

Technical Insights of KURARAY LIQUID RUBBER

Introduction of Liquid Farnesene Rubber

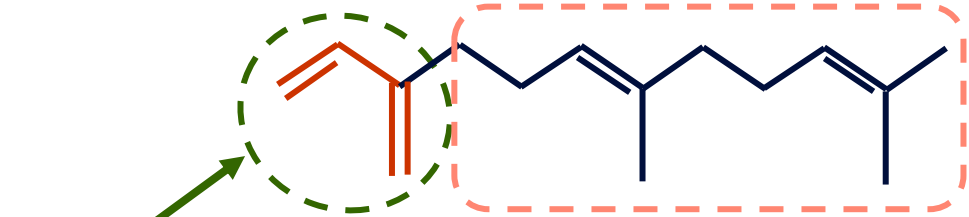
Elastomer R&D Department
Elastomer Division

kuraray

Liquid Farnesene Rubber (LFR)

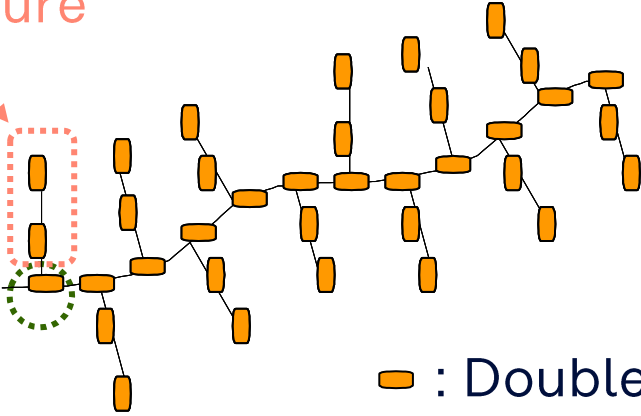
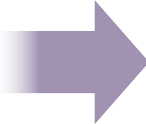


Sugarcane



β -Farnesene

Branched Structure



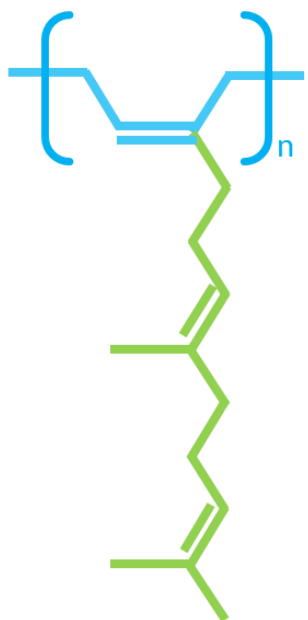
Orange : Double Bond

Liquid Farnesene Rubber : Branched Polymer

Characteristics

- Renewable monomer
- Low viscosity
- High reactivity

Grade & Typical Properties

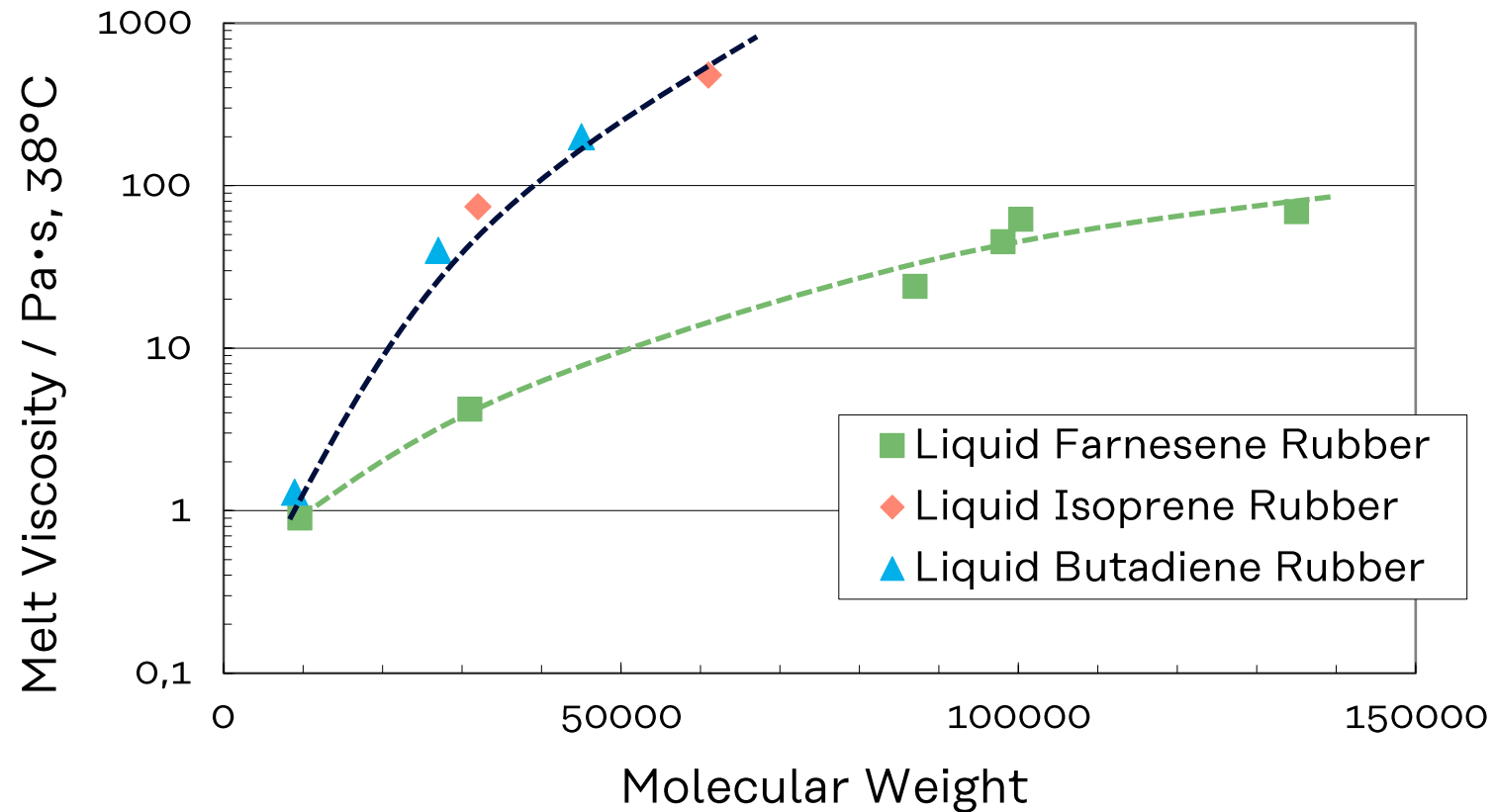


Grade	Structure	Mw	Melt Vis. @38°C (Pa.s)	Tg (°C)
L-FR-107L	Far	135,000	69	-71
L-FBR-742	Far/Bd	30,000	12	-78
L-FBR-746	Far/Bd	100,000	603	-78

Chemical Structure of LFR

- Less entanglement between molecules because of highly branched structure.
→ High Mw & Low viscosity

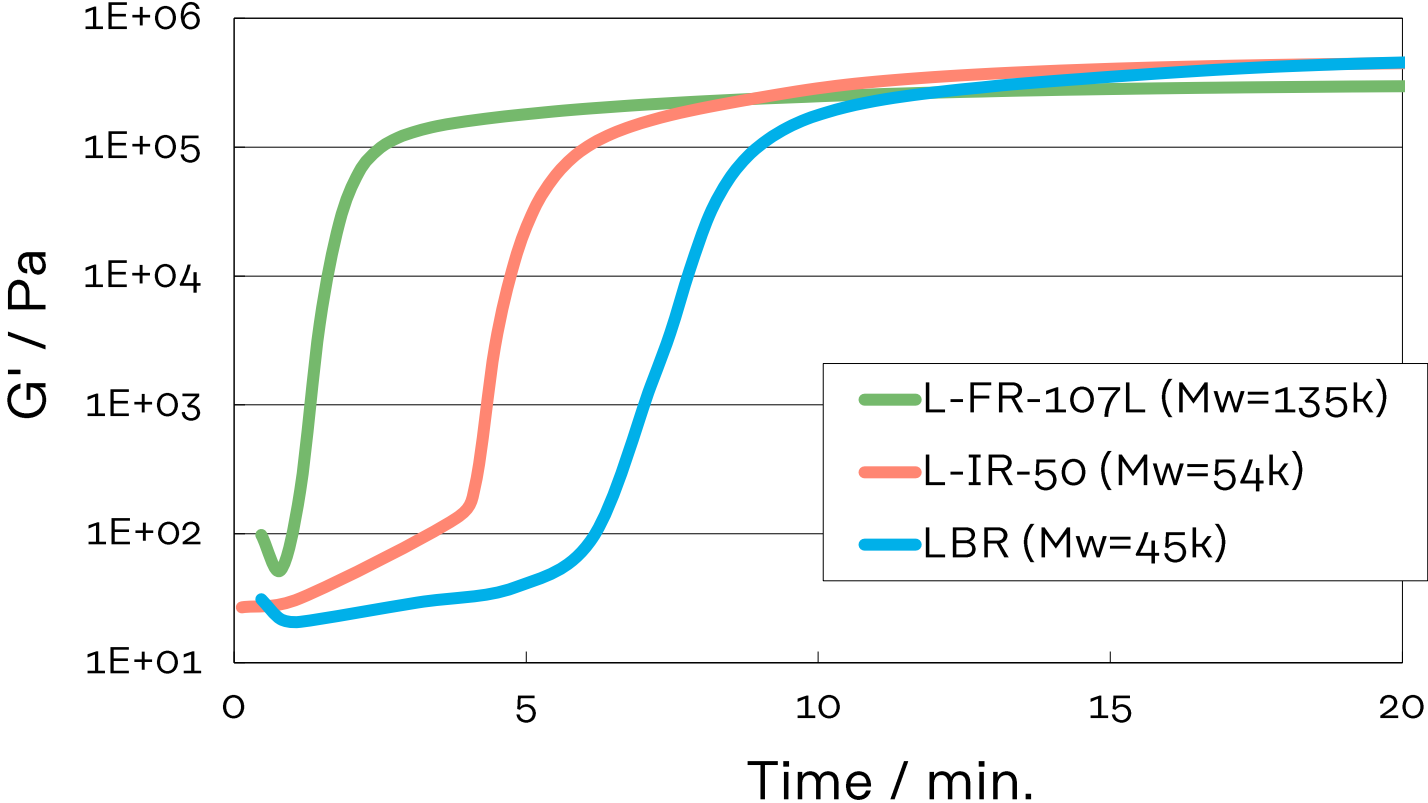
Viscosity of KURARAY LIQUID RUBBER



✓ Lower viscosity than liquid isoprene / butadiene rubber because of less entanglement.

Sulfur Curing of Liquid Rubbers

Crosslinked
↑
Uncrosslinked
Paste

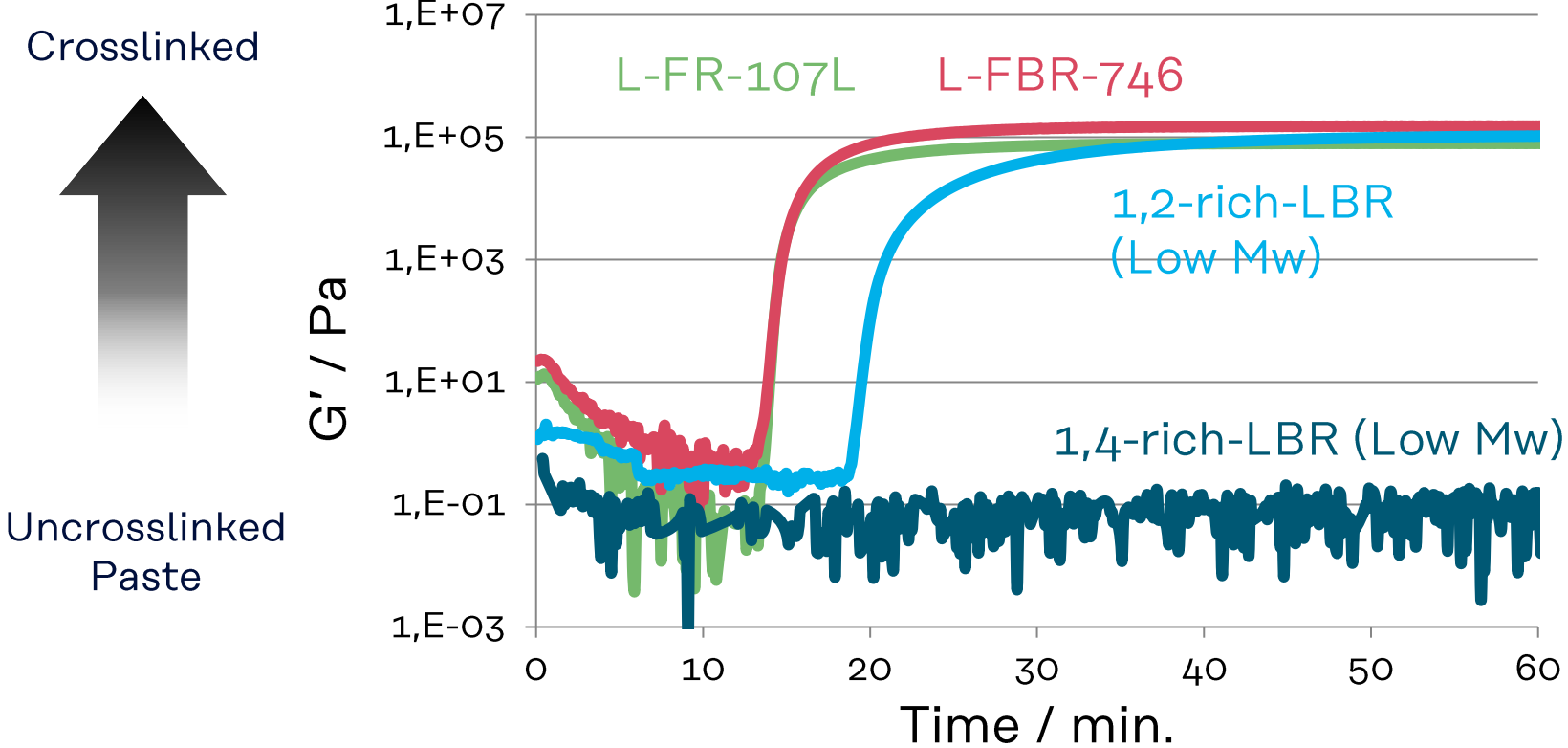


Formulation
Liquid Rubber 100,
ZnO 2, SA 1, AO 1, S
3, DM 1.5, DT 0.5

Dynamic Viscoelastic
Measurement
Method
Frequency: 10 Hz
Strain: 5.0%
Temp: 125 °C

✓ Crosslinking speed of L-FR-107L is much faster than LIR or LBR.

Peroxide Curing of Liquid Rubbers



Formulation
Liquid Rubber 100, PO 1

Dynamic Viscoelastic Measurement Method
Frequency: 10 Hz
Strain: 5%
Temp: 150 °C

	Melt Vis. @38°C (Pa.s)
L-FR-107L	69
L-FBR-746	520

✓ L-FR/L-FBR exhibit fast curing with peroxide compared to high vinyl LBR while maintaining good low temp properties.

LFR in Tires



Expected properties in tire formulation

- Ice grip improvement
- Less migration

Formulation

Formulation	phr
Natural Rubber	70
BR	30
Softener	
TDAE	10
Liquid Rubber	10
Carbon Black (N220)	35
Silica	35
Silane coupling agent (Si-75)	2.8
ZnO	3.5
Stearic acid	2.0
Anti oxidant 6C ¹⁾	2.0
Anti oxidant RD ²⁾	1.0
Wax	1.5
Sulfur	2.0
Accelerator NS ³⁾	1.0
Accelerator DPG ⁴⁾	0.5

1st Stage	Banbury mixer
0'00"	NR, BR (60 °C)
0'20"	CB, Silica, Softener, AO, ZnO, Stearic acid
5'30"	Dump out (150-160 °C)
2nd Stage	Banbury mixer
0'00"	Compound, Sulfur, Accelerators (50 °C)
0'75"	Dump out (95-105°C)

1) N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine

2) Polymerized 2,2,4-trimethyl-1,2-dihydroquinoline

3) N-tert-Butyl-2-benzothiazolesulfenamide

4) 1,3-Diphenylguanidine

Measurement of Friction Performance



RTM friction tester



Size:
Diameter 80mm
Width 16mm



Road surface :
Ice, Safety walk, Asphalt

Mode :
Ice, Wet, Dry grip, RR

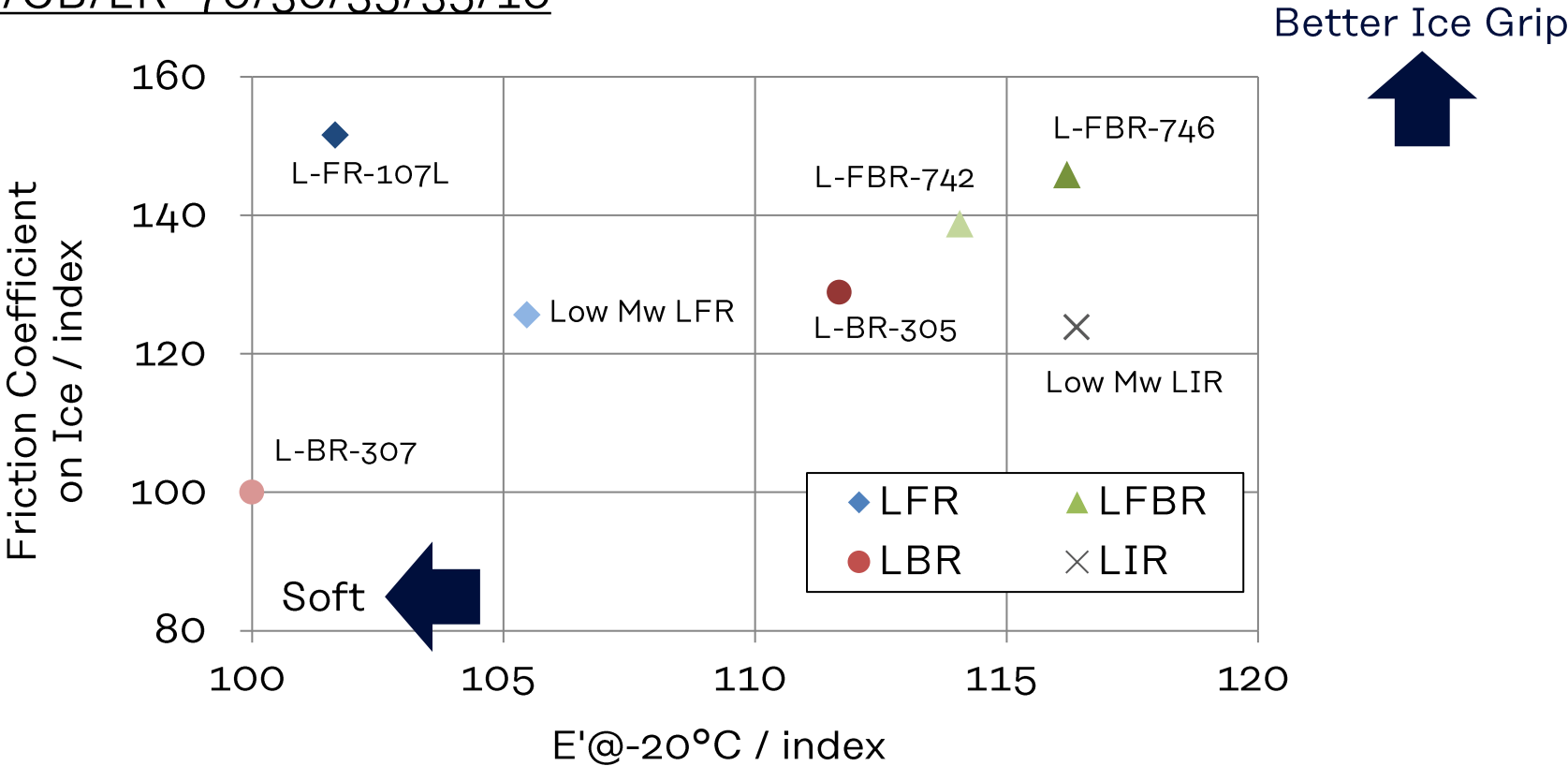
✓ Friction between road surface and miniature tire was measured

RTM Friction Tester



Friction Test Results

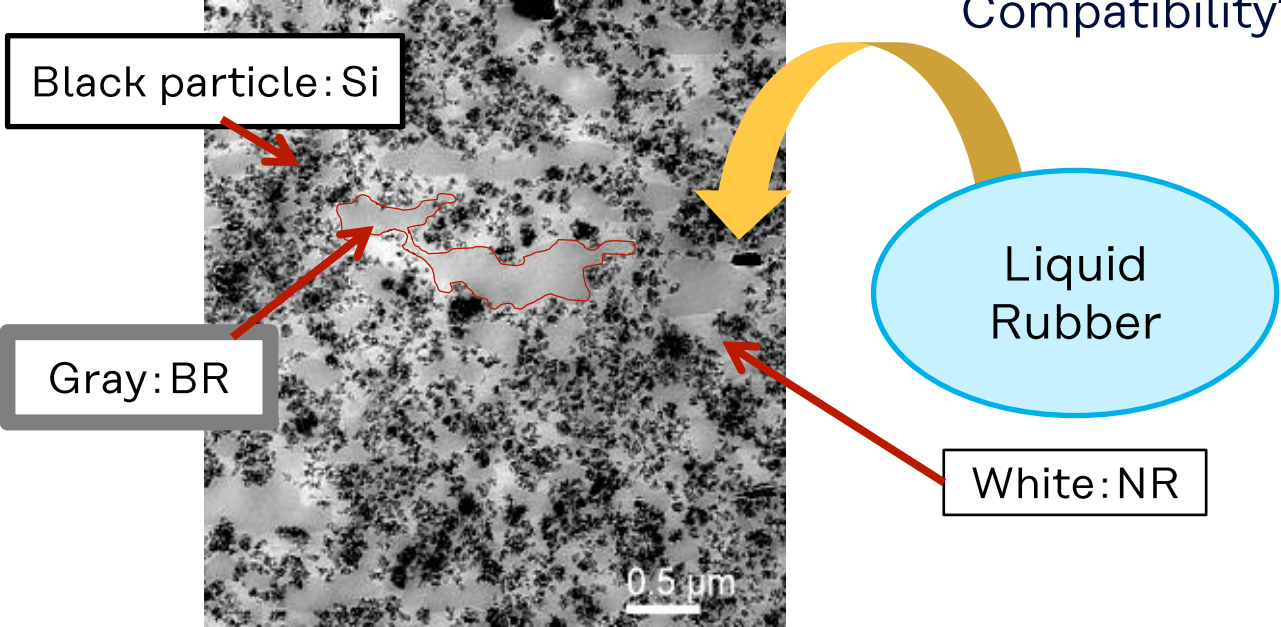
NR/BR/Si/CB/LR=70/30/35/35/10



- ✓ Especially LFR and L-FBR showed good ice grip
- ✓ E' have little correlation with actual ice grip

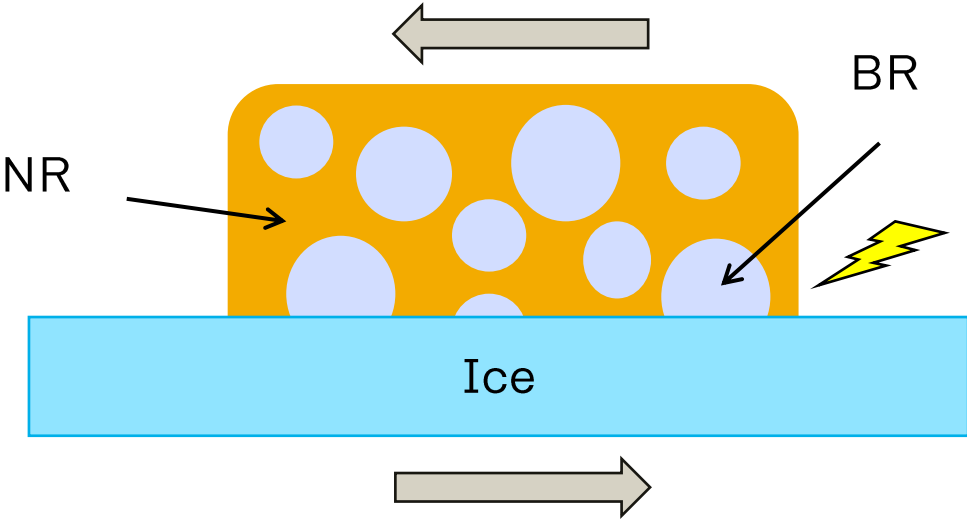
Hypothesis

NR/BR/Si (TEM)



Where to locate?
Compatibility?

Different LR shows different distribution to NR and BR



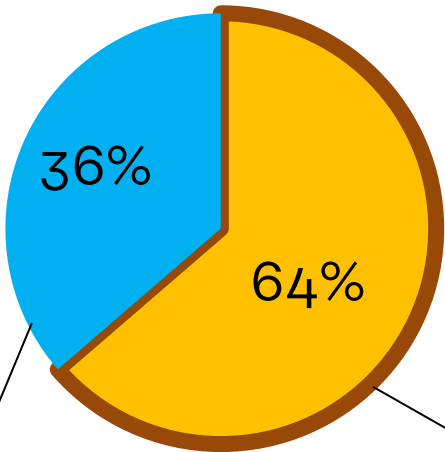
Contact area : NR > BR
→ Increased friction coefficient
by softening NR phase

Distribution Ratio by DSC

NR/BR/LR = 50/50/20

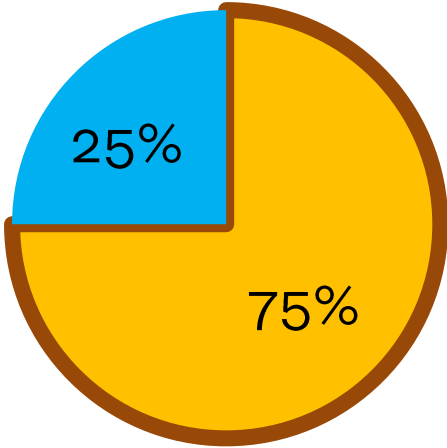
All Liquid rubbers have same range Mw (8000-10000).

L-BR



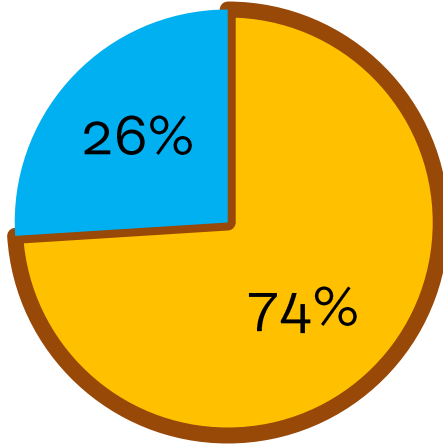
The ratio of LR which is miscible in BR

L-IR

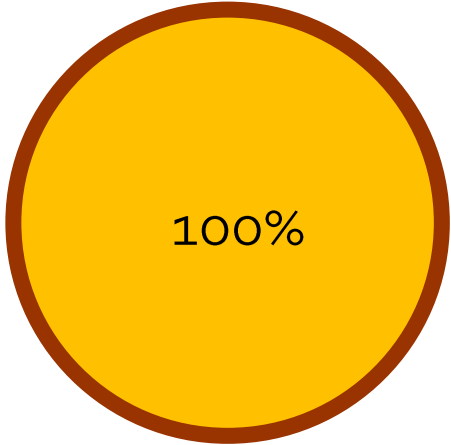


The ratio of LR which is miscible in NR

L-FBR



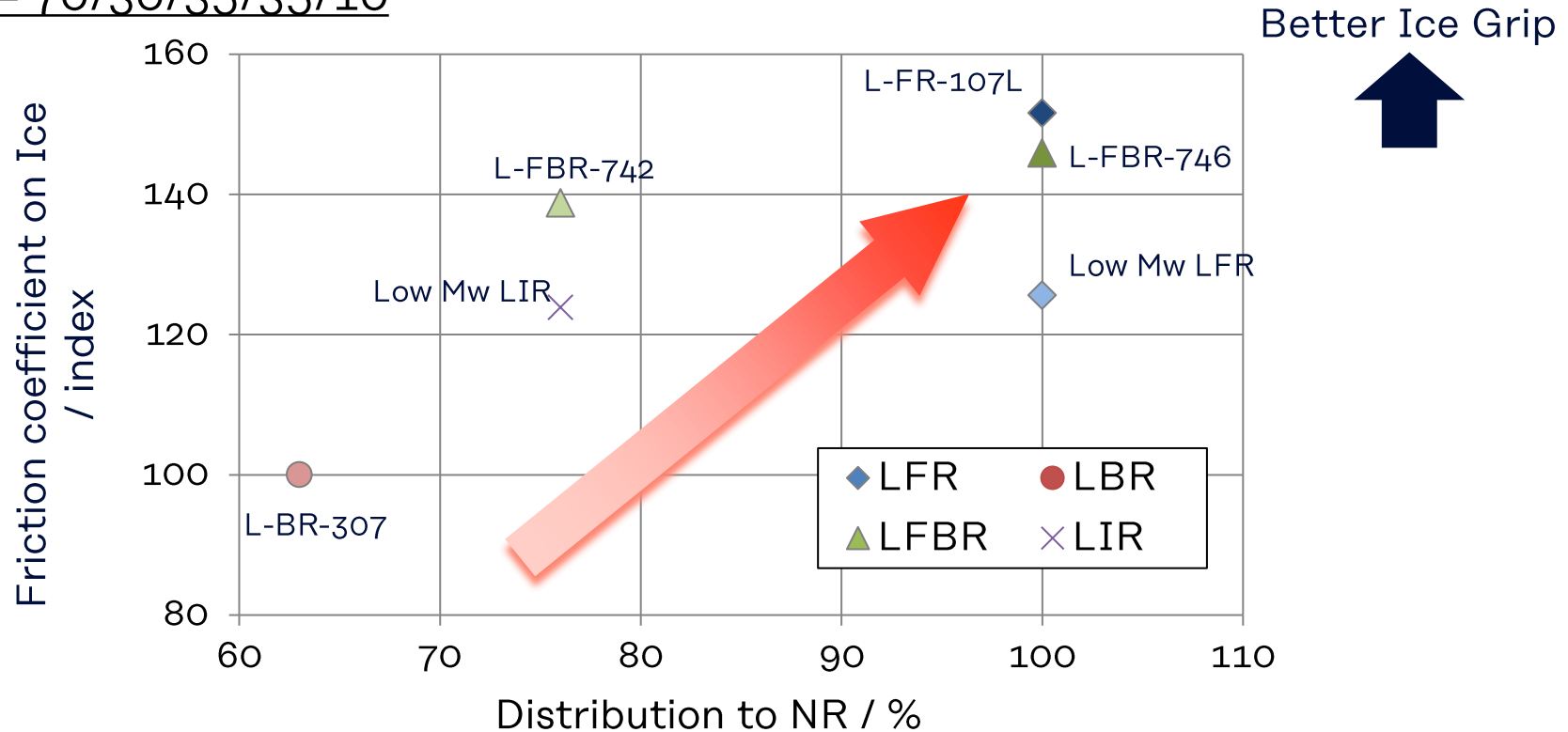
L-FR



✓ LFR localized to sea phase in NR/BR formulation

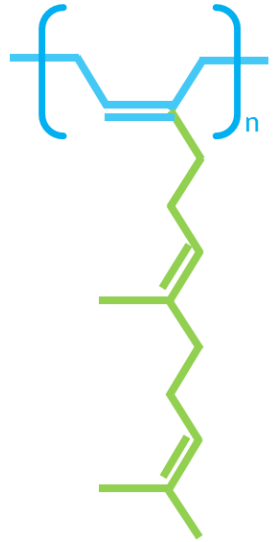
Friction & Distribution Ratio

NR/BR/Si/CB/LR = 70/30/35/35/10



- ✓ Higher distribution ratio to sea phase shows higher ice grip.
- ✓ L-FR&L-FBR can effectively improve ice grip

Summary



□ Characteristics of polymer

- ✓ Renewable monomer
- ✓ Low viscosity
- ✓ High reactivity
- ✓ Low Tg

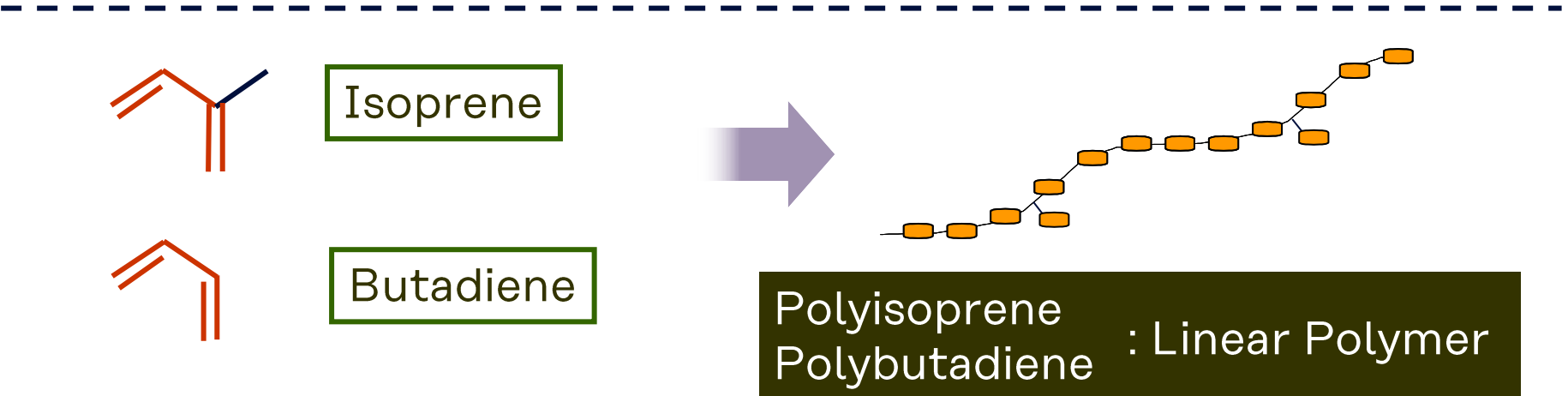
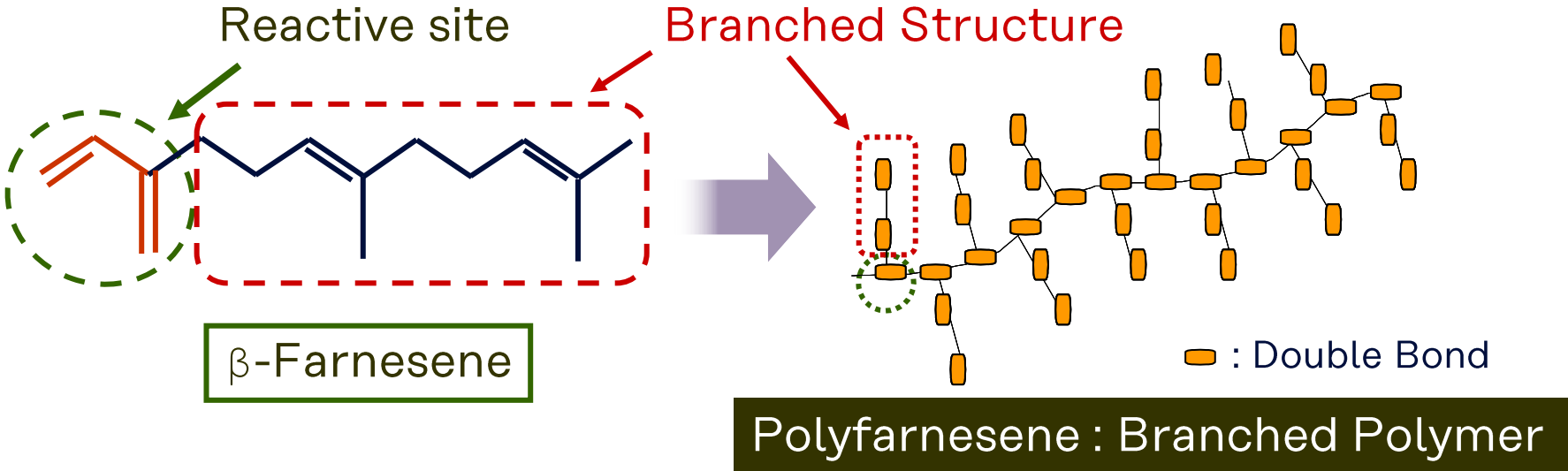
□ Expected features in rubber formulation

- ✓ Compatible with NR
- ✓ Softness at low temperature
- ✓ Less migration



APPENDIX

PolyFarnesene



Grade List of KURARAY LIQUID RUBBER

	Grade	Structure (wt)	Tg (°C)	Mw	Visc. @38°C (Pa.s)
Commercial Grade	L-FR-107L	Far=100	-71	135k	69
	L-FBR-742	Far/Bd=60/40	-78	29k	15
	L-FBR-746	Far/Bd=60/40	-78	88k	520
Development Grade	L-FR-101	Far=100	-73	9k	0.4
	L-FR-103	Far=100	-72	37k	6.5
	L-FSR-251	Far/St=50/50	-17	8k	318

Raw materials

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® 7000GR	Evonik Industries AG	Specific surface area (N2) 175 m ² /g
Carbon black	DIABLACK™ I	Mitsubishi Chemical Corporation	ASTM N220
Silane Coupling Agent	Si-75	Evonik Industries AG	
TDAE	VIVATEC 500	H&R GmbH Co. KGaA	

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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.

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