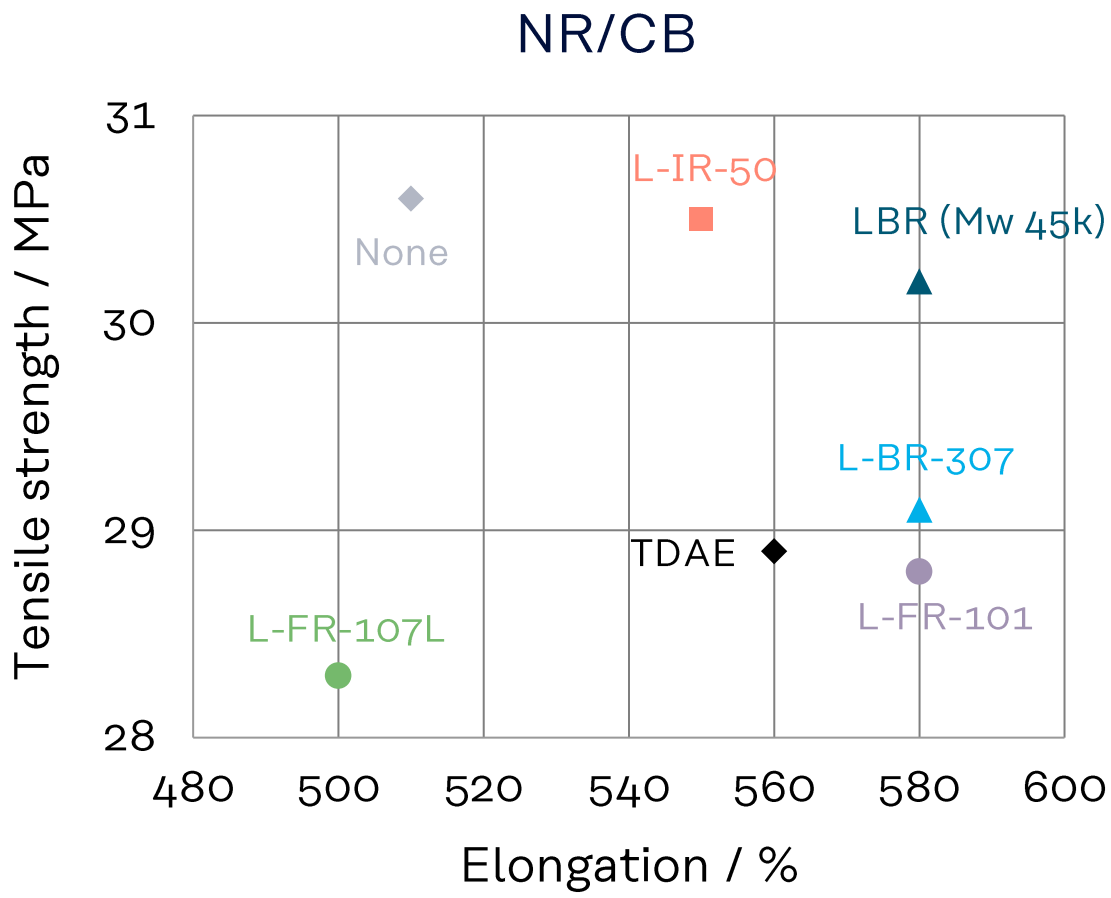



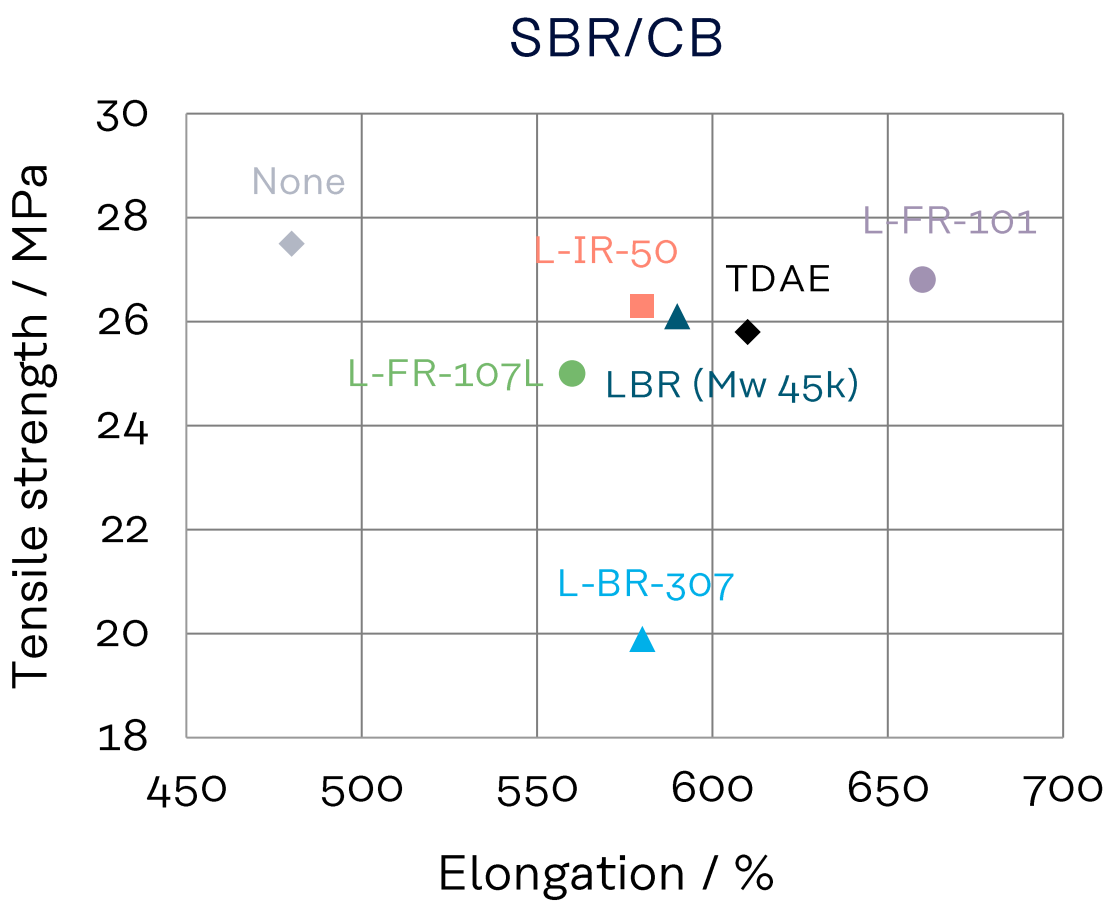
# Hardness (Shore A) 2



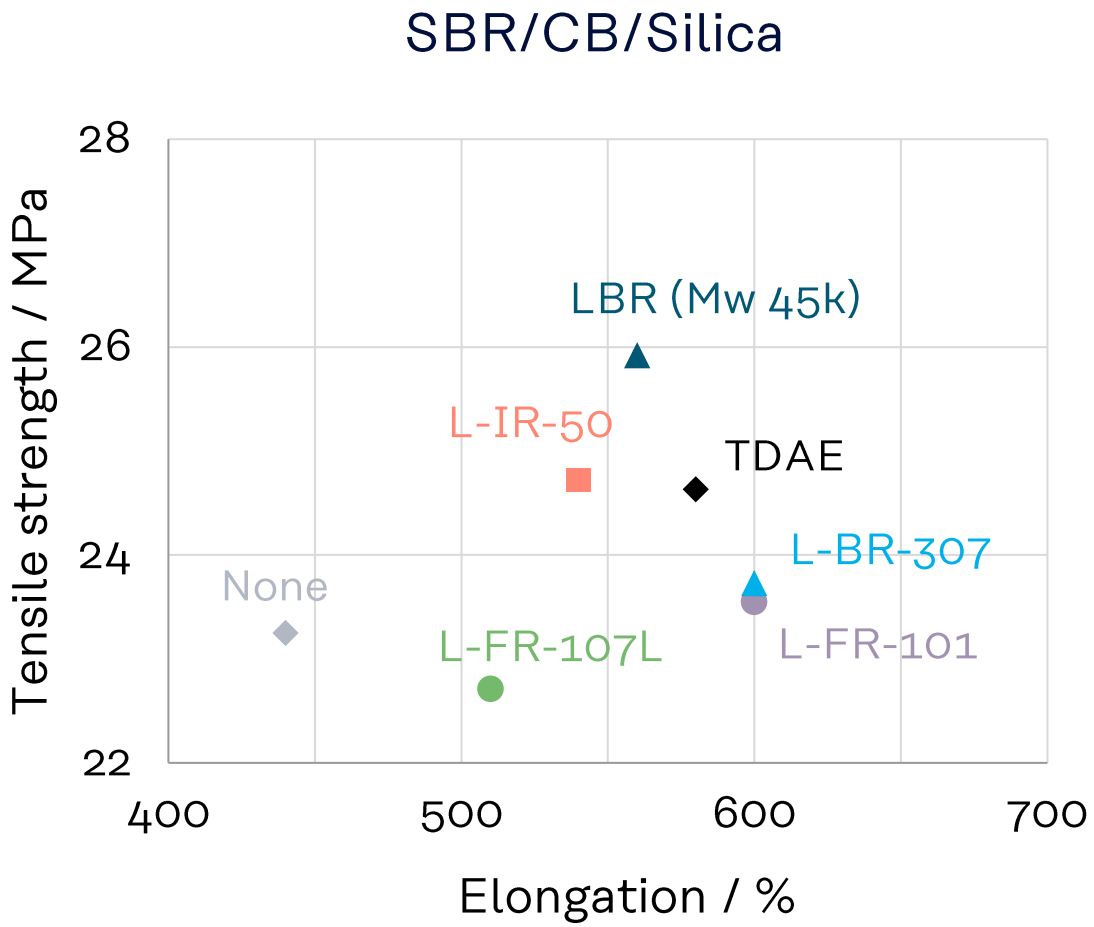



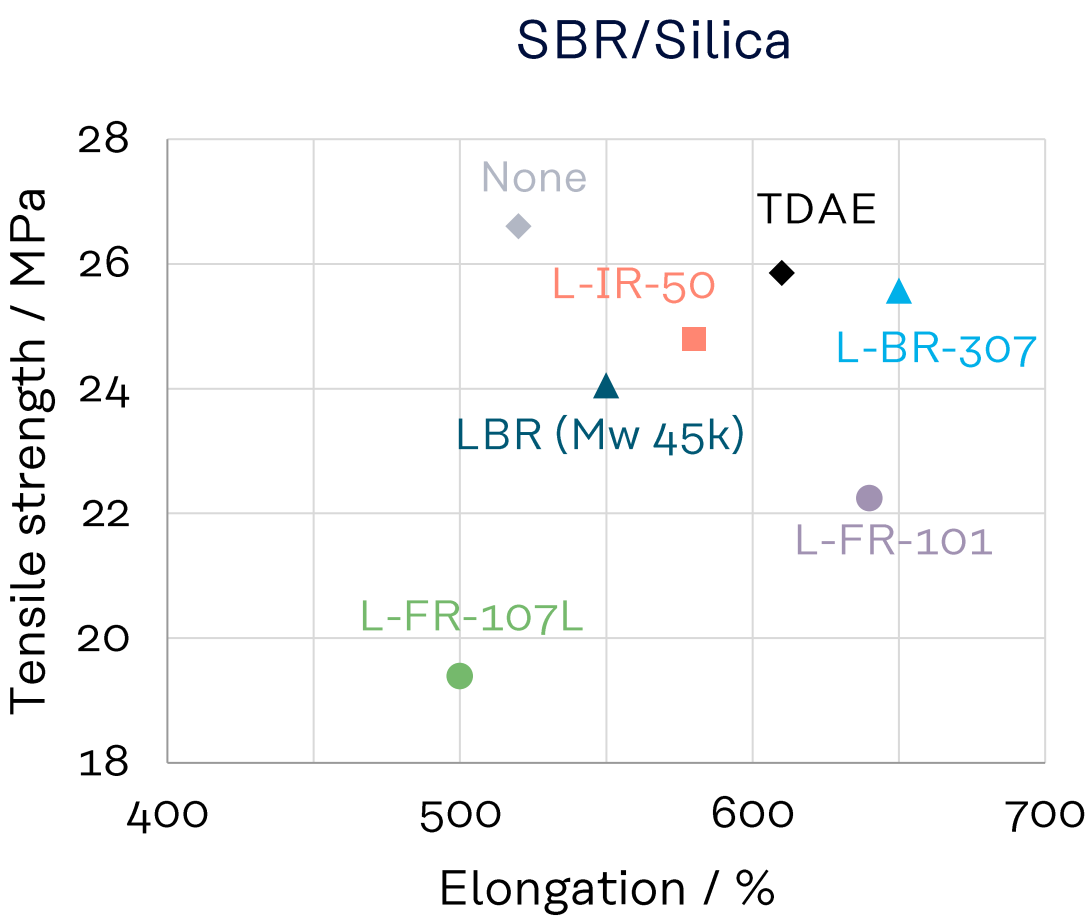
# Tensile Properties



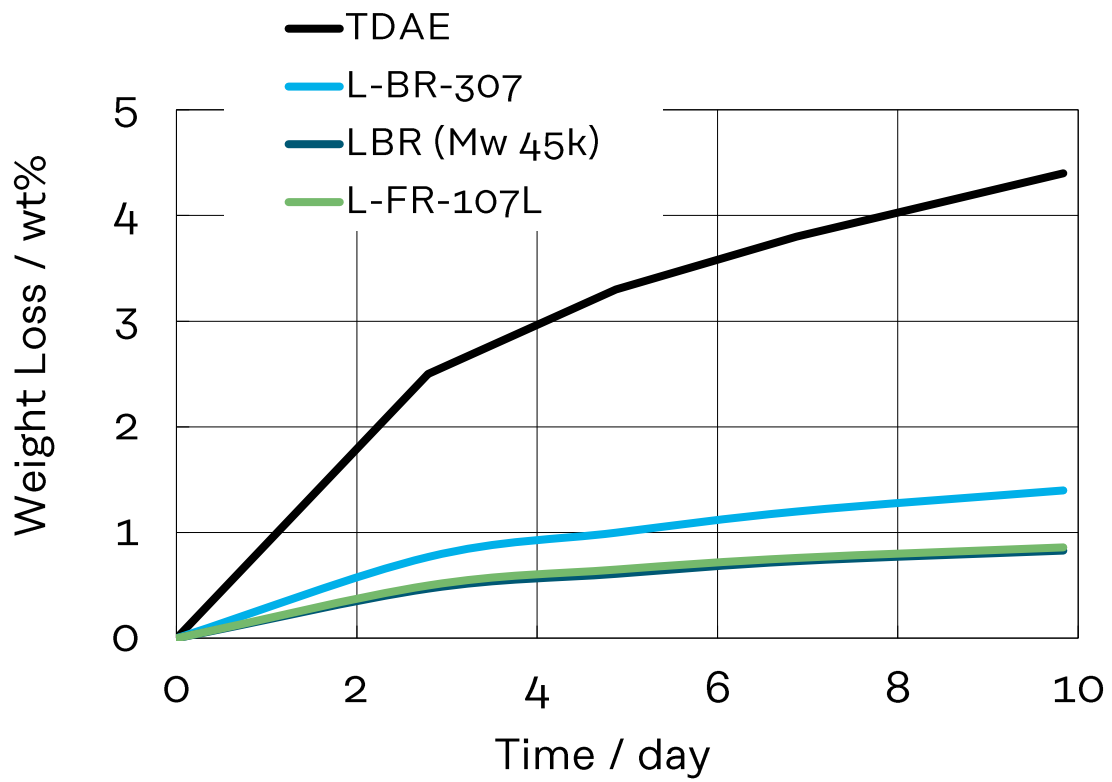
# Tensile Properties



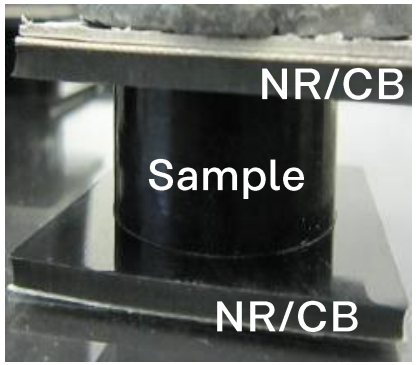
# Migration Property

Good




-Formulation-
SBR/CB/Plasticizer
=100/70/40
-Test condition-
Temp.: 70°C

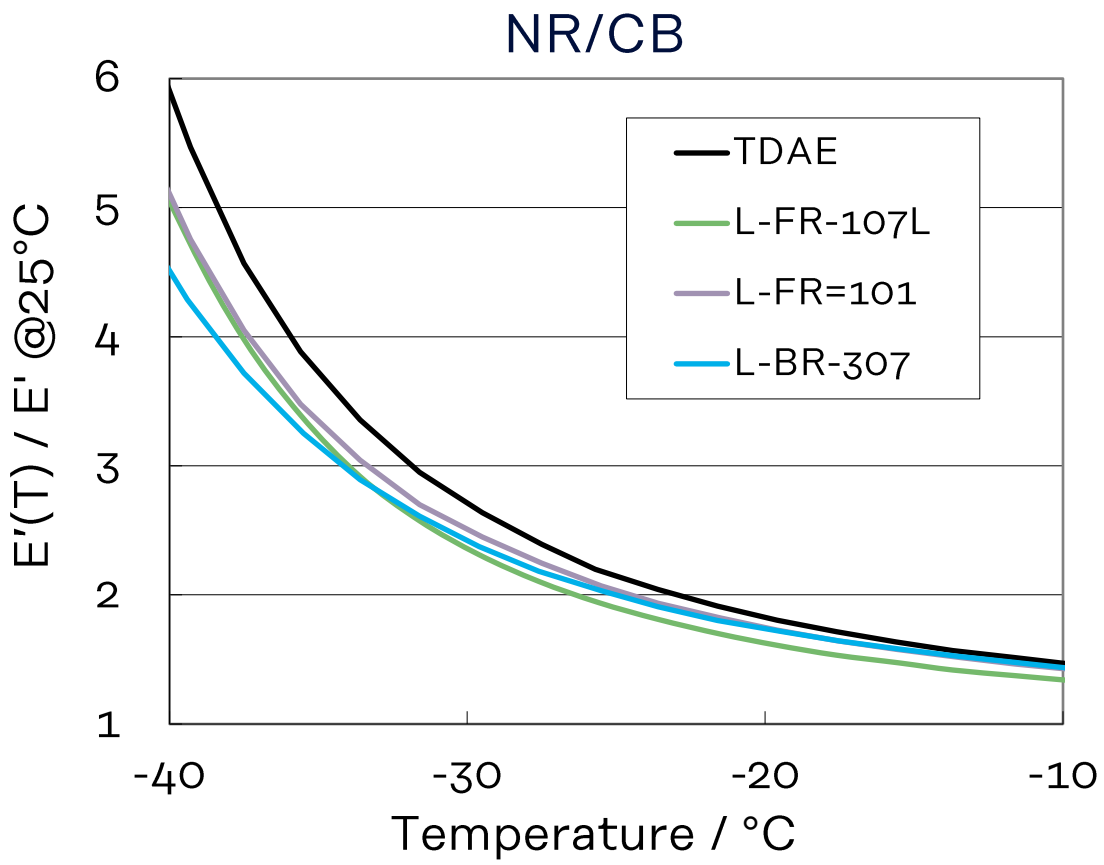
10N Load

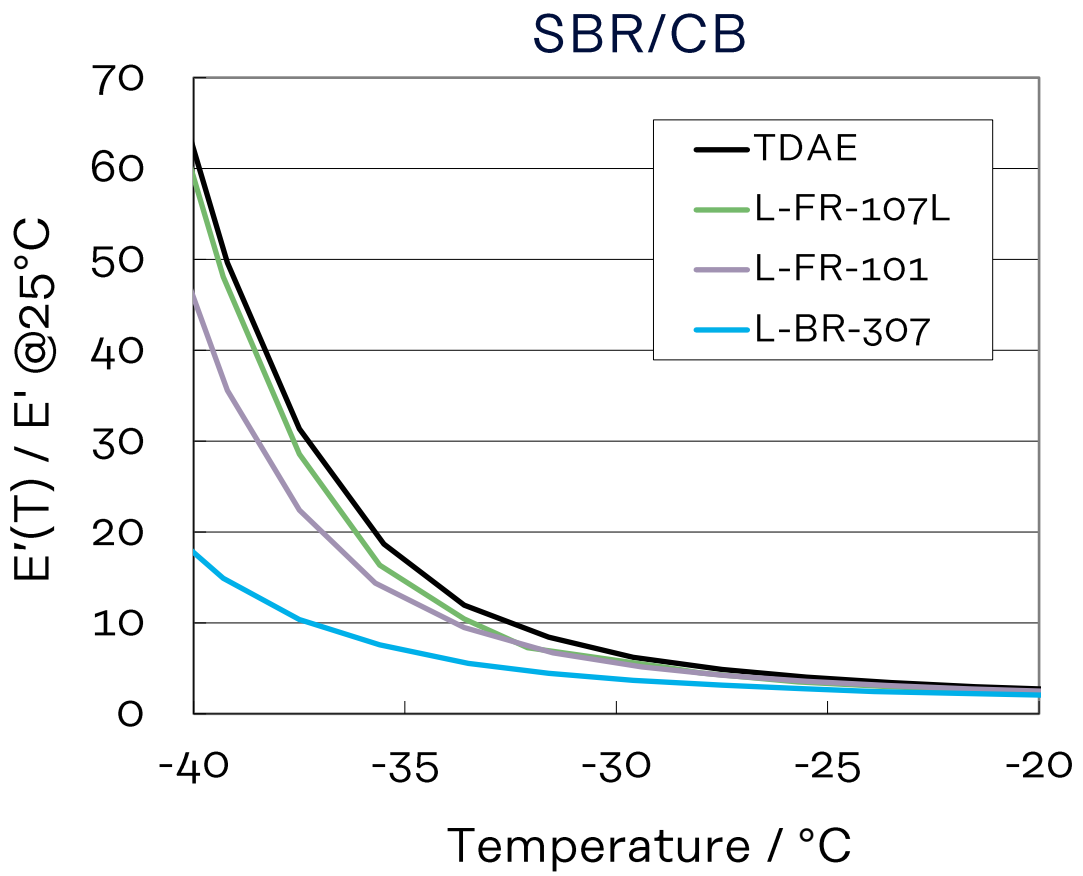



✓ Less migration property => Expected long term performance

# Low Temperature Property

-Test condition-
Static strain:0.5%
Dynamic Strain:0.1%
Frequency:10Hz

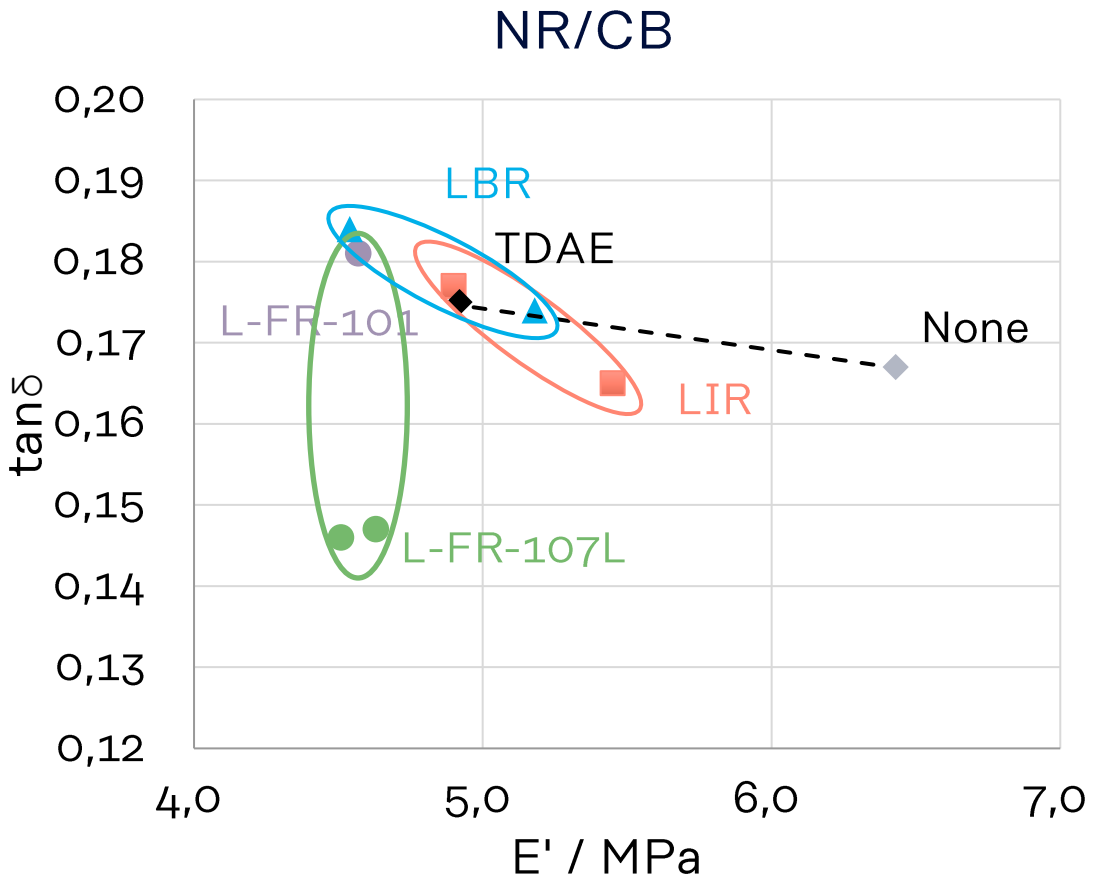


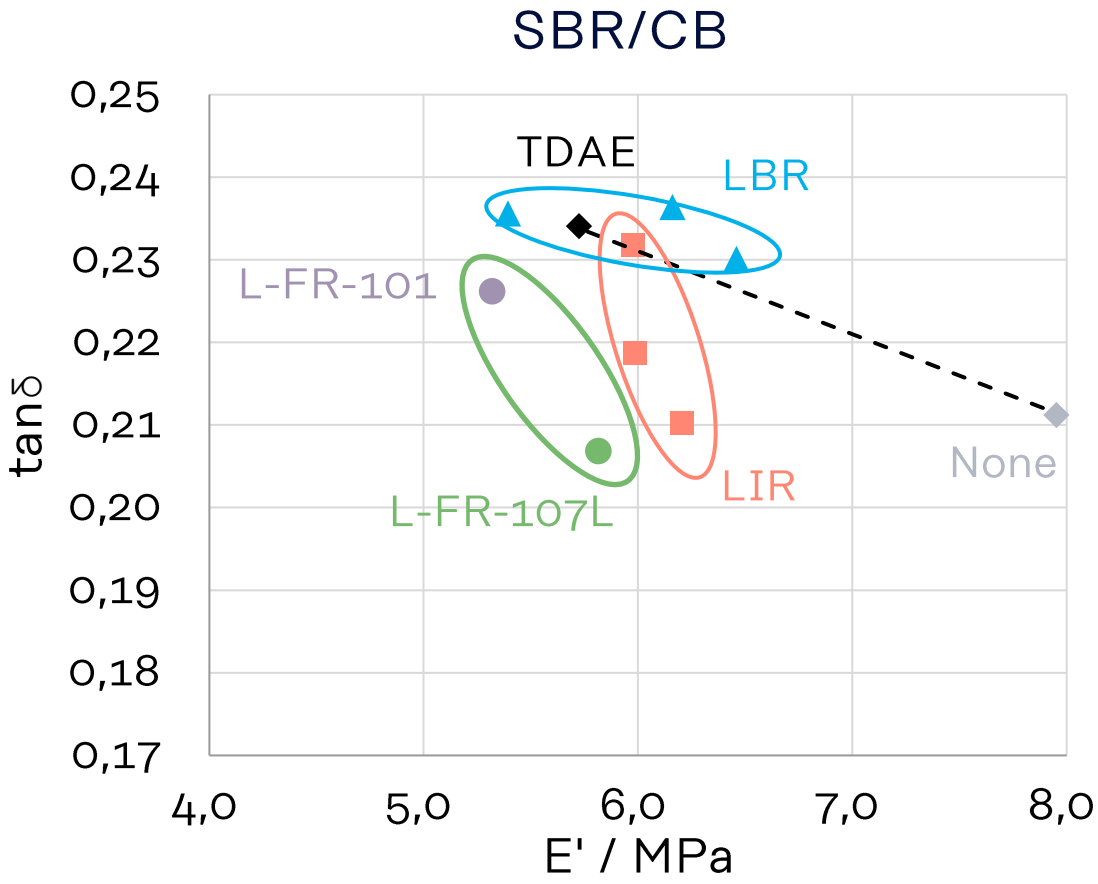




✓ Good low temperature property

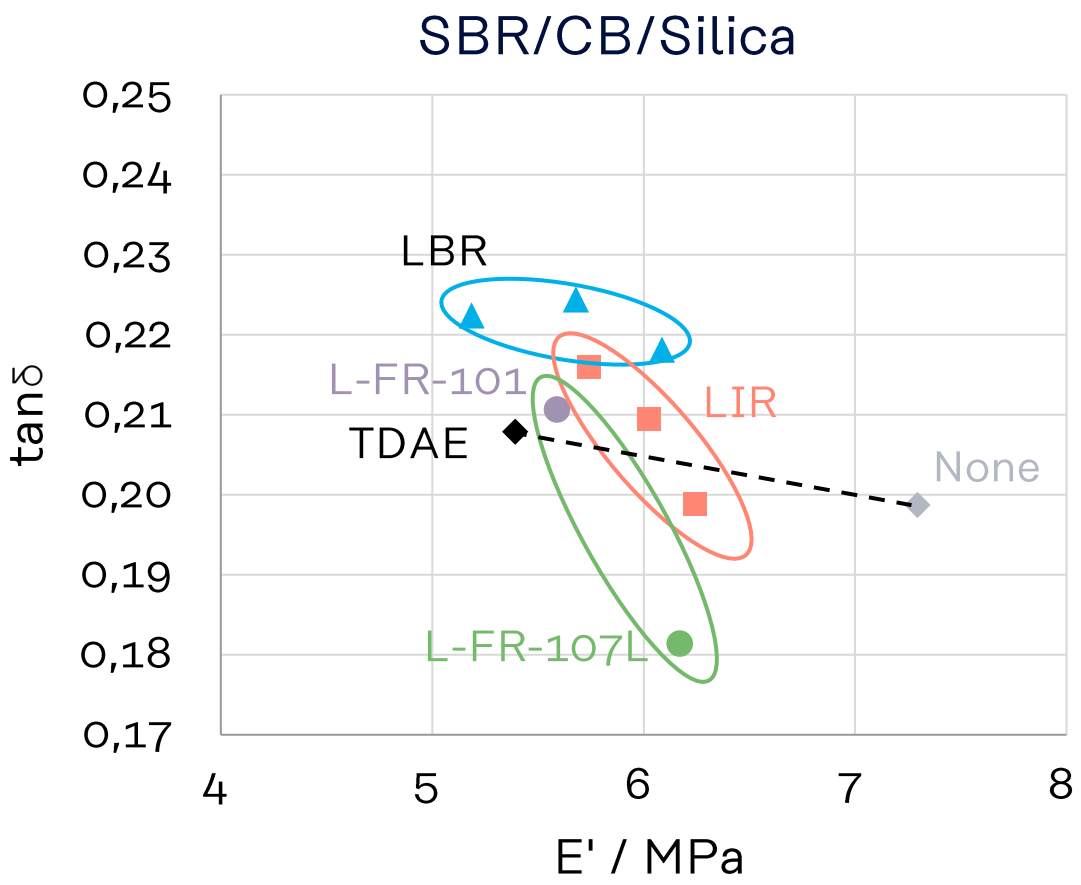
# tanδ and E′ at 25 °C

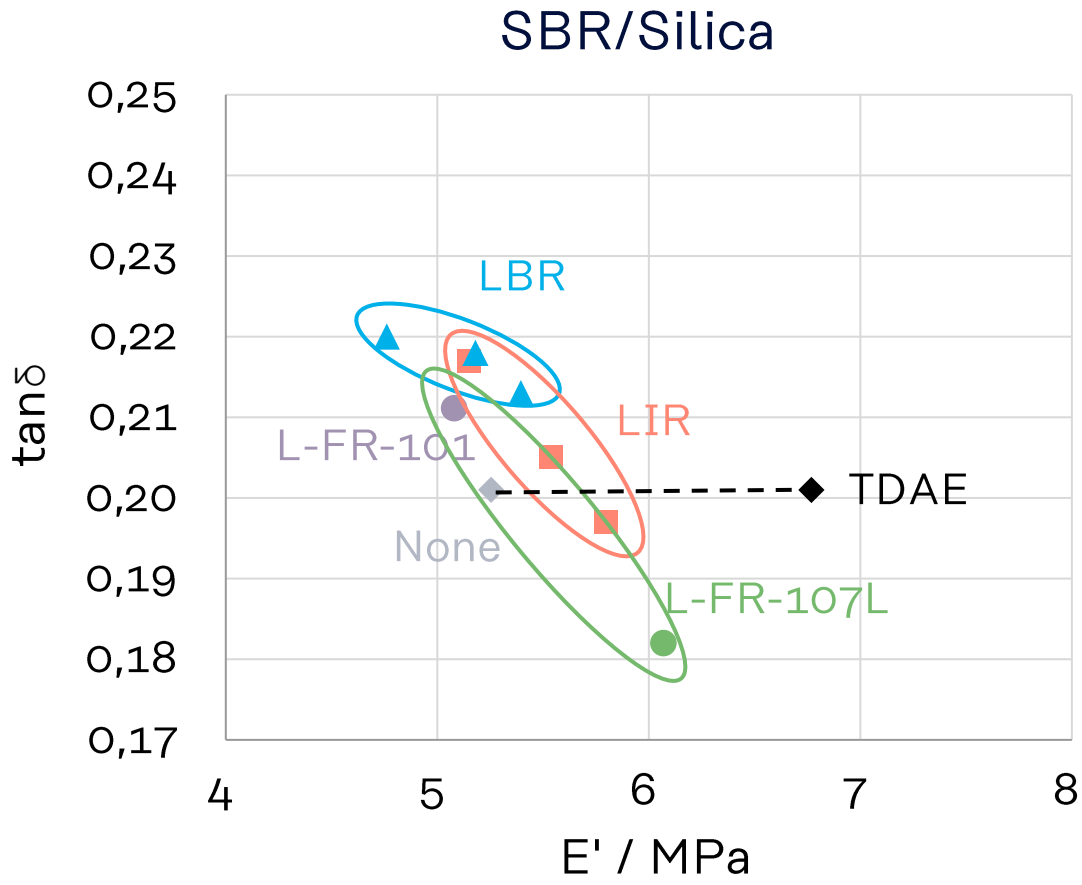
-Test Conditions-
Static strain: 0.5%
Dynamic Strain: 0.1%
Frequency: 10Hz



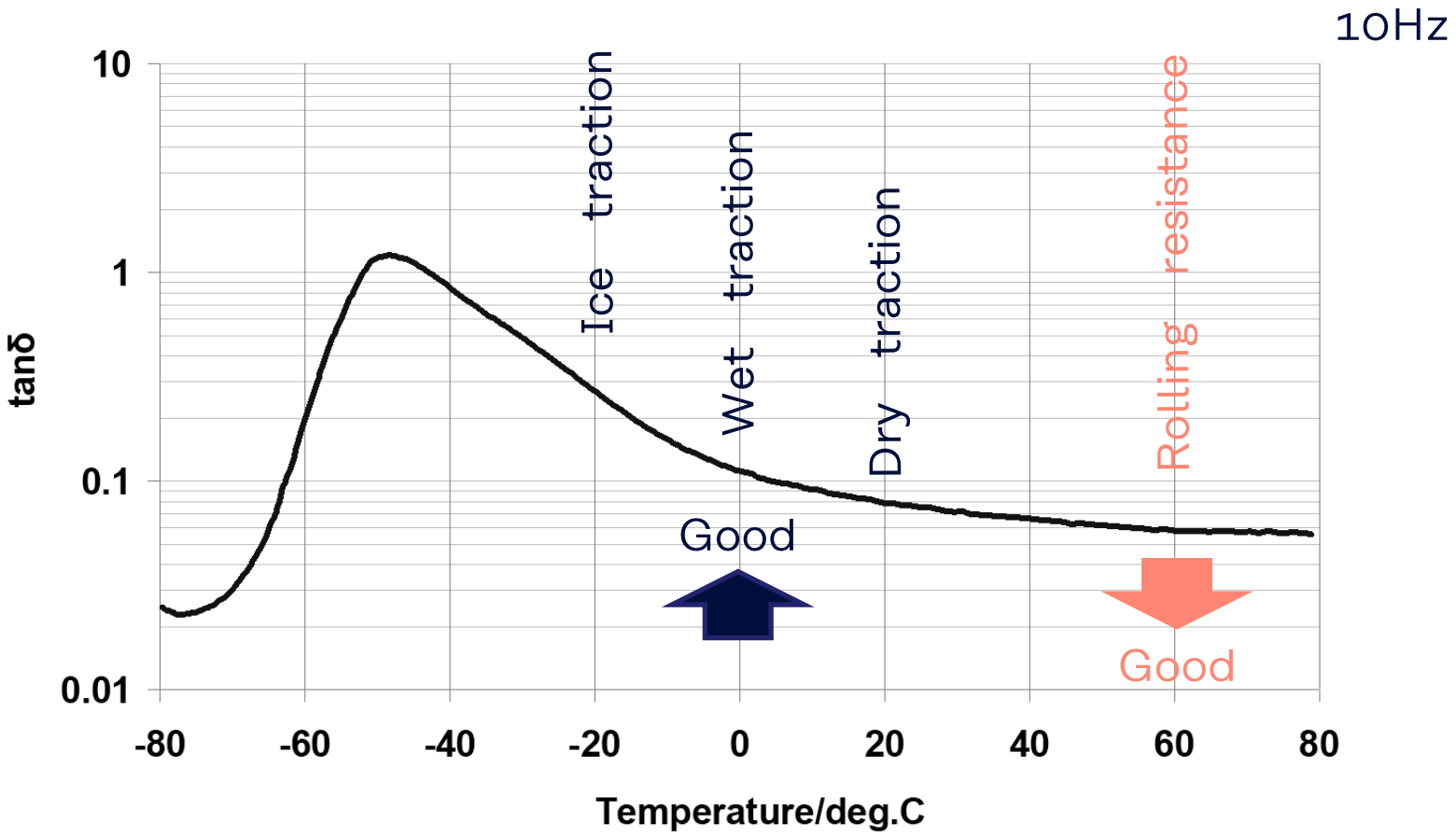
# tanδ and E′ at 25 °C




Better fuel efficiency was suggested by lower tanδ.

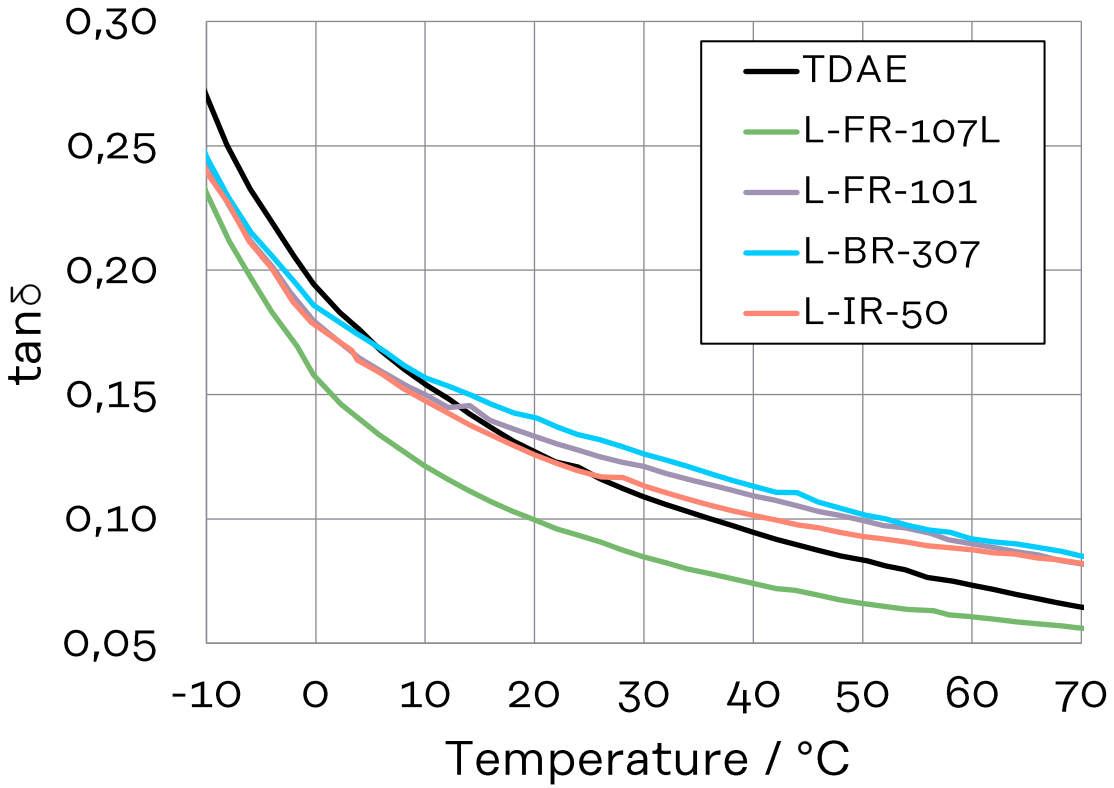
# Required Performance and tanδ

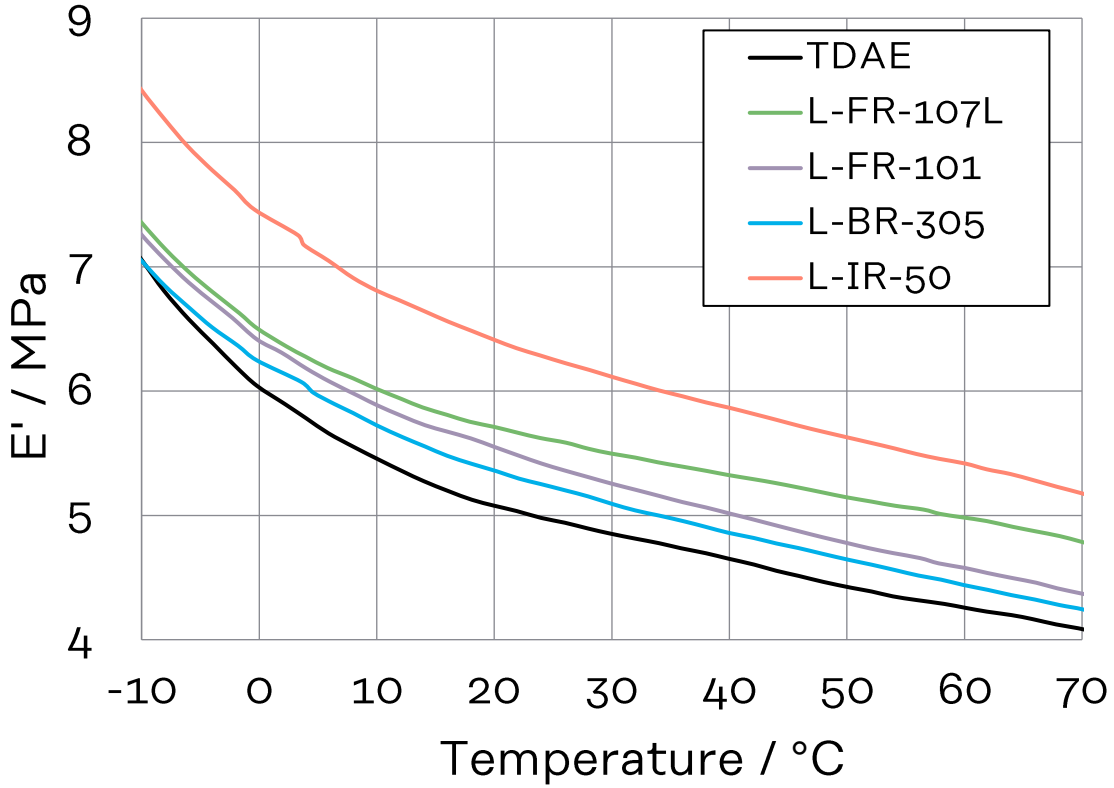


# Viscoelastic Property

-Test condition-
Static strain: 10%
Dynamic Strain: 2%
Frequency: 10Hz

NR/CB




Better fuel efficiency was suggested by lower tanδ.

# Consideration of Silica-Reinforcement Mechanism

E’ of Liquid Farnesene Rubber was increased in Silica formulation compared with CB formulation. Better silica dispersion and reinforcement around silica was suggested.

Moderate Mooney viscosity of Liquid Farnesene Rubber suggest a certain interaction between silica and polymer. (Functionalized polymer increases viscosity dramatically due to too strong interaction.)

Prospected Mechanism in Silica Formulation

1) Silane coupling agent reacts with silica surface.
2) Silica and coupling agent are covered with Liquid Farnesene Rubber.
3) Sulfide bond on coupling agent cleaves and reacts with high branched (reactive) Liquid Farnesene Rubber rather than SBR.
4) And then Liquid Farnesene Rubber is co-vulcanized with SBR.
5) Molecular mobility of Liquid Farnesene Rubber is inhibited. Accordingly, low tanδ was observed.

# Summary

Our new polymer provides...

1) Bio-based
2) Unique structure
3) High plasticizing effect
4) Low migration property
5) Good low temperature traction
6) Improved silica dispersion and reinforcement
7) Better fuel efficiency

Technical Insight of KURARAY LIQUID RUBBER

# High molecular weight Liquid Farnesene Rubber

Elastomer R&D Department
Elastomer Division

kuraray

# Evaluation of high molecular weight LFR

Evaluated effect of molecular weight ( more than Mw=100k)
⇒Confirmed improvement of fracture resistance

| LFR (Homopolymer) | Molecular weight |
|---|---|
| L-FR-107L | 130k |
| L-FR-109* | 206k |
| L-FR-100L* | 276k |
| L-FR-100H* | 420k |
| L-FR-100HH* | 880k |

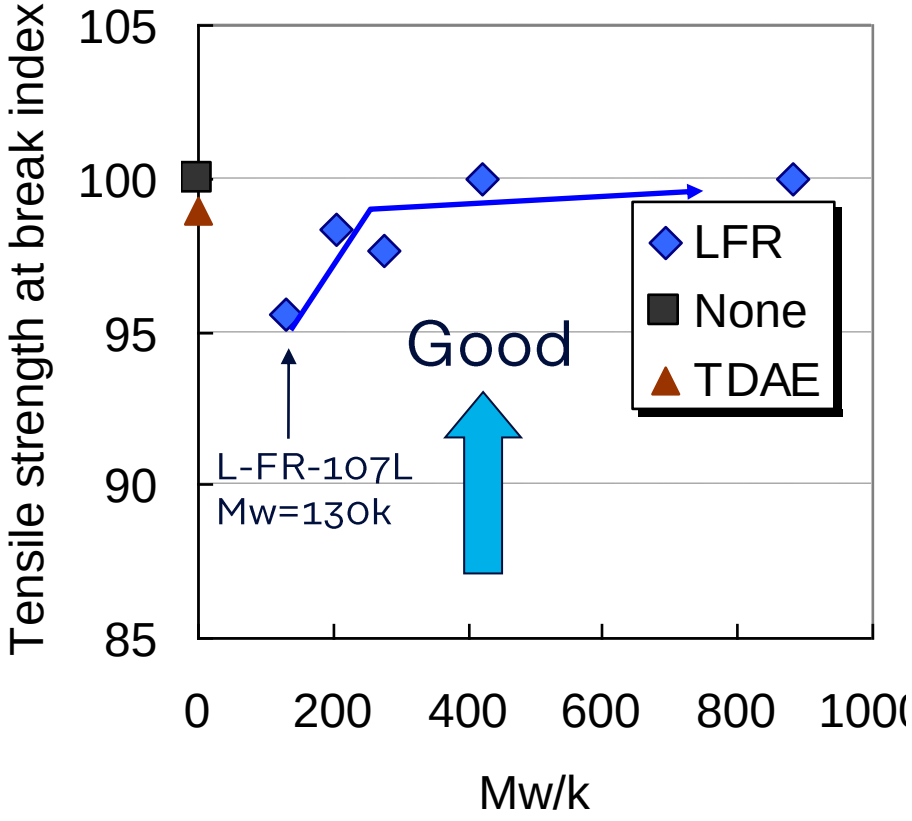
* Development Grade

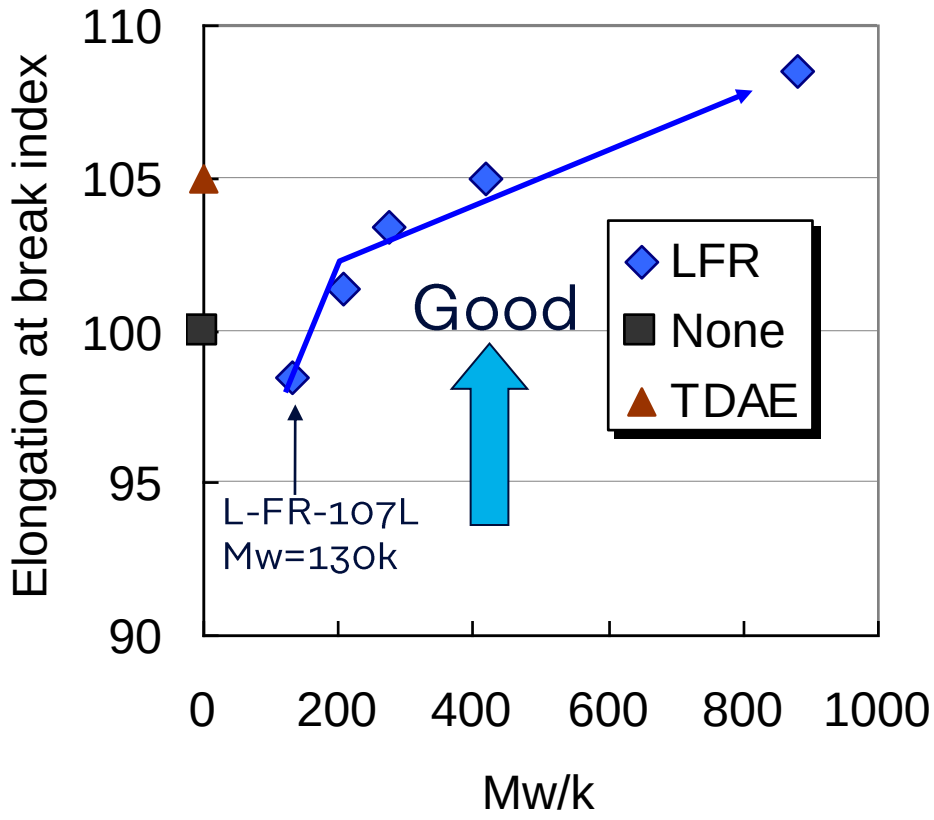
⇒in NR/CB/plasticizer = 100/40/5 formulation

# Evaluation summary

| Plasticizer | | None | TDAE | L-FR-107L | L-FR-109 | L-FR-100L | L-FR-100H | L-FR-100HH |
|---|---|---|---|---|---|---|---|---|
| Mooney Vis., ML1+4 (130°C) | | 43 | 44 | 43 | 43 | 45 | 46 | 46 |
| Mooney Scorch time (130°C) | | | | | | | | |
| t5 | (min.) | 17 | 18 | 16 | 16 | 17 | 17 | 16 |
| t35 | (min.) | 21 | 21 | 20 | 19 | 20 | 19 | 20 |
| Curelastometer (145°C) | | | | | | | | |
| t90 | (min.) | 12.5 | 11.9 | 11.9 | 11.8 | 12.0 | 12.0 | 11.9 |
| Mechanical Properties | | | | | | | | |
| Hardness | Type A | 60 | 56 | 57 | 57 | 58 | 58 | 59 |
| EB | (%) | 550 | 530 | 500 | 510 | 520 | 530 | 550 |
| TB | (MPa) | 29.4 | 29.1 | 28.1 | 28.9 | 28.7 | 29.4 | 29.4 |
| M100 | (MPa) | 2.5 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| M200 | (MPa) | 6.8 | 6.0 | 6.4 | 6.2 | 6.0 | 6.0 | 5.9 |
| M300 | (MPa) | 13.5 | 11.8 | 12.9 | 12.4 | 12.1 | 12.0 | 11.7 |
| Viscoelasticity (25°C) | | | | | | | | |
| E′ (5%) | (MPa) | 4.6 | 4.1 | 3.8 | 3.9 | 4.0 | 4.1 | 4.3 |
| tanδ (5%) | (-) | 0.14 | 0.14 | 0.10 | 0.10 | 0.11 | 0.12 | 0.13 |
| DIN abrasion | ($mm^3$) | 126 | 132 | 134 | 133 | 135 | 131 | 133 |

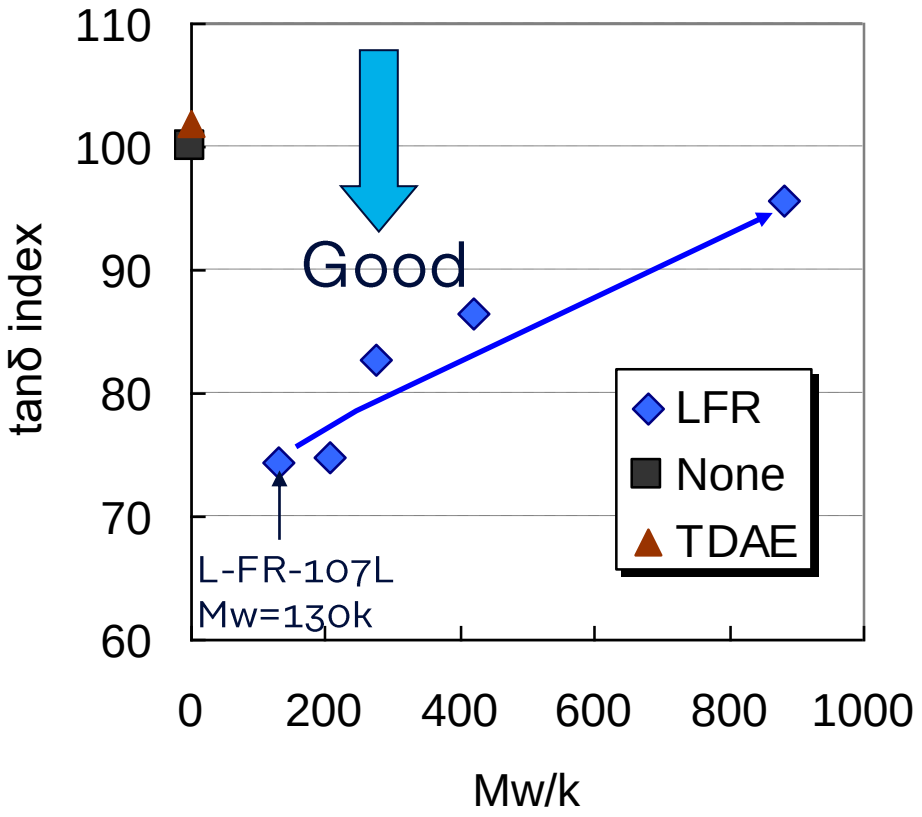
# Evaluation result




✓Higher Mw⇒Better tensile properties
✓More than Mw=200k showed good reinforcement

# Evaluation result




✓Less than Mw=400k ⇒ low tanδ

✓Mw=200k ⇒ Same level as L-FR-107L

# Summary

- More than Mw=200k showed improved fracture resistance
- Less than Mw=400k showed tanδ reduction

⇒Especially LFR of Mw=206k showed better tan δ reduction and fracture resistance.

# APPENDIX

# NR/CB Formulation

| Formulation | phr |
|---|---|
| Natural Rubber (STR20) | 100 |
| Plasticizer | 5 |
| Carbon Black (N220) | 40 |
| ZnO | 3.5 |
| Stearic acid | 2 |
| Sulfur | 1.5 |
| Accelerator NS[1)] | 1.2 |
| Antioxidant 6C[2)] | 1 |
| Antioxidant RD[3)] | 1 |

1) N-tert-Butyl-2-benzothiazolesulfenamide
2) N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine
3) Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline

Mixing Conditions

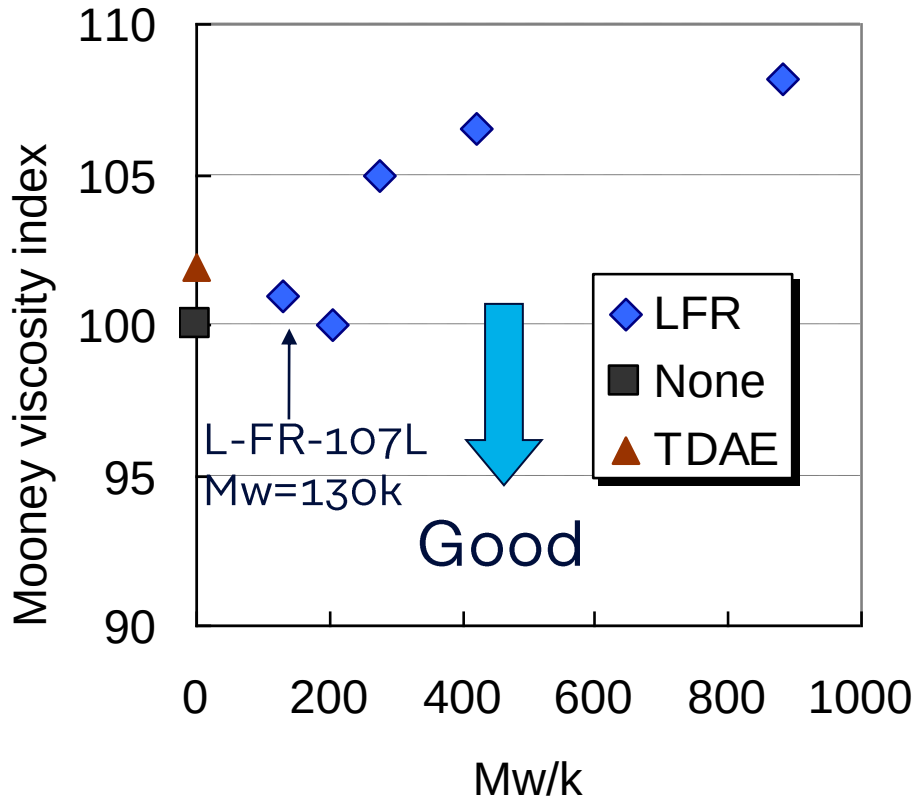
| | |
|---|---|
| 1st stage: | Banbury mixer |
| 0'00" | NR (75°C) |
| 0'20" | CB, TDAE/Liquid Rubber AO, ZnO, Stearic acid |
| 6'00" | Dump out (150-160°C) |
| | |
| 2nd stage: | Banbury mixer |
| 0'00" | Compound Sulfur, Accelerator (50°C) |
| 7'00" | Dump out (95-105°C) |

kuraray

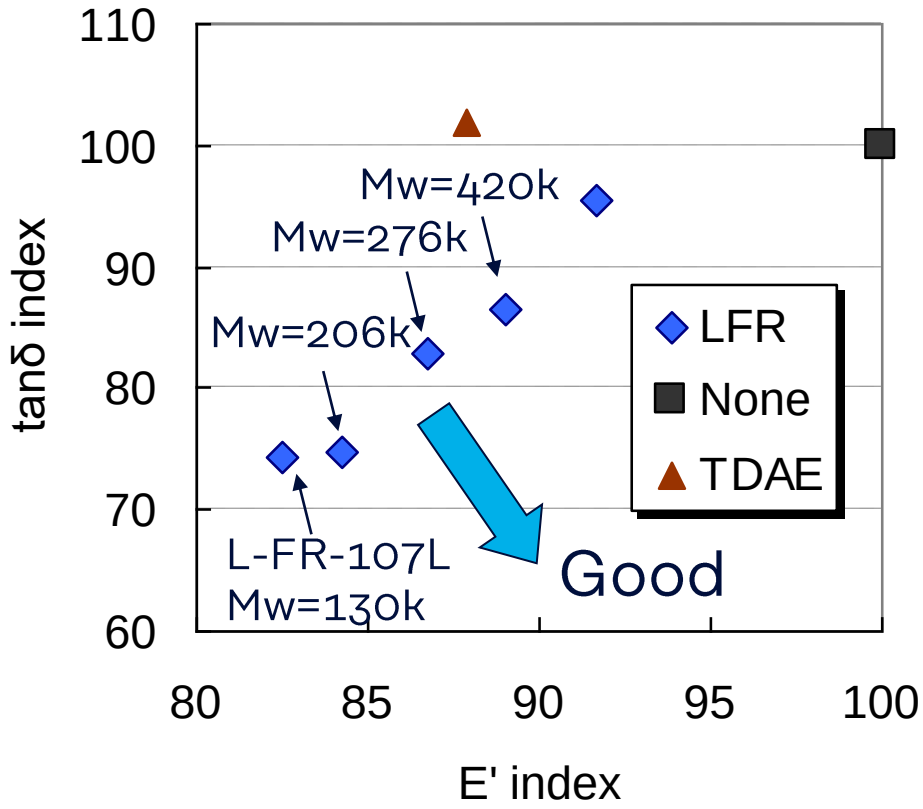
# Raw materials

| Material | Product Name | Manufacturer | Note |
|---|---|---|---|
| Natural Rubber | STR20 | Von Bundit Co., Ltd. | |
| Carbon black | DIABLACK™ I | Mitsubishi Chemical Corporation | ASTM N220 |
| TDAE | VIVATEC 500 | H&R GmbH Co. KGaA | |

# Evaluation result

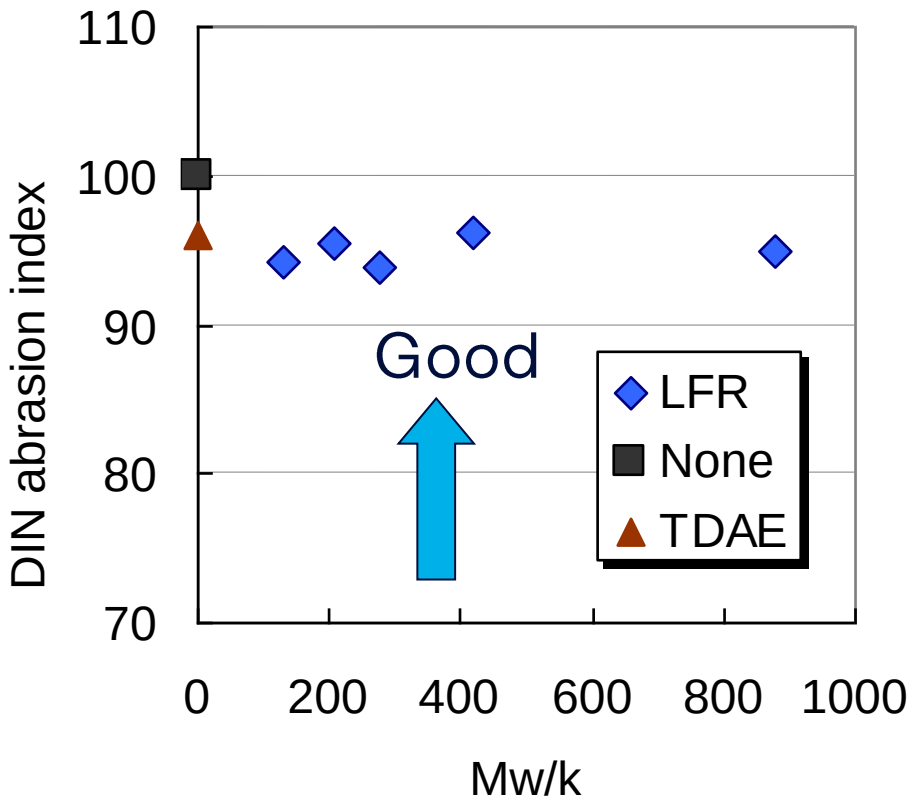



✓Higher Mw⇒ Higher viscosity
✓Mw=200k⇒ Same level as L-FR-107L




✓Higher Mw⇒ Better reinforcement
✓Mw=200k⇒ Better than L-FR-107L

# Evaluation result



Technical Insight of KURARAY LIQUID RUBBER

# Influence of molecular weight and addition amount

Elastomer R&D Department
Elastomer Division

kuraray

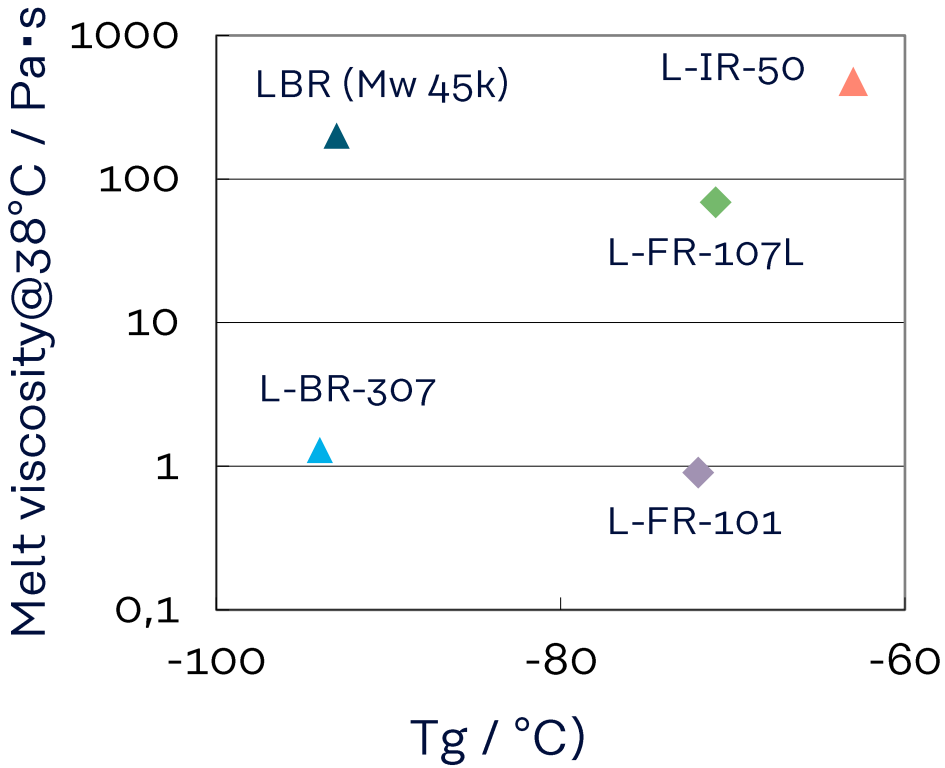
# Agenda

- Introduction of Bio-based Liquid Rubber
- Influence of Molecular Weight in NR/CB Formulation
- Influence of Added Amount in NR/CB Formulation

# Grade List

| Grade | Structure | Tg (°C) | Mw | Visc. @38°C (Pa.s) |
|---|---|---|---|---|
| L-FR-101* | polyfarnesene | -73 | 9k | 0.4 |
| L-FR-107L | polyfarnesene | -71 | 135k | 69 |
| L-BR-307 | polybutadiene | -94 | 8k | 1.3 |
| LIR-50 | polyisoprene | -63 | 54k | 480 |

*Development Grade



# NR/CB Formulation

| Formulation | phr |
|---|---|
| Natural Rubber (TSR20) | 100 |
| TDAE[1)] or Liquid Rubber | 10 |
| Carbon Black (N330) | 50 |
| ZnO | 3.5 |
| Stearic acid | 2 |
| Sulfur | 1.5 |
| Accelerator NS[2)] | 1 |
| Anti oxidant 6C[3)] | 1 |

1) VIVATEC 500 (H&R GmbH Co. KGaA)
2) N-tert-butyl-2-benzothiazolesulfenamide
3) N-(1,3-dimethylbutyl)-N'-phenyl-*p*-phenylenediamine

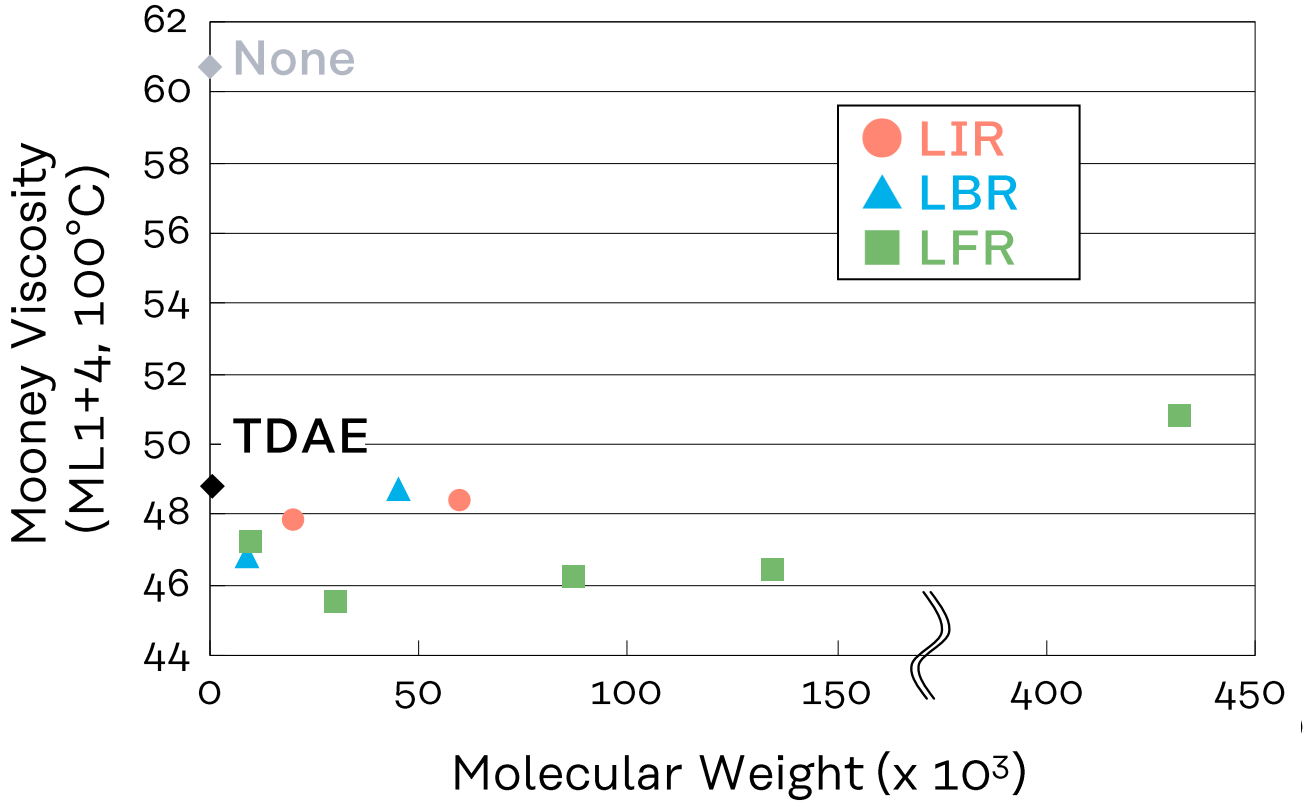
Mixing Conditions

| | |
|---|---|
| 1st stage: | Banbury mixer |
| 0‘00” | NR (85°C) |
| 0’20” | CB, TDAE/Liquid Rubber<br>AO, ZnO, Stearic acid |
| 6’00” | Dump out (150-160°C) |
| | |
| 2nd stage: | Roll mill |
| 0’00” | Compound (55-60°C) |
| 0’30” | Sulfur, Accelerator |
| 7’00” | Sheeting |

# NR/CB Formulation Summary

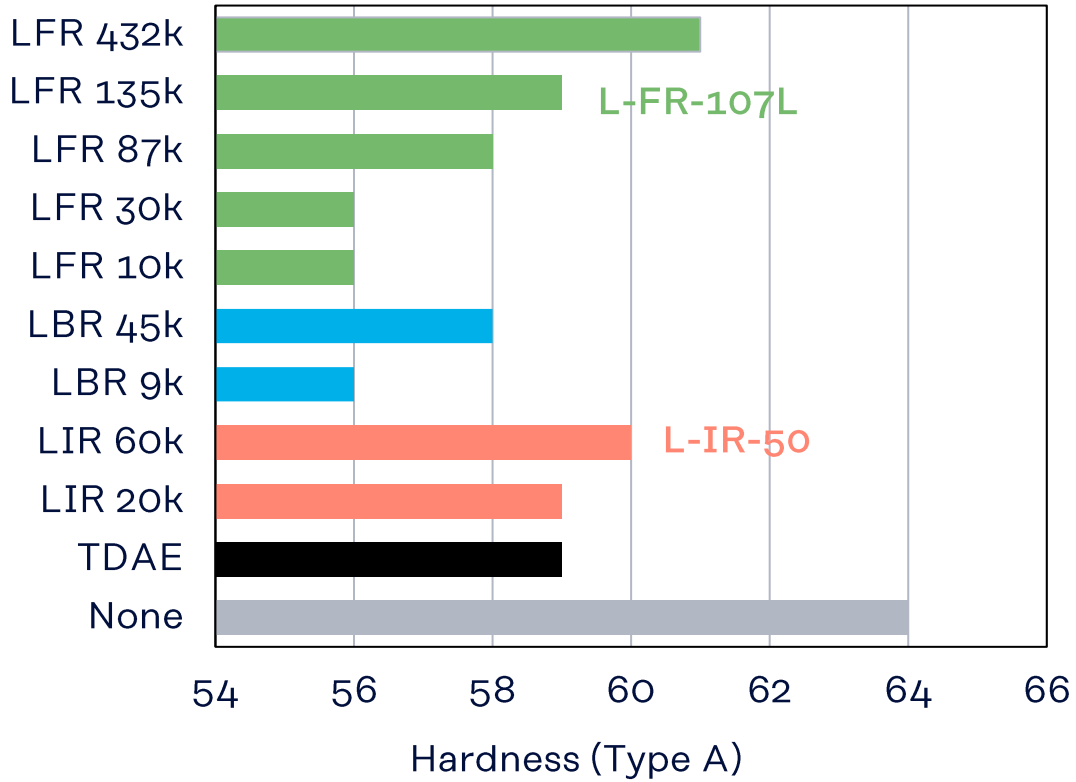
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plasticizer | | None | TDAE | LIR 20k | LIR 60k (L-IR-50) | LBR 9k (L-BR-307) | LBR 45k | LFR 10k (L-FR-101) | LFR 30k | LFR 87k | LFR 135k (L-FR-107L) | LFR 432k |
| Mooney Vis. ML1+4 (100°C) | | 60.7 | 48.8 | 47.8 | 48.4 | 46.8 | 48.7 | 47.2 | 45.5 | 46.2 | 46.4 | 50.8 |
| Curelastometer (145°C) | t90 | 11.1 | 12.1 | 11.7 | 11.4 | 11.4 | 11.3 | 10.4 | 10.2 | 11.5 | 10.3 | 10.6 |
| Bound Rubber | % | 35.4 | 35.9 | 35.4 | 36.8 | 35.8 | 37.6 | 37.7 | 37.7 | 38.7 | 39.4 | 38.9 |
| Toluene extraction | % | 2.84 | 8.46 | 3.99 | 3.01 | 6.78 | 3.04 | 5.38 | 3.23 | 3.07 | 2.94 | 2.97 |
| Mechanical Properties | | | | | | | | | | | | |
| Hardness | Type A | 64 | 59 | 59 | 60 | 56 | 58 | 56 | 56 | 58 | 59 | 61 |
| EB | (%) | 510 | 560 | 550 | 550 | 580 | 580 | 580 | 550 | 510 | 500 | 500 |
| TB | (MPa) | 30.6 | 28.9 | 29.5 | 30.5 | 29.1 | 30.2 | 28.8 | 29.1 | 28.3 | 28.3 | 28.8 |
| M100 | (MPa) | 3.11 | 2.34 | 2.34 | 2.31 | 2.07 | 2.27 | 2.16 | 2.26 | 2.27 | 2.32 | 2.38 |
| M300 | (MPa) | 16.4 | 11.3 | 12.3 | 12.6 | 11.1 | 12.3 | 11.5 | 12.1 | 13.9 | 13.5 | 13.5 |
| Viscoelasticity (25°C) | | | | | | | | | | | | |
| 5% E' | | 6.43 | 4.29 | 4.90 | 5.45 | 4.54 | 5.18 | 4.57 | 4.67 | 4.51 | 4.63 | 5.37 |
| 5% tanδ | | 0.167 | 0.175 | 0.177 | 0.165 | 0.184 | 0.174 | 0.181 | 0.163 | 0.146 | 0.147 | 0.153 |

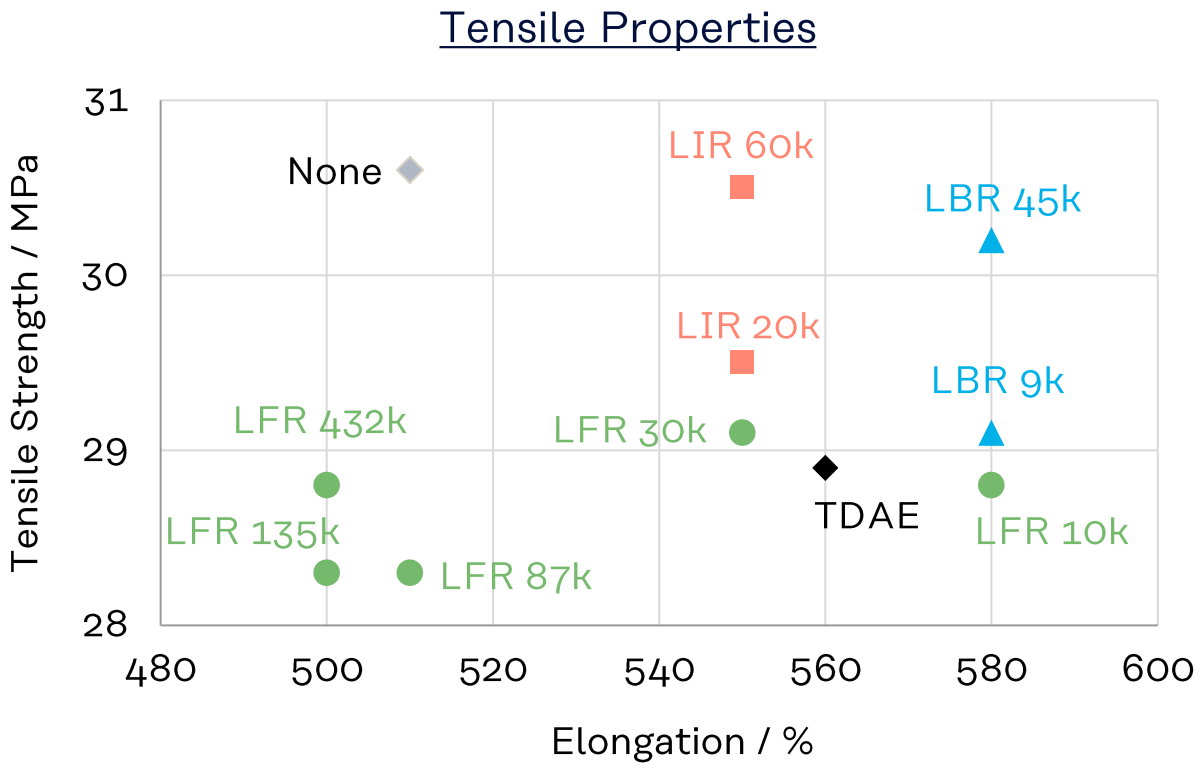
# Mooney Viscosity




✓ Liquid Farnesene Rubber shows better plasticizing effect than TDAE.
✓ Too high Mw deteriorates plasticizing effect.

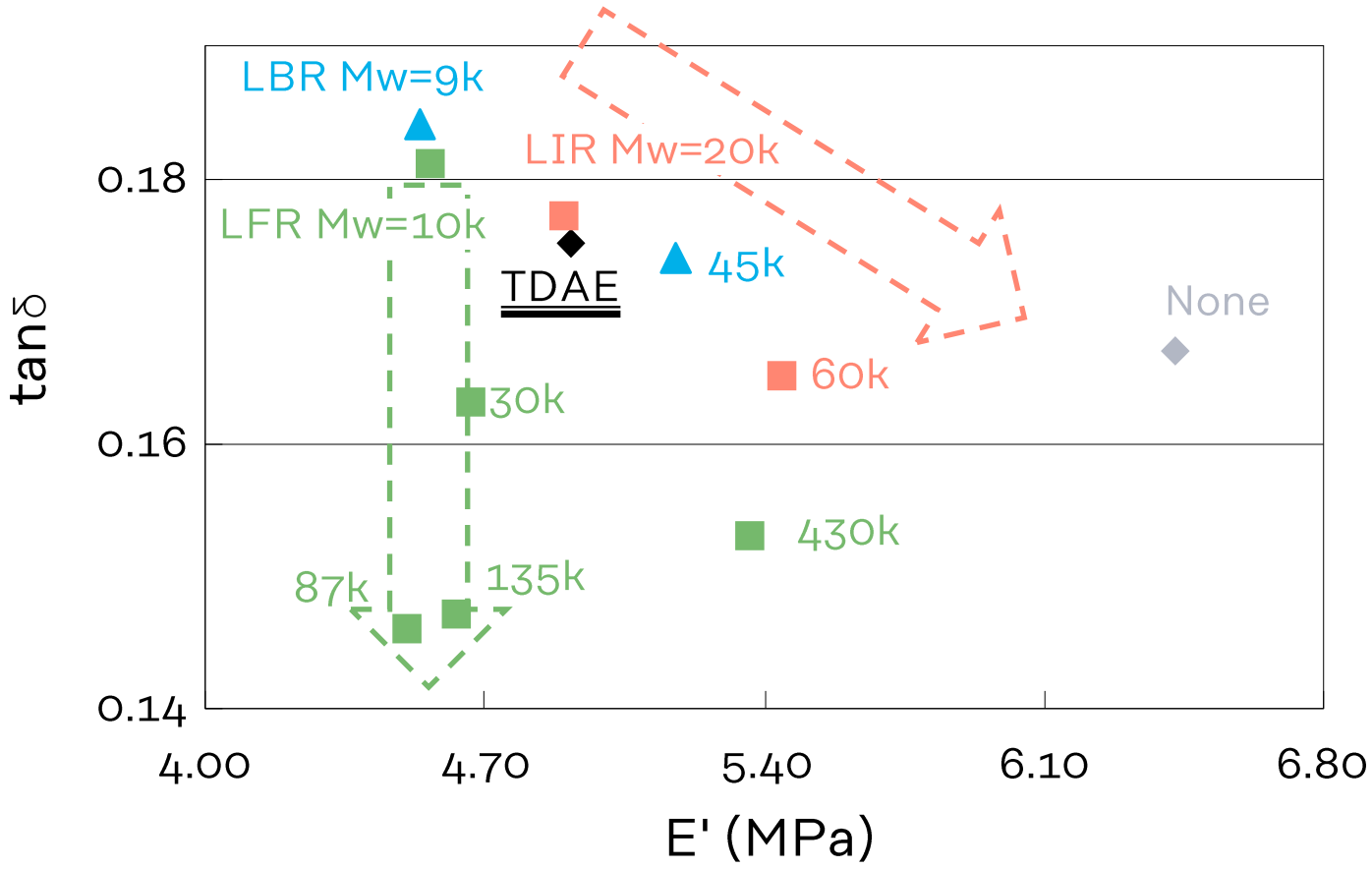
# Vulcanized Properties




- Tensile property of low MW liquid rubbers were similar to TDAE.
- High MW LIR and LBR showed higher strength.
- High MW Liquid Farnesene Rubber deteriorated elongation.

# Dynamic Mechanical Analysis




-Test condition-

Temp: 25°C

Static strain: 15%

Dynamic Strain: 5%

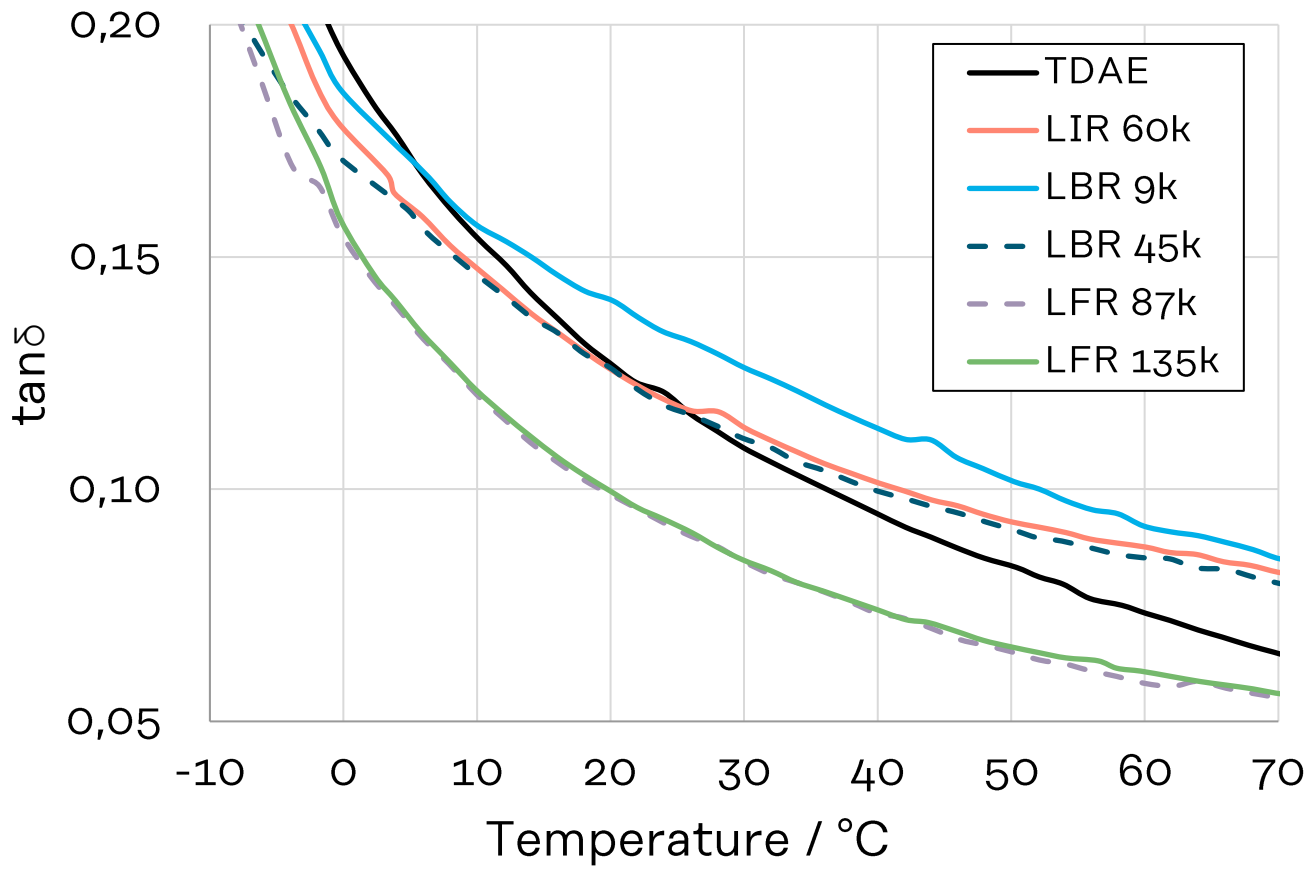
Frequency: 10Hz

✓ Higher Mw Liquid Farnesene Rubber tends to reduce tanδ.

✓ The tendency is saturated around Mw=100k.

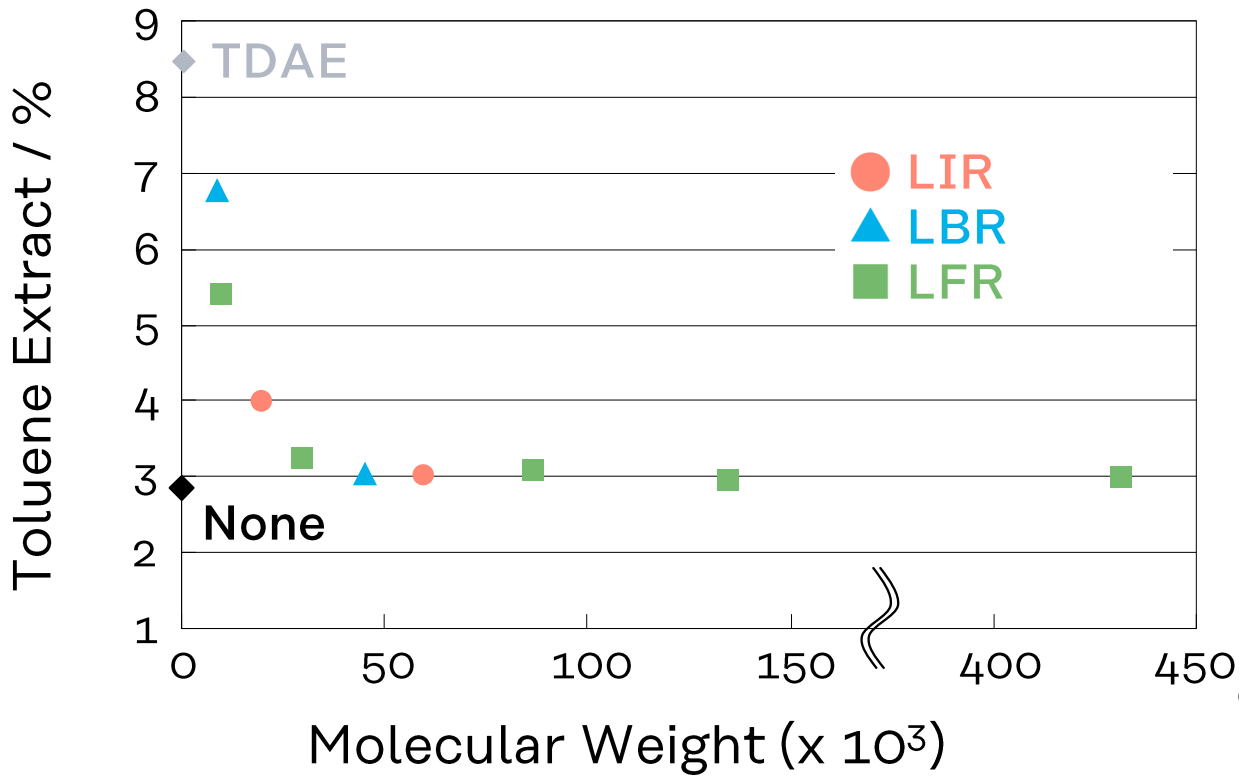
kuraray

# Viscoelastic Data (Temp Sweep)




✓ L-FR-107L reduced tanδ over wide range of temp.

# Toluene Extraction Test




- ✓ Liquid Rubber having Mw of 30,000 or higher was not extracted.
- ✓ Higher Mw Liquid Farnesene Rubber never bleeds out, unlike oil.

# CB Macro-Dispersion

| Sample | TDAE | LIR 60k<br>LIR-50 | LBR 9k | LBR 45k | LFR 10k | LFR 135k<br>L-FR-107L |
|---|---|---|---|---|---|---|
| Cross-section |  |  |  |  |  |  |
| Dispersion | Good | Good | Poor | Excellent | Fair | Excellent |

✓ Cross-section of vulcanized sheet was observed by micro-scope.
✓ L-FR-107L gave excellent CB dispersion.

# NR/CB Formulation Summary

## Features of L-FR-107L

- Good plasticizing effect
- Low tanδ
- High reactivity
  => Co-vulcanization with base rubber
  => Inhibit molecular mobility of L-FR-107L
  => Not increase tanδ
- No Bleeding & No Migration
  => Mw=30k or higher is co-vulcanizable
  => Long term reliability

# Agenda

- Introduction of Bio-based Liquid Rubber
- Influence of Molecular Weight in NR/CB Formulation
- Influence of Added Amount in NR/CB Formulation

# Objective

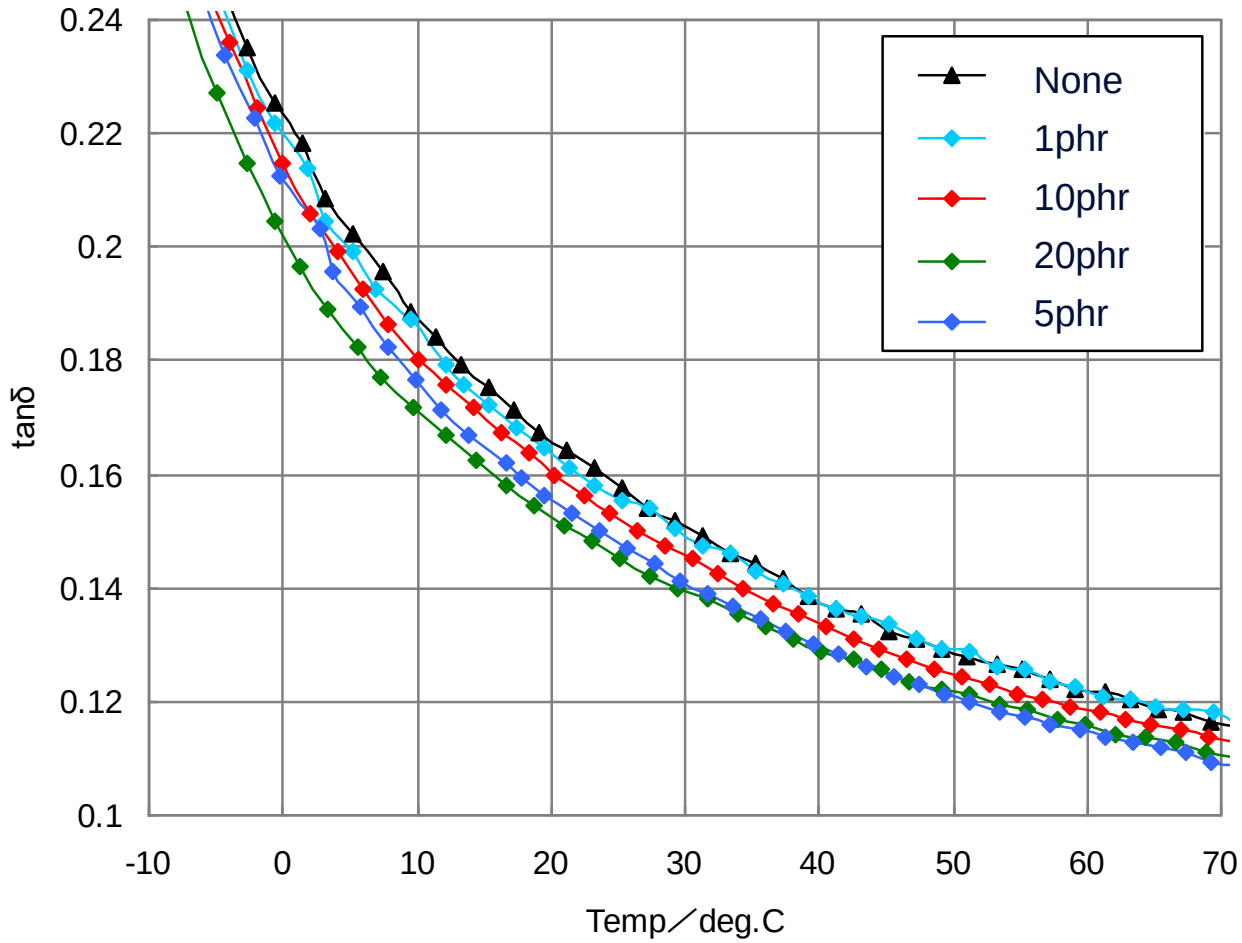
L-FR-107L reduces tanδ in NR/CB formulation.
However, too much addition of L-FR-107L may deteriorate physical properties.
=> Influence of L-FR-107L amount was evaluated.

# Influence of L-FR-107L amount

| | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| NR | | 100 | 100 | 100 | 100 | 100 |
| L-FR-107L | | 0 | 1 | 5 | 10 | 20 |
| CB | | 50 | 50 | 50 | 50 | 50 |
| Mooney Viscosity, ML1+4 (100°C) | | 62 | 60 | 54 | 47 | 35 |
| Curelastometer (145°C) | | | | | | |
| t10 | (min.) | 6.9 | 6.7 | 6.8 | 7.0 | 7.2 |
| t90 | (min.) | 12.4 | 12.1 | 12.3 | 12.3 | 12.6 |
| ML | (N.m) | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| MH | (N.m) | 1.5 | 1.5 | 1.4 | 1.3 | 1.1 |
| Mechanical properties | | | | | | |
| Hs | Type A | 66 | 64 | 63 | 59 | 53 |
| EB | (%) | 509 | 509 | 527 | 516 | 535 |
| TB | (MPa) | 31.6 | 31.2 | 30.4 | 28.2 | 26.5 |
| M50 | (MPa) | 1.6 | 1.6 | 1.4 | 1.3 | 1.0 |
| M100 | (MPa) | 3.3 | 3.2 | 2.8 | 2.5 | 1.8 |
| M300 | (MPa) | 17.5 | 16.9 | 15.3 | 13.8 | 11.6 |
| DIN abrasion | index | 100 | 115 | 108 | 87 | 79 |

✓ Tensile and abrasion properties were maintained up to 5phr addition.

# Viscoelastic Data

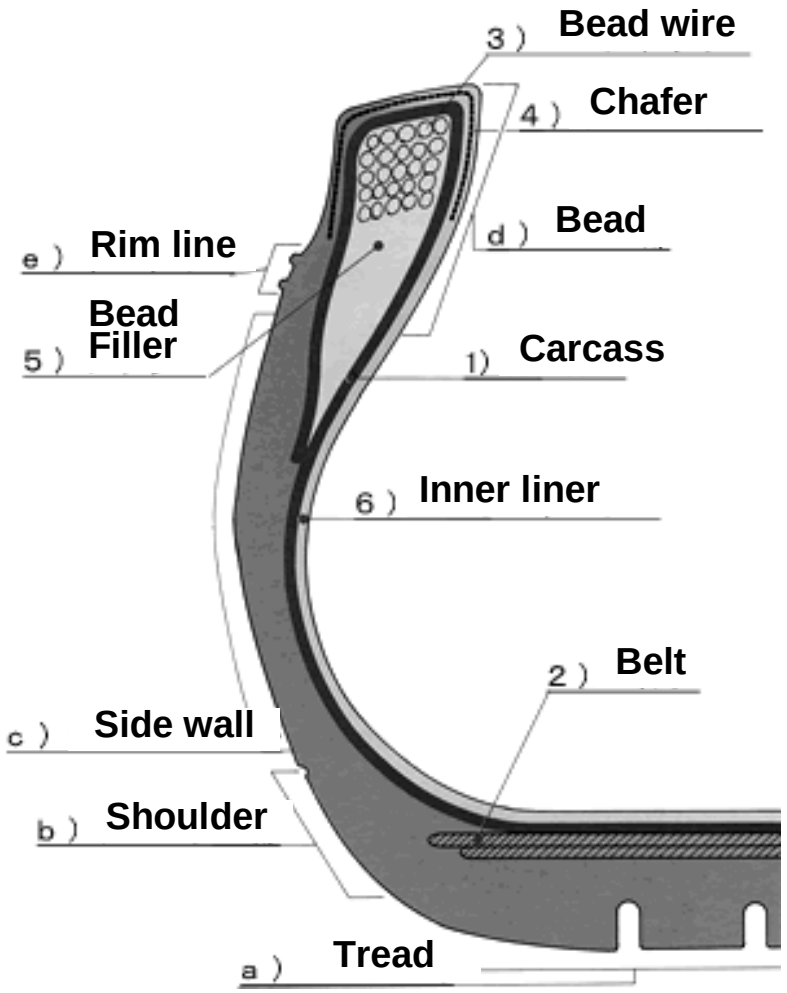



✓ 5 phr addition of L-FR-107L decreased tanδ effectively.

# Influence of L-FR-107L Summary

5 phr of L-FR-107L achieved well balanced properties, the lowest tanδ, physical properties and abrasion resistance.

# Suitable Application of Liquid Farnesene Rubber




## TBR Compound

- ✓ Replacement of resin or oil
- ✓ Good plasticizing effect
- ✓ No migration
- ✓ Low tanδ

# Summary

- Renewable Biomass Material
- Good Plasticizing Effect
- No Bleeding & No Migration
- Decrease tanδ

# Raw materials

| Material | Product Name | Manufacturer | Note |
|---|---|---|---|
| Natural Rubber | STR20 | Von Bundit Co., Ltd. | |
| Carbon black | DIABLACK™ I | Mitsubishi Chemical Corporation | ASTM N220 |
| TDAE | VIVATEC 500 | H&R GmbH Co. KGaA | |

Technical Insight of KURARAY LIQUID RUBBER

# Comparison with oils & resins

Elastomer R&D Department
Elastomer Division

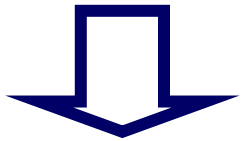
kuraray

# Agenda

- Introduction of Bio-based Liquid Rubber
- Comparison with various plasticizer
- Influence of Added Amount in NR/CB Formulation

# Replacement of Hydrocarbon Resin

- In TBR, hydrocarbon resin is used as plasticizer rather than process oil to reduce migration.
- Resin increases tanδ higher than process oil.



- L-FR-107L achieves good plasticizing effect without migration.
  Besides, it gives tremendously low tanδ.

# List of Plasticizers

| Category | Product Description | Tg (°C) | Supplier |
|---|---|---|---|
| Liquid Rubber | Polyfarnesene (L-FR-107L) | -71 | Kuraray |
| Resins | C5 Aliphatic Hydrocarbon (Escorez™ 1102) | 46 | Exxon Mobil Corporation |
| | Alicyclic Hydrocarbon (Quintone 1105) | 49 | Zeon Corporation |
| | C9 Coumarone-Indene (G90) | 49 | NITTO CHEMICAL CO., LTD. |
| Oil | Aromatic (JSO AROMA 790) | -44 | JAPAN SUN OIL COMPANY, LTD. |
| | Naphthenic (SUNTHENE 450) | -63 | JAPAN SUN OIL COMPANY, LTD. |
| | Paraffinic (DIANA Process Oil PW 380) | -59 | Idemitsu Kosan Co., Ltd. |
| | TDAE (VIVATEC 500) | -50 | H&R GmbH Co. KGaA |

# NR/CB Formulation

| Formulation | phr |
|---|---|
| Natural Rubber (STR20) | 100 |
| Plasticizer | 4 |
| Carbon Black (N220) | 45 |
| ZnO | 3.5 |
| Stearic acid | 2 |
| Sulfur | 1.5 |
| Accelerator NS[1)] | 1.2 |
| Antioxidant 6C[2)] | 1 |
| Antioxidant RD[3)] | 1 |

1) N-tert-butyl-2-benzothiazolesulfenamide
2) N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine
3) Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline

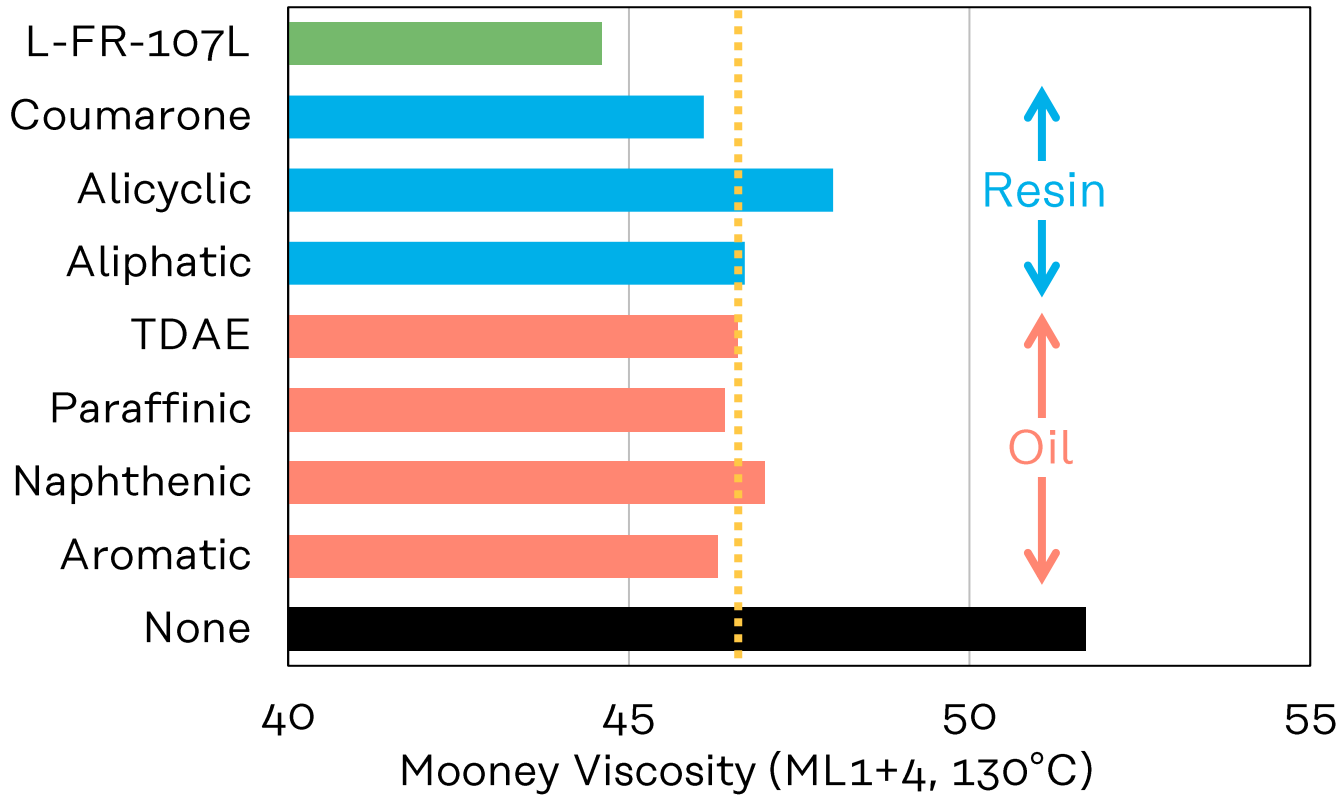
Mixing Conditions

| | |
|---|---|
| 1st stage: | Banbury mixer |
| 0‘00" | NR (75°C) |
| 0’20" | CB, TDAE/Liquid Rubber<br>AO, ZnO, Stearic acid |
| 6’00" | Dump out (150-160°C) |
| | |
| 2nd stage: | Roll mill |
| 0’00" | Compound (55-60°C) |
| 0’30" | Sulfur, Accelerator |
| 7’00" | Sheeting |

# NR/CB Formulation Summary

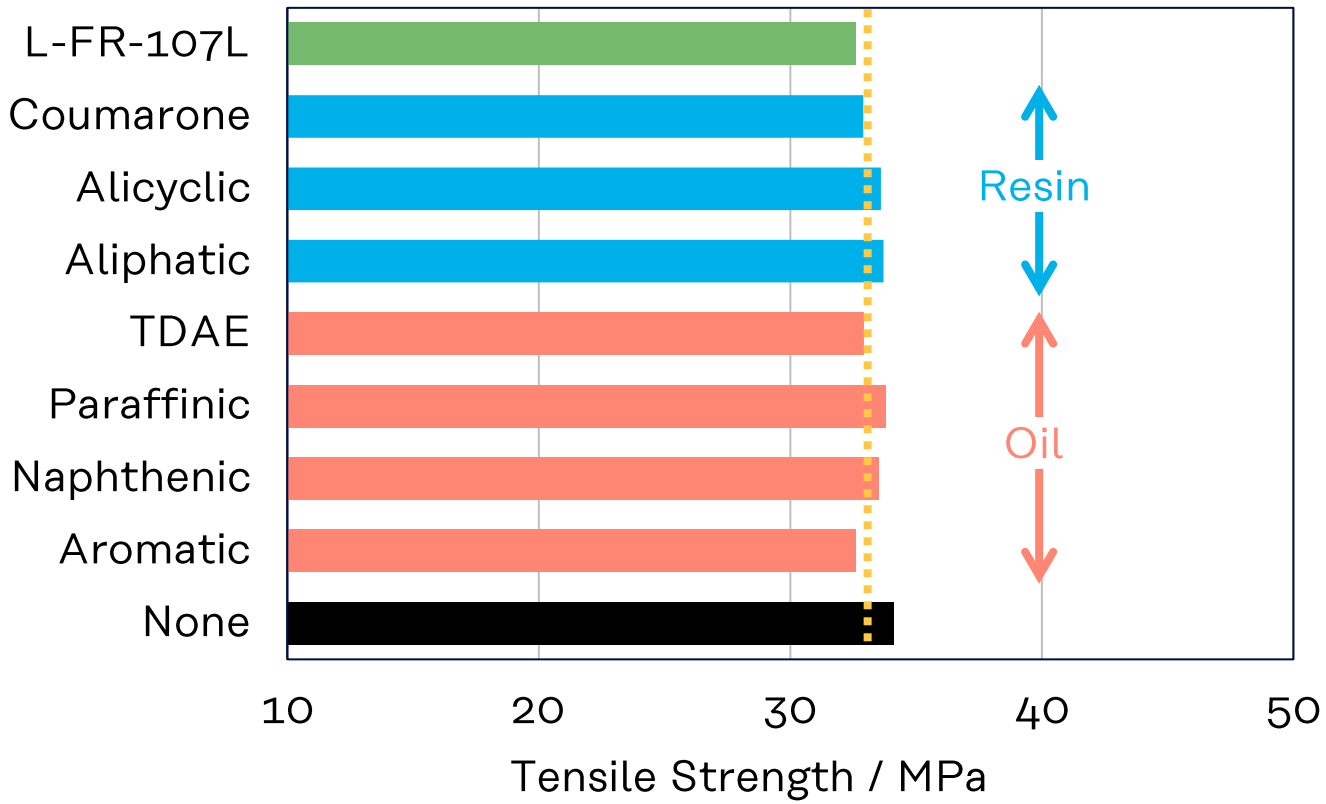
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Category | | | Oil | | | | Resin | | | |
| Plasticizer | | None | Aromatic | Naphthenic | Paraffinic | TDAE | Aliphatic | Alicyclic | Coumarone | L-FR-107L |
| Mooney Vis., ML1+4 (130°C) | | 51.7 | 46.3 | 47.0 | 46.4 | 46.6 | 46.7 | 48.0 | 46.1 | 44.6 |
| Mooney Scorch time (130°C) | | | | | | | | | | |
| t5 | (min.) | 18.6 | 19.8 | 21.3 | 21.4 | 20.6 | 20.6 | 24.5 | 18.3 | 19.9 |
| t35 | (min.) | 21.0 | 22.3 | 23.8 | 23.9 | 23.1 | 23.0 | 27.3 | 20.5 | 22.4 |
| Curelastometer (155°C) | | | | | | | | | | |
| t10 | (min.) | 3.5 | 3.5 | 3.8 | 3.9 | 3.8 | 3.7 | 4.3 | 3.2 | 3.5 |
| t90 | (min.) | 5.8 | 5.7 | 6.3 | 6.5 | 6.3 | 6.2 | 6.5 | 5.4 | 5.8 |
| ML | (N.m) | 0.25 | 0.23 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.22 |
| MH | (N.m) | 1.48 | 1.39 | 1.38 | 1.36 | 1.38 | 1.34 | 1.23 | 1.35 | 1.37 |
| Mechanical Properties | | | | | | | | | | |
| Hardness | Type A | 66 | 64 | 64 | 63 | 64 | 64 | 63 | 66 | 65 |
| EB | (%) | 540 | 572 | 574 | 575 | 560 | 563 | 607 | 565 | 547 |
| TB | (MPa) | 34.1 | 32.6 | 33.5 | 33.8 | 32.9 | 33.7 | 33.6 | 32.9 | 32.6 |
| M50 | (MPa) | 1.61 | 1.41 | 1.44 | 1.40 | 1.43 | 1.47 | 1.34 | 1.51 | 1.45 |
| M100 | (MPa) | 3.16 | 2.63 | 2.72 | 2.66 | 2.71 | 2.80 | 2.43 | 2.82 | 2.77 |
| M300 | (MPa) | 16.3 | 13.7 | 14.1 | 14.2 | 14.3 | 14.6 | 12.6 | 14.3 | 14.7 |
| Viscoelasticity (25°C) | | | | | | | | | | |
| E′ | (MPa) | 5.81 | 5.24 | 5.28 | 5.28 | 5.27 | 5.49 | 5.37 | 5.42 | 5.11 |
| tanδ | (-) | 0.171 | 0.189 | 0.177 | 0.176 | 0.176 | 0.185 | 0.200 | 0.191 | 0.155 |

# Mooney Viscosity



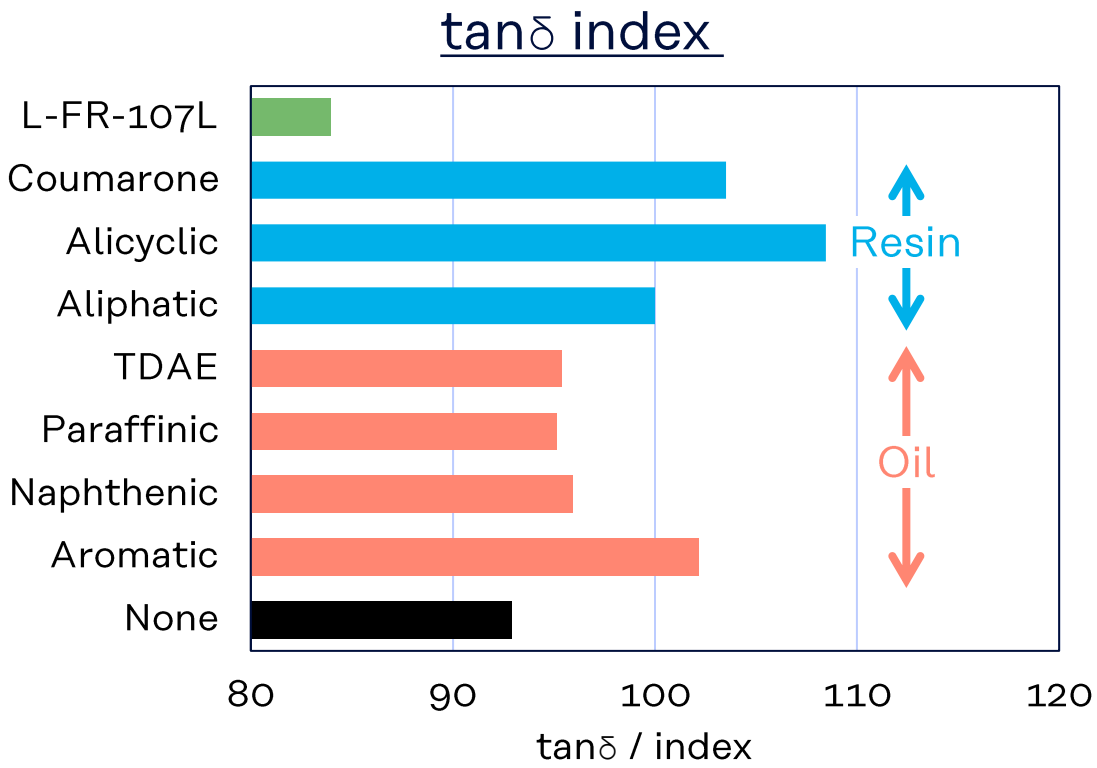

✓ Good plasticizing effect

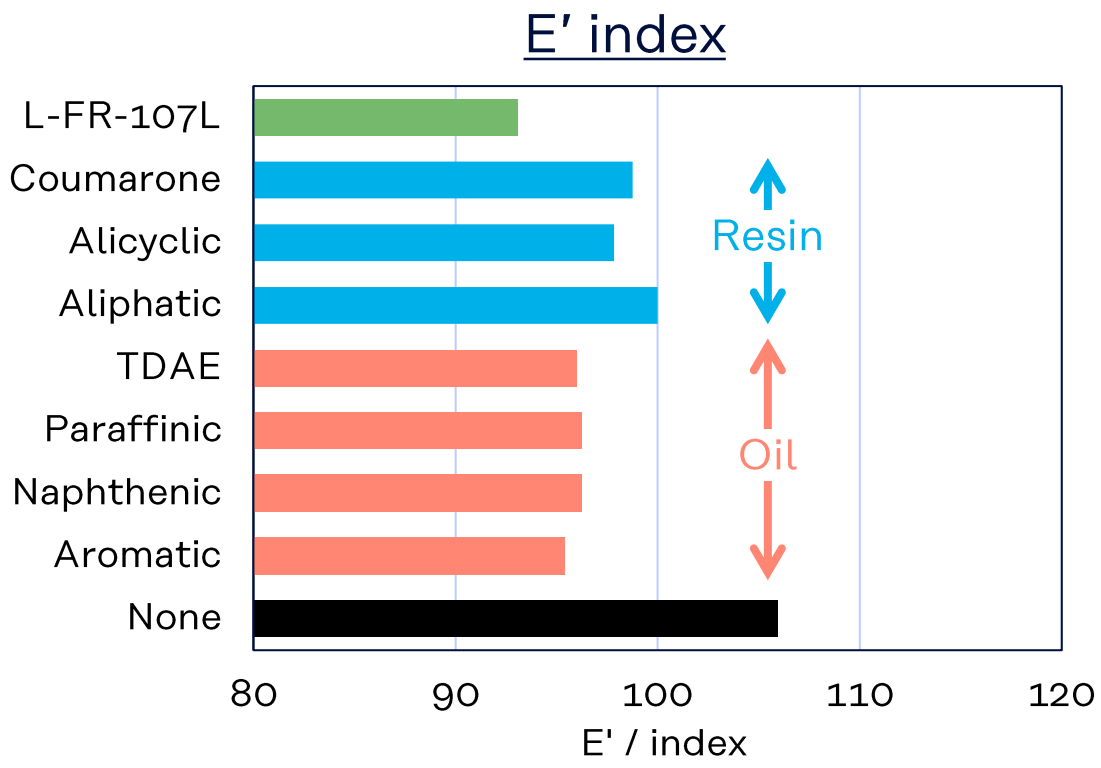
# Tensile Strength




✓ Equivalent tensile strength

# Viscoelastic Data (25°C)

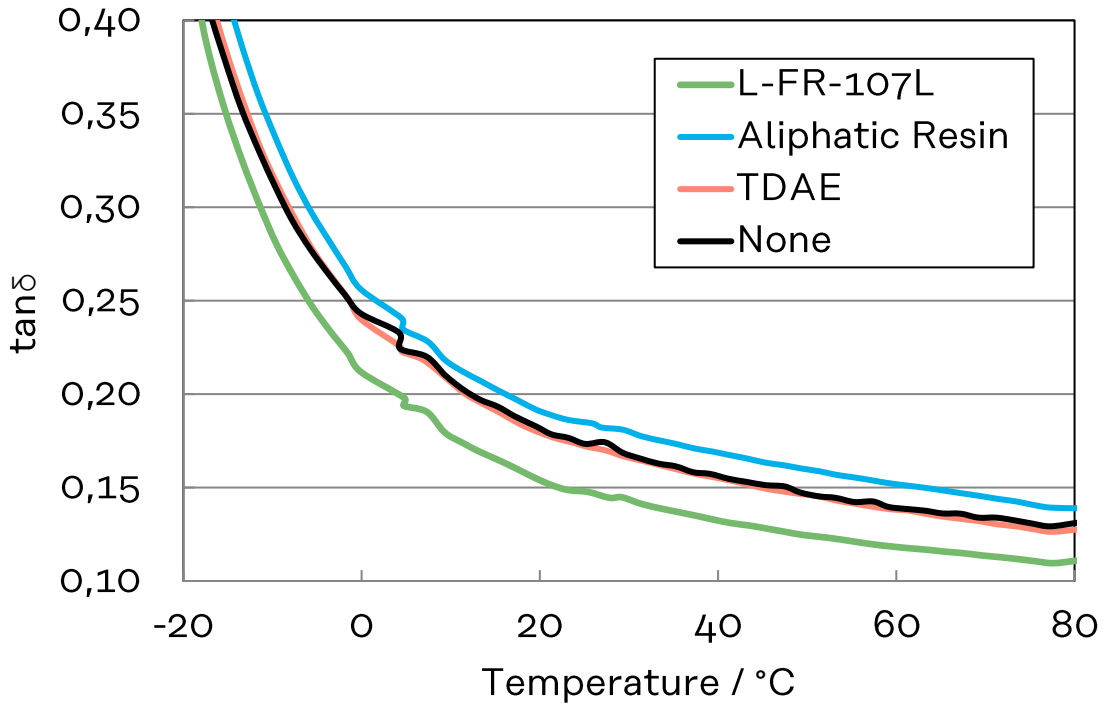


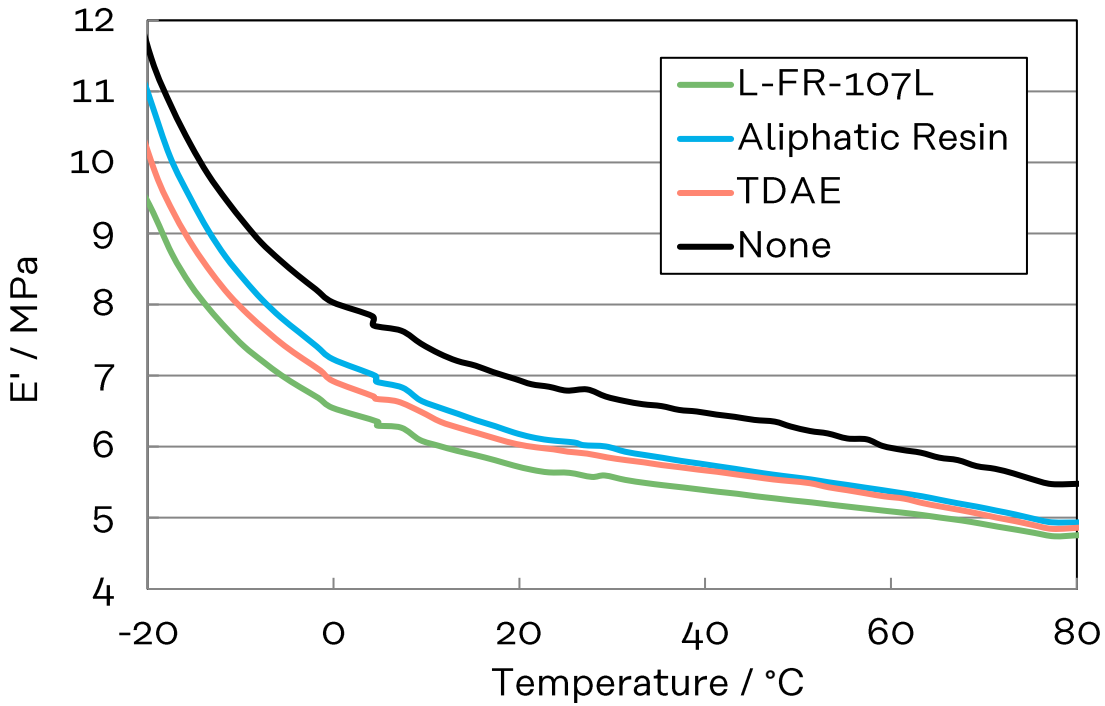

- ✓ 20% tanδ reduction compared with resins
- ✓ Equivalent E′ to oils

# Viscoelastic Data (Temp Sweep)

tanδ (temp. sweep)




E′ (temp sweep)




✓ Lower tanδ over wide range of temp

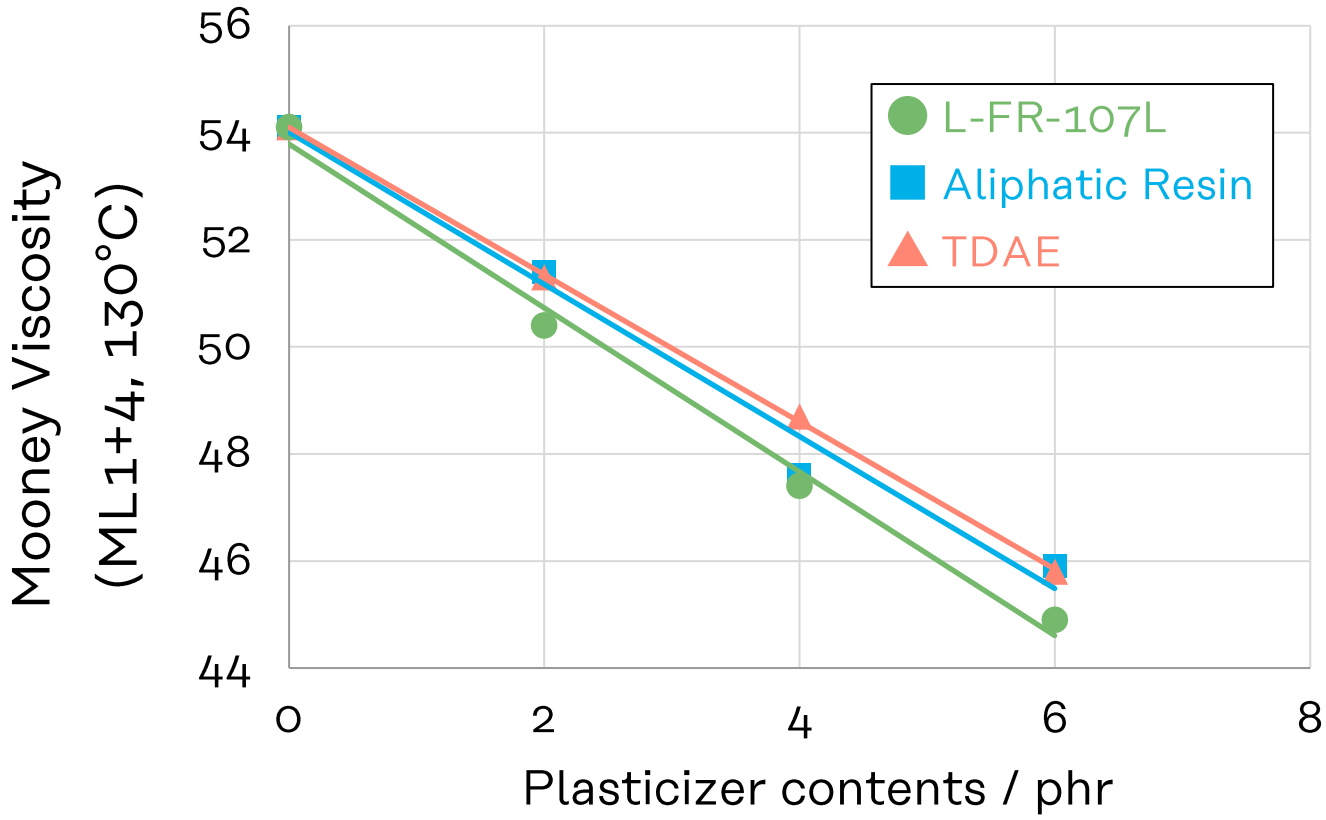
# Agenda

- Introduction of Bio-based Liquid Rubber
- Comparison with various plasticizer
- Influence of Added Amount in NR/CB Formulation

# NR/CB Formulation Summary

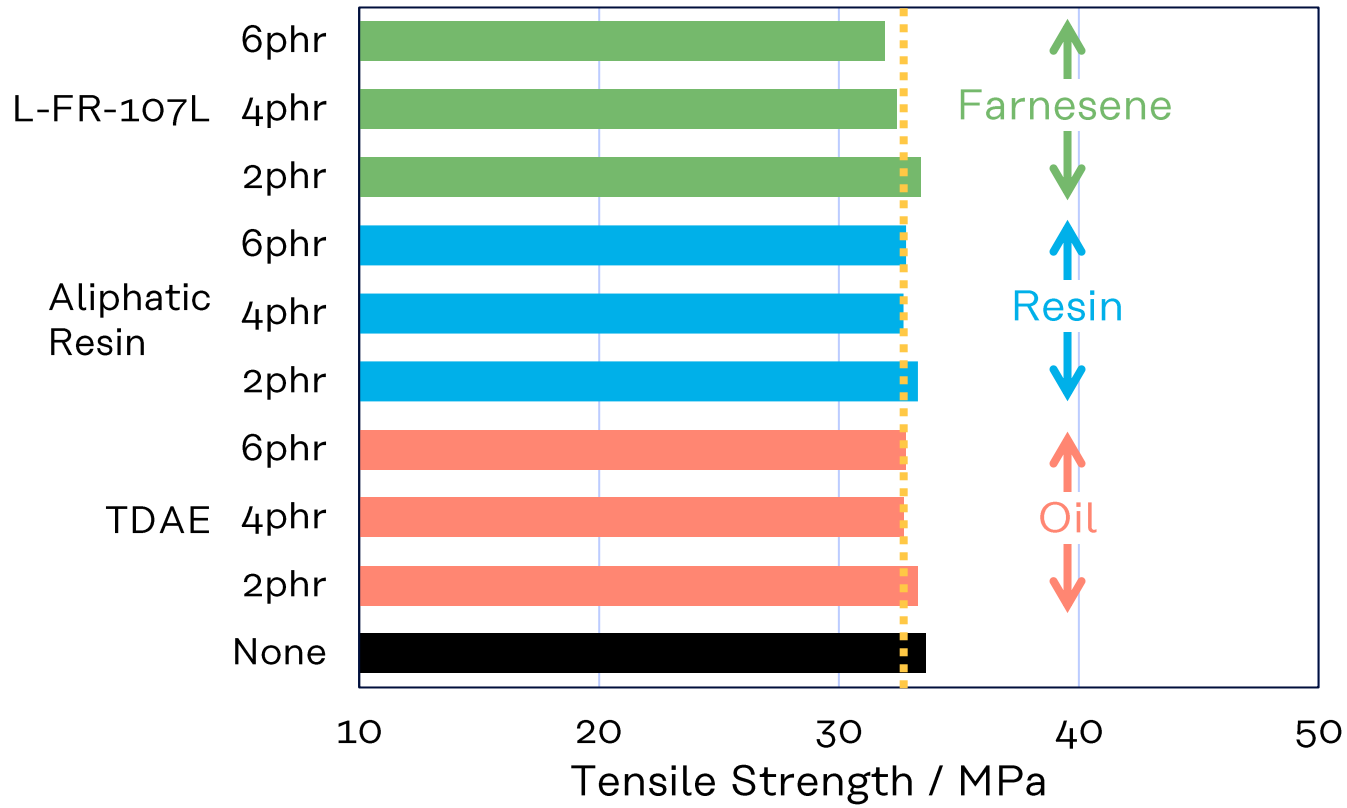
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plasticizer | | None | | TDAE | | | Aliphatic Resin | | | L-FR-107L | |
| Amount | (phr) | 0 | 2 | 4 | 6 | 2 | 4 | 6 | 2 | 4 | 6 |
| Mooney Vis., ML1+4 (130°C) | | 51.4 | 51.4 | 47.6 | 45.9 | 51.3 | 48.7 | 45.8 | 50.4 | 47.4 | 44.9 |
| Mooney Scorch time (130°C) | | | | | | | | | | | |
| t5 | (min.) | 20.3 | 20.3 | 21.1 | 22.0 | 21.1 | 21.5 | 22.6 | 21.1 | 20.1 | 20.4 |
| t35 | (min.) | 22.8 | 22.9 | 23.8 | 24.9 | 23.9 | 24.1 | 25.3 | 23.9 | 23.0 | 23.3 |
| Curelastometer (155°C) | | | | | | | | | | | |
| t10 | (min.) | 3.9 | 3.9 | 4.1 | 4.2 | 4.1 | 4.2 | 4.3 | 4.1 | 4.1 | 4.1 |
| t90 | (min.) | 6.4 | 6.5 | 6.7 | 6.8 | 6.8 | 6.9 | 7.0 | 6.7 | 6.7 | 6.7 |
| ML | (N.m) | 0.25 | 0.24 | 0.23 | 0.22 | 0.24 | 0.22 | 0.21 | 0.24 | 0.23 | 0.22 |
| MH | (N.m) | 1.51 | 1.45 | 1.39 | 1.33 | 1.44 | 1.37 | 1.30 | 1.46 | 1.41 | 1.37 |
| Mechanical Properties | | | | | | | | | | | |
| Hardness | Type A | 65 | 65 | 64 | 63 | 65 | 64 | 63 | 65 | 64 | 63 |
| EB | (%) | 538 | 556 | 560 | 577 | 548 | 553 | 581 | 552 | 545 | 541 |
| TB | (MPa) | 33.6 | 33.3 | 32.7 | 32.8 | 33.3 | 32.7 | 32.8 | 33.4 | 32.4 | 31.9 |
| M50 | (MPa) | 1.58 | 1.49 | 1.40 | 1.33 | 1.51 | 1.42 | 1.39 | 1.50 | 1.42 | 1.37 |
| M100 | (MPa) | 3.03 | 2.85 | 2.63 | 2.50 | 2.89 | 2.68 | 2.61 | 2.83 | 2.67 | 2.58 |
| M300 | (MPa) | 16.0 | 15.0 | 13.9 | 13.1 | 15.3 | 14.3 | 13.6 | 15.0 | 14.3 | 14.0 |
| Viscoelasticity (25°C) | | | | | | | | | | | |
| E' | (MPa) | 5.67 | 5.43 | 5.12 | 4.97 | 5.55 | 5.40 | 5.23 | 5.45 | 5.25 | 5.03 |
| tanδ | (-) | 0.171 | 0.169 | 0.173 | 0.181 | 0.182 | 0.190 | 0.197 | 0.169 | 0.161 | 0.161 |

# Mooney Viscosity



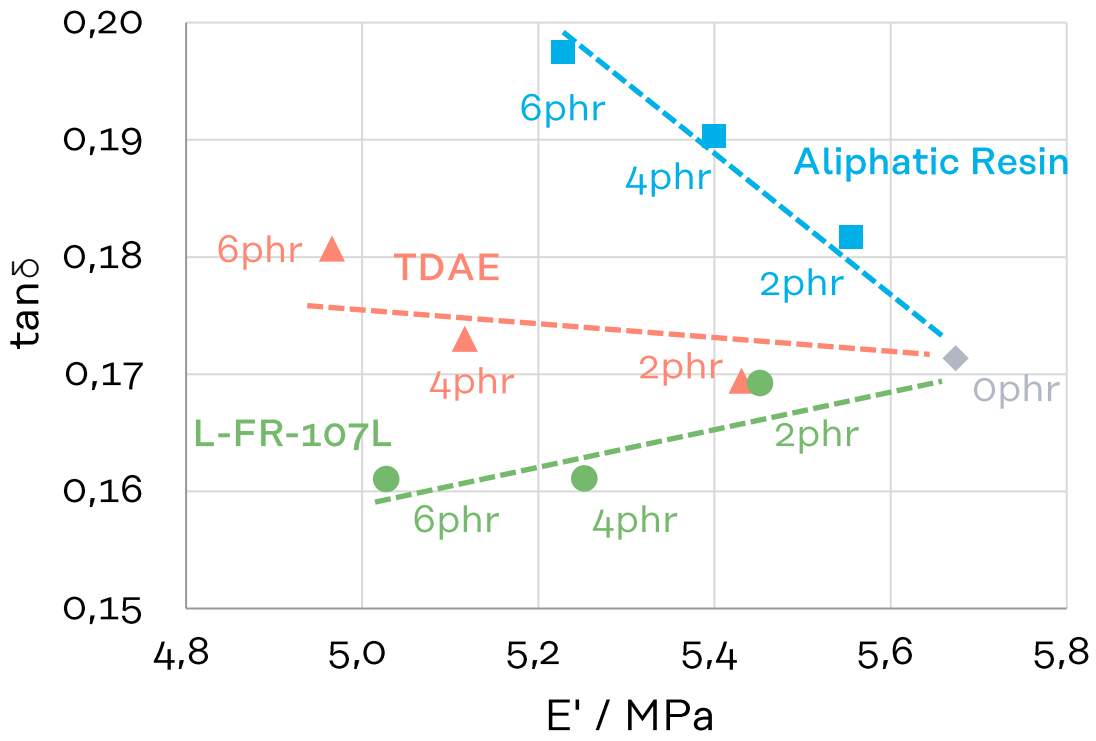

✓ Good Plasticizing Effect

# Tensile Strength



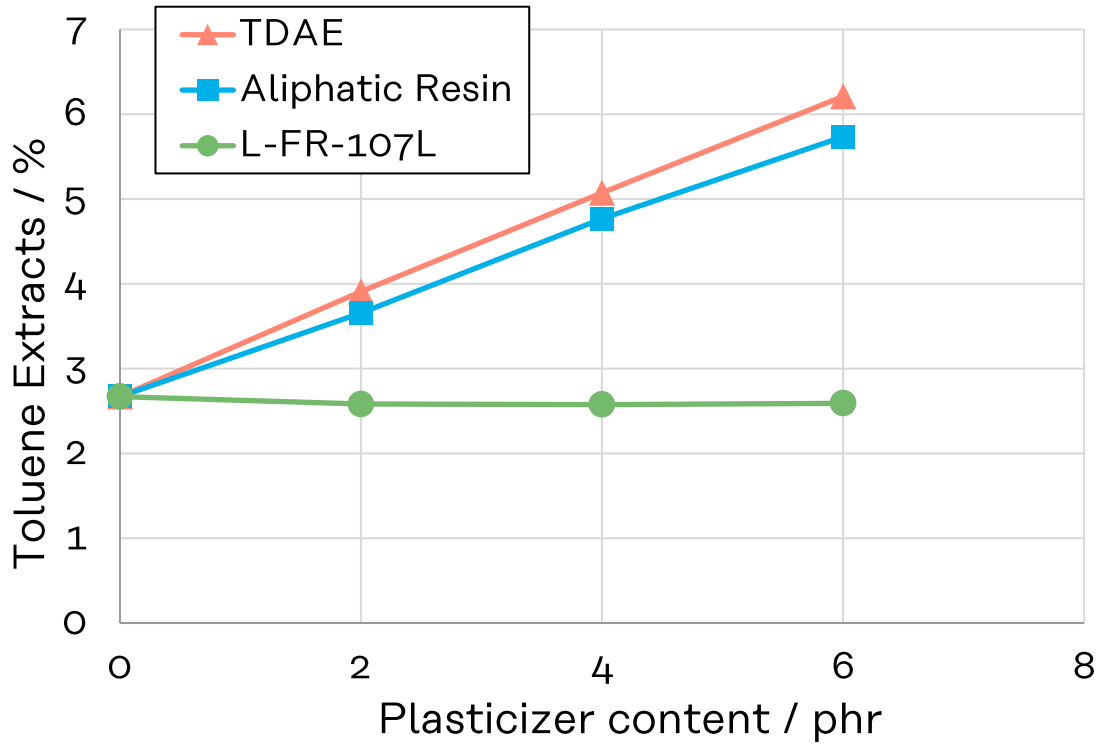

✓ Similar tensile strength

# Viscoelastic Data (25°C)




- ✓ The resin increases tanδ in proportion to additive amount.
- ✓ 4-6 phr of L-FR-107L reduces tan δ the most effectively.
- ✓ Even 2 phr of L-FR-107L is effective compared with the resin.

# Toluene Extraction Test



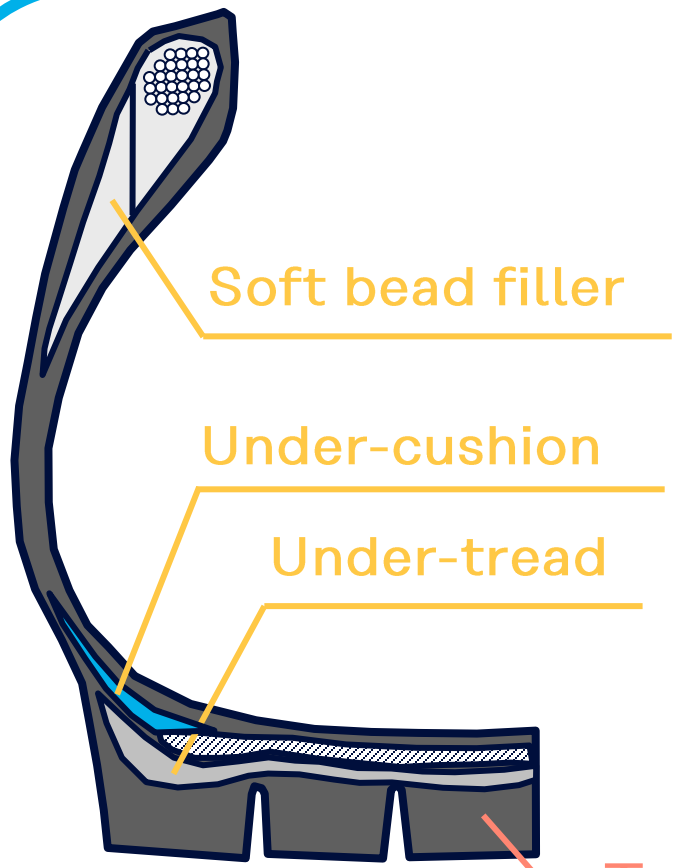

✓ L-FR-107L is not extracted due to co-vulcanization.
✓ Less or no migration.
✓ Long term reliability is expected.

# Summary

## Features of KB-107 in NR/CB Formulation

- Low tanδ
- Biomass Material
- Good plasticizing effect
- No Migration

# Idea of Application




## TBR Compound

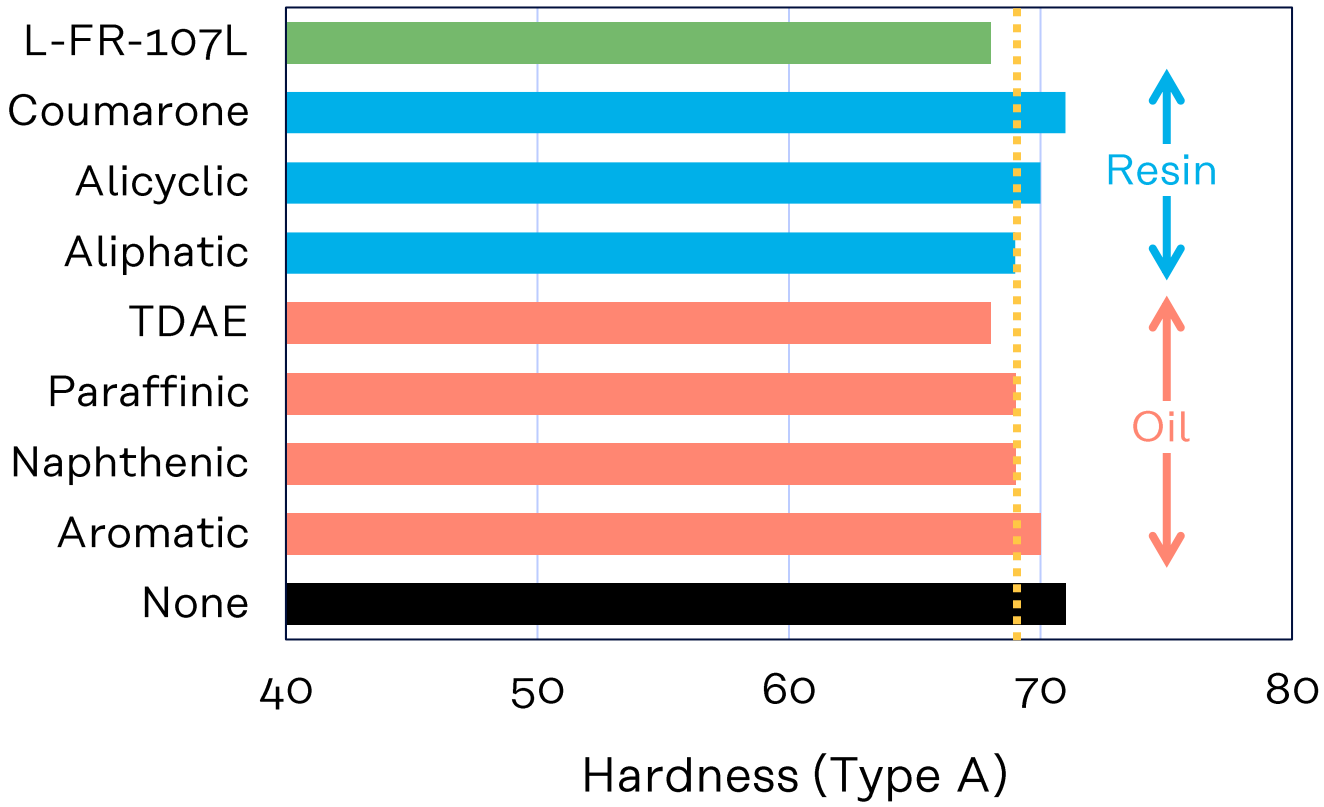
- ✓ Replacement of resin or oil
- ✓ Good plasticizing effect
- ✓ No migration
- ✓ Low tanδ

# APPENDIX

# Raw materials

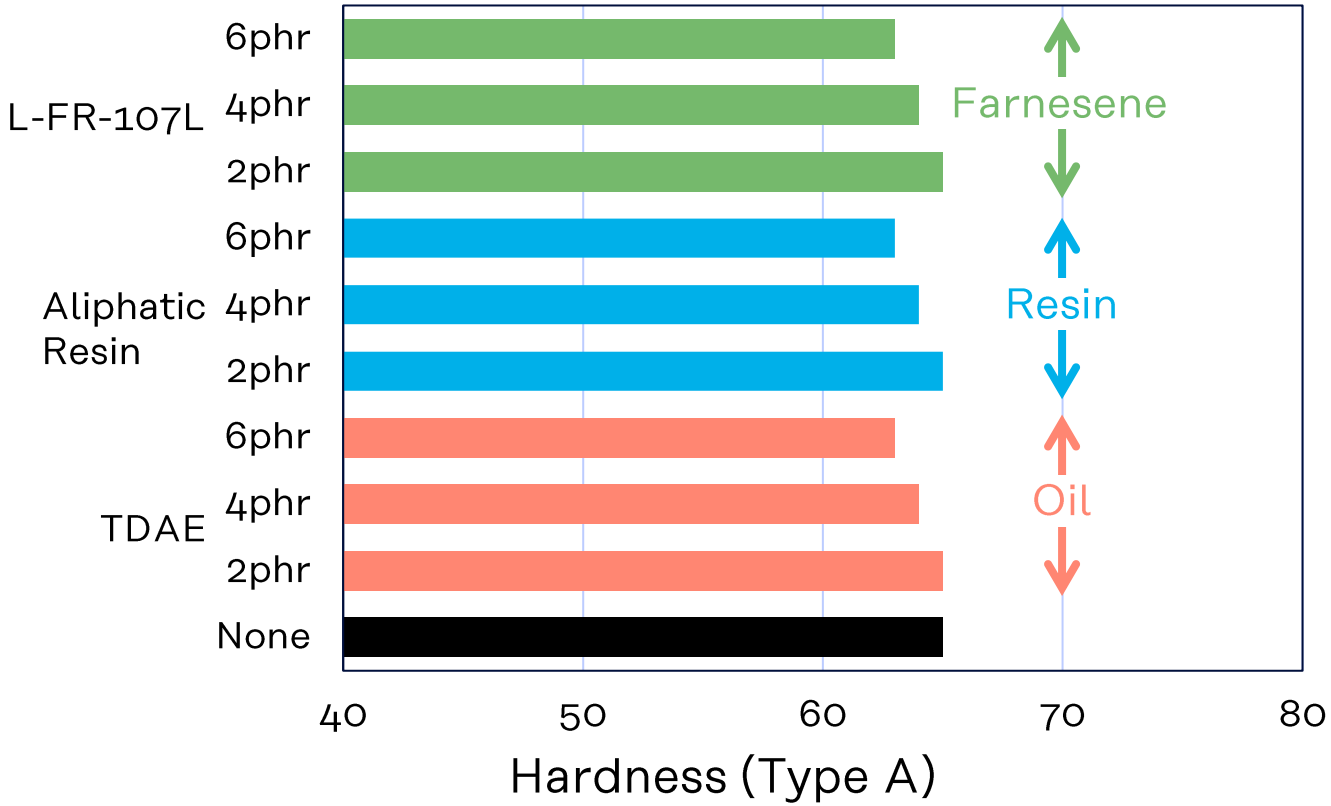
| Material | Product Name | Manufacturer | Note |
|---|---|---|---|
| Natural Rubber | STR20 | Von Bundit Co., Ltd. | |
| Carbon black | DIABLACK™ I | Mitsubishi Chemical Corporation | ASTM N220 |
| TDAE | VIVATEC 500 | H&R GmbH Co. KGaA | |

# Hardness (NR/CB/Plasticizer=100/45/4)



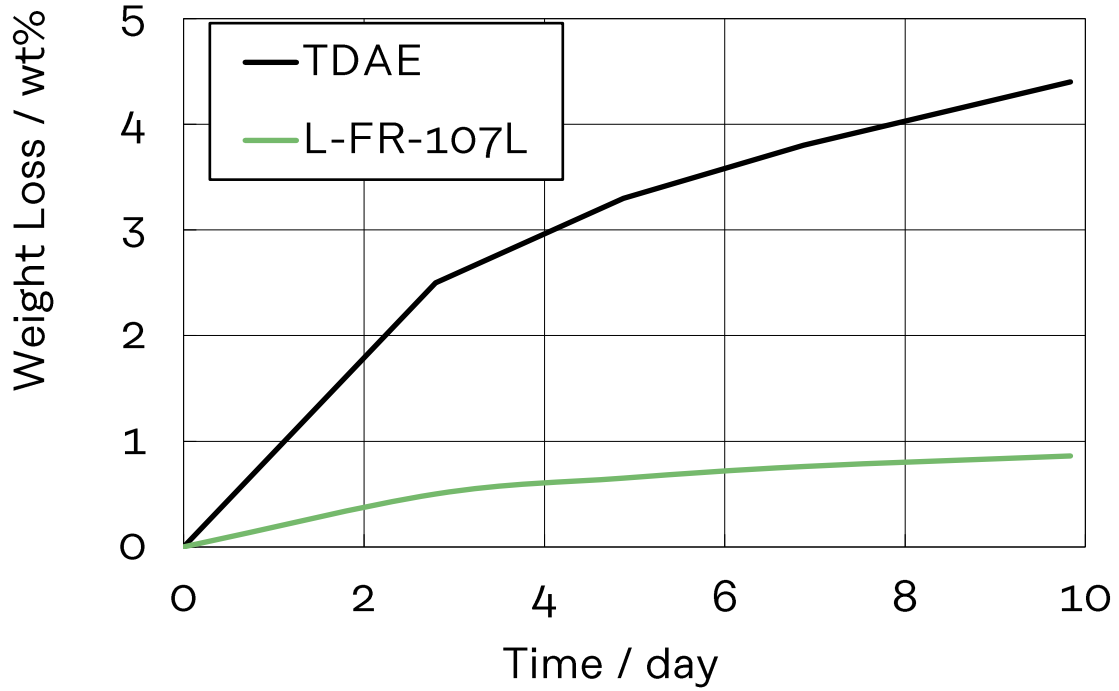

✓ Same range of Hardness

# Hardness (NR/CB/Plasticizer=100/45/2-6)



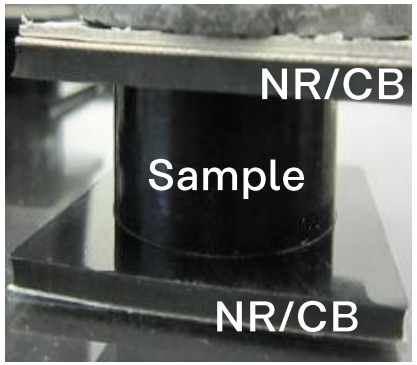
# Migration Property

Good




-Formulation-
SBR/CB/Plasticizer
=100/70/40
-Test condition-
Temp.: 70°C

10N Load




✓ Less migration property => Expected long-term reliability

**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


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 RUBBAR 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