

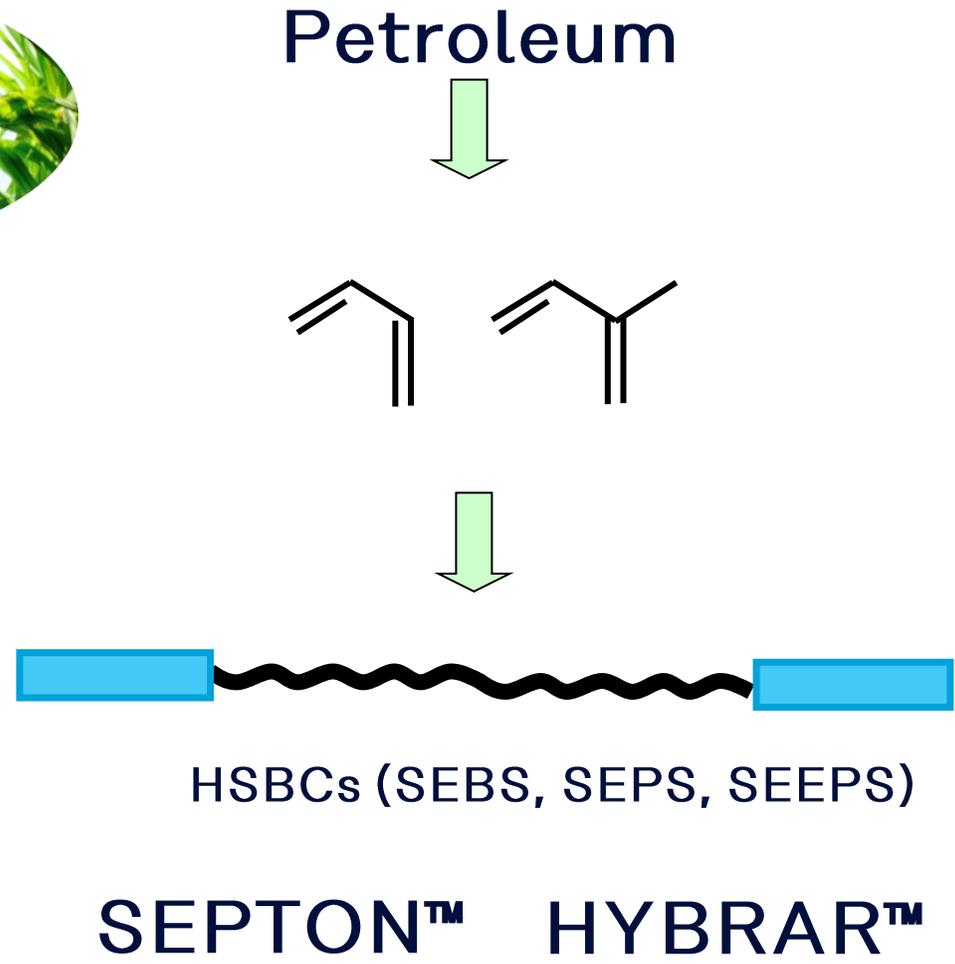
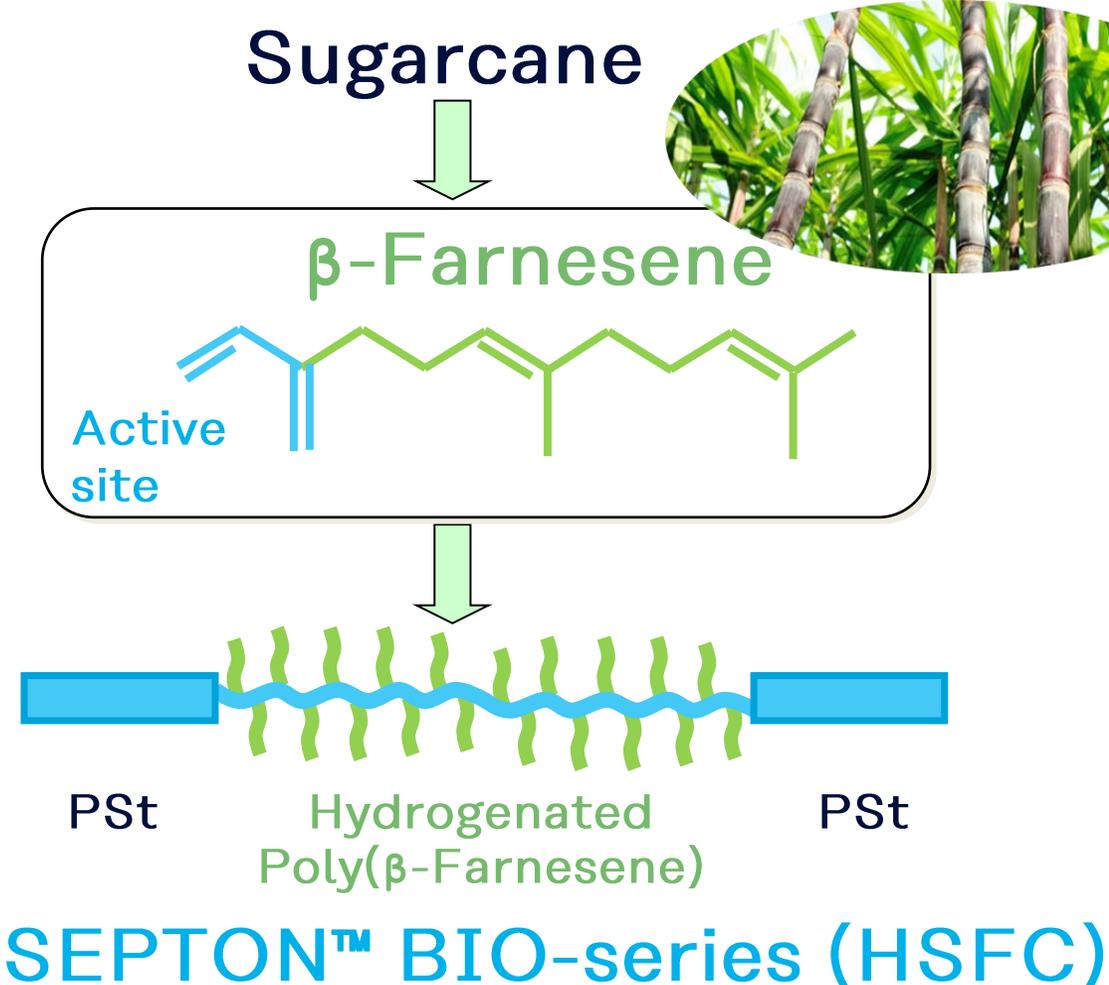
New Thermoplastic Rubber

Introduction of SEPTON™ BIO-series

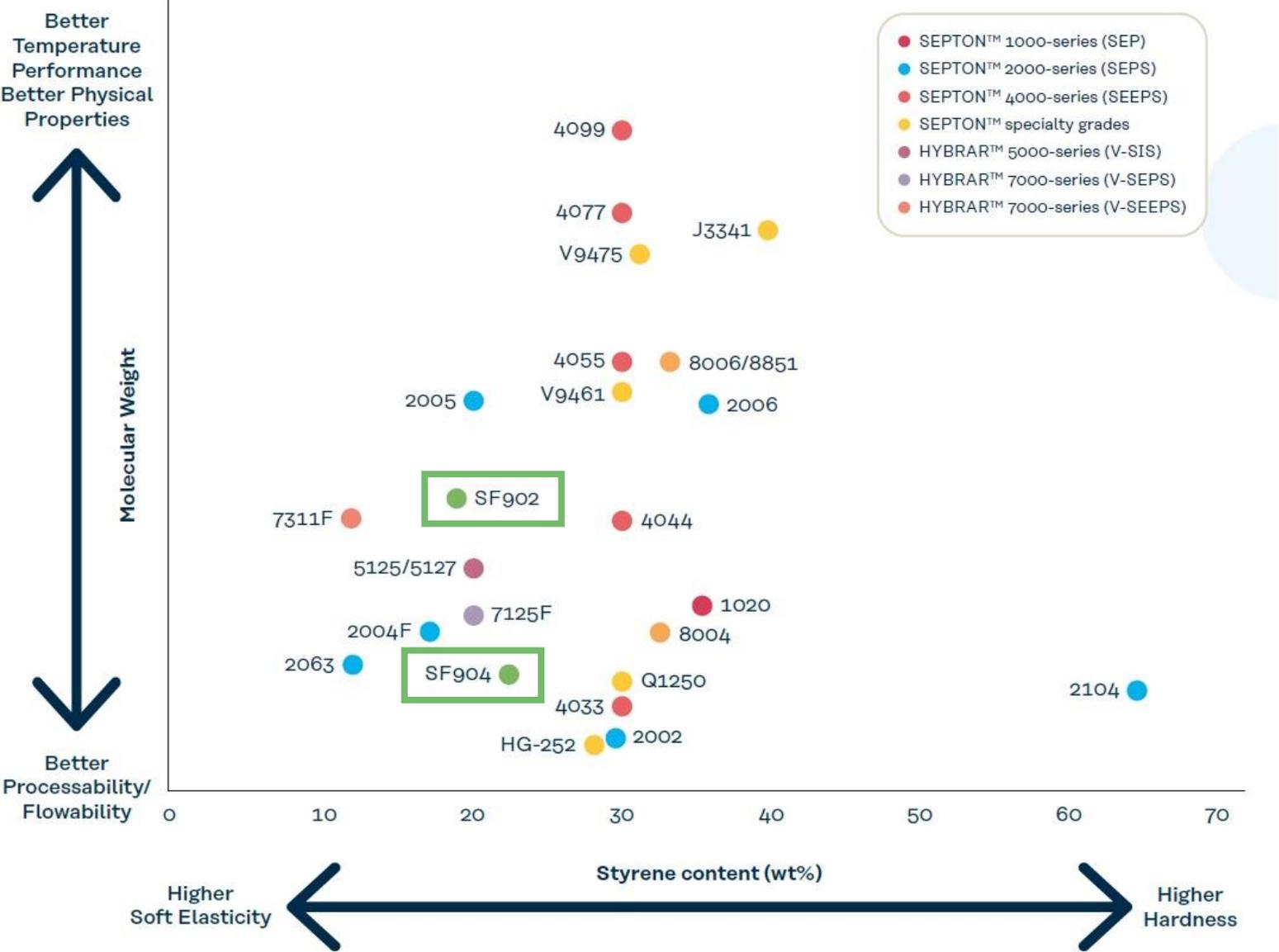
Elastomer R&D department
Elastomer division

kuraray **Septon™** BIO-series

What is SEPTON™ BIO-series (HSFC - Hydrogenated Styrene Farnesene Block Copolymer) ?



Grade Map



Typical Properties

Grade	Styrene Content (wt%)	Peak Temp. of tanδ (deg. C)	Glass Transition Temp. (deg. C)	Specific Gravity	Hardness (Type A)	Tensile Property			MFR			Solution Viscosity					Physical Form
						100% Modulus (MPa)	Tensile Strength (MPa)	Elongation (%)	190 deg. C, 2.16 kg (g/10 min)	230 deg. C, 2.16 kg (g/10 min)	230 deg.C, 10 kg (g/10 min)	5wt% (mPa.s)	10wt% (mPa.s)	15wt% (mPa.s)	20wt% (mPa.s)	30wt% (mPa.s)	
SEPTON™ BIO-series SF902	18	-50	-59	0.88	8	0.2	4.8	820	No Flow	No Flow	55	-	11	20	-	-	Pellet
SEPTON™ BIO-series SF904	21	-49	-57	0.89	25	0.3	5.8	900	15	48	>700	-	-	32	-	-	Pellet
HYBRAR™ 5127	20	15	8	0.94	84	2.8	12.4	730	5	-	-	-	-	-	-	540	Pellet
HYBRAR™ 5125	20	-8	-13	0.94	60	1.6	8.8	730	4	-	-	-	-	-	100	650	Pellet
HYBRAR™ 7125F	20	-7	-15	0.90	64	1.7	7.1	680	0.7	4	-	-	-	-	55	350	Pellet
HYBRAR™ 7311F	12	-22	-32	0.89	41	0.6	6.3	1,050	0.5	2	-	-	-	90	240	-	Pellet
SEPTON™ 4055	30	(-54)	-56	0.91	-	-	-	-	No Flow	No Flow	No Flow	90	5,800	-	-	-	Powder
Measurement Method	-	Tested by ARES	DSC, (Temp. increase by 10deg.C/min)	ISO 1183	ISO 7619	ISO 37			ISO 1133			Toluene solution, 30deg.C					-

1. Precautions should be taken in handling and storing. Refer to the appropriate Material Safety Data Sheet for further safety information.
 2. In using SEPTON™ BIO-series, please confirm related law and regulations, and examine its safety and suitability for the application.
 3. SEPTON™ BIO-series should not be used in any devices or materials intended for implantation in the human body, for medical, health care and food contact applications.
- * The figures, graphs, and charts in this technical information are representative ones measured by Kuraray, and those are without guarantee because each conditions of use are beyond Kuraray's control.

Typical Properties

		SEPTON™ BIO-series	
		SF902	SF904
Mw		Middle	Low
Styrene content		18	21
Properties			
Hardness	Type A	8	25
MFR [190 deg. C, 2.16 kg]	g/10 min	No flow	15
MFR [230 deg. C, 10 kg]	g/10 min	55	>700
100% Modulus * ¹	Mpa	0.2	0.3
Tensile Strength * ¹	Mpa	4.8	5.8
Elongation * ¹	%	820	900
Compression set [25 deg. C]	%	6	28
Compression set [70 deg. C]	%	35	100
ODT * ²	deg. C	330	210
Bio-based content* ³	%	80	48

*1. Compression molded sheet of 1 mm thickness 2. Order-Disorder transition Temperature

*3. Calculation by Kuraray method developed from ASTM6866 / Feeding ratio of farnesene

Features

Strengths

- Softness
- High flowability
- Low compression set, Low permanent set
- High damping property
- High $\tan \delta$ in wide temp. range
- High adhesiveness
- Isotropy
- Plasticizer Less
- High grip
- Eco-friendly

Weakness

- Low Tensile strength
- Tackiness

Analysis of Bio-based Content

Bio-based Content Analysis using ASTM 6866 (Accelerator Mass Spectrometry)

1) Sample Preparation

- a) The sample was oxidized by heating to produce CO₂ gas, without chemical pretreatment.
- b) The produced CO₂ gas was purified in a vacuum line.
- c) The purified CO₂ gas sample was reduced to graphite by hydrogen using iron as a catalyst.
- d) The produced graphite was pressed into a target holder with a hole of 1mm diameter for the AMS ¹⁴C dating, using a hand-press machine.

2) Measurement

- The graphite sample was measured against a standard of Oxalic acid (HOxII).
- ¹⁴C-AMS (accelerator mass spectrometry) system based on the tandem accelerator.

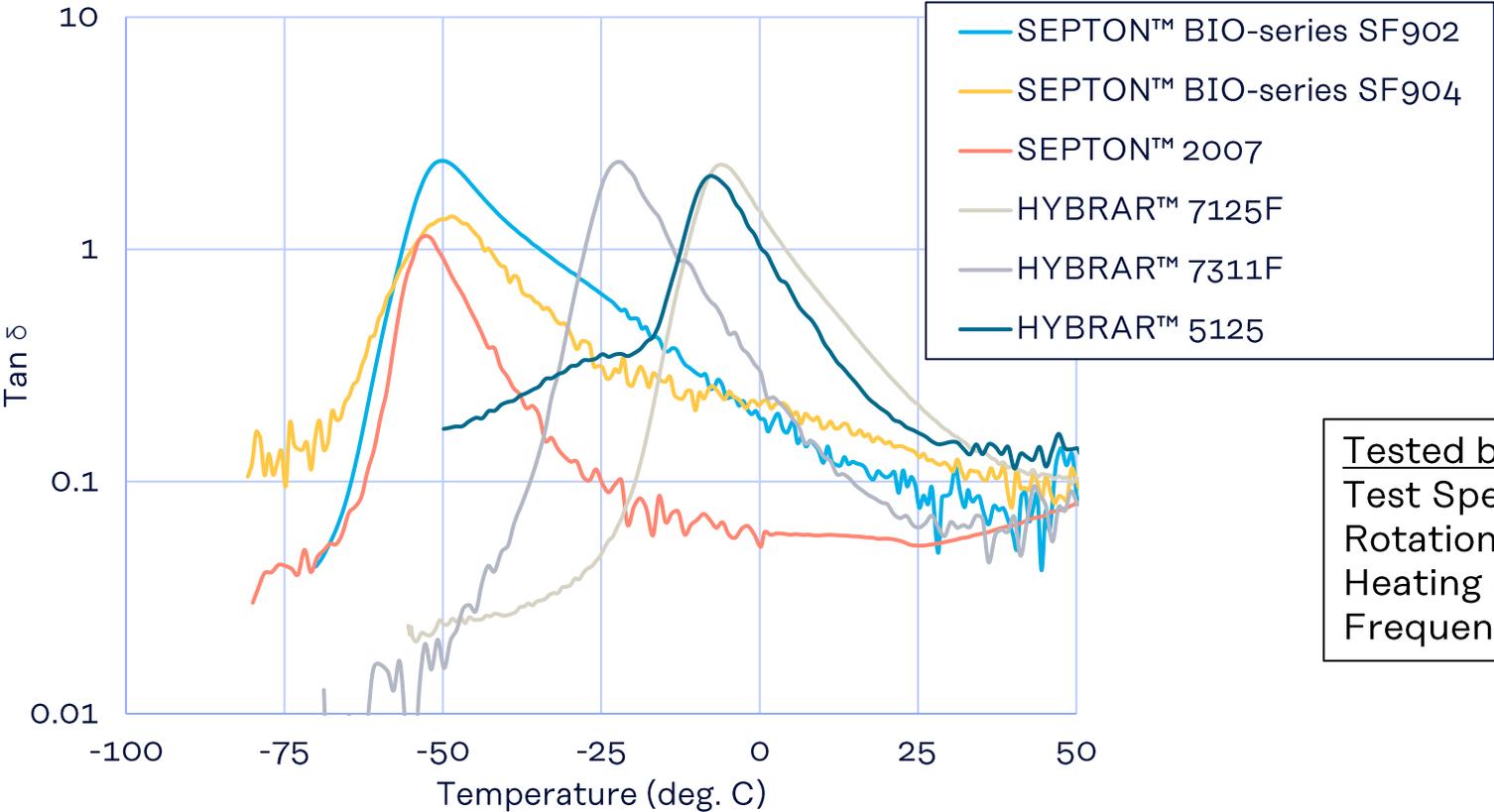
3) Result

Sample Name	Sample State	Mean Bio-based Result by using ASTM 6866 *
SEPTON™ BIO-series SF902	Solid	80%
SEPTON™ BIO-series SF904	Solid	50%
β-Farnesene	Liquid	99%

* Ratio of bio-based component in the material, assuming that all the materials are of present day or fossil origins.

Damping Property

- SEPTON™ BIO-series show high $\tan \delta$ value in wide temperature range.

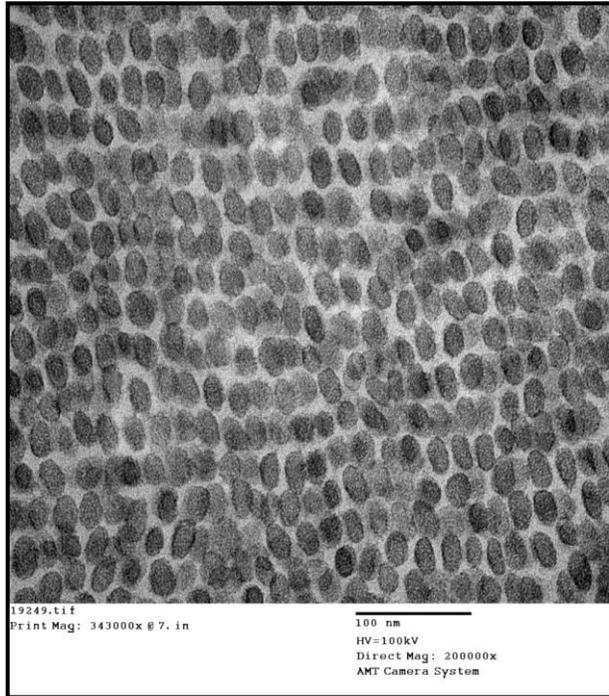


Tested by ARES
Test Specimen; Cylinder, diameter = 8 mm, height = 2 mm
Rotation mode
Heating rate; 2 deg. C/min
Frequency; 1 Hz

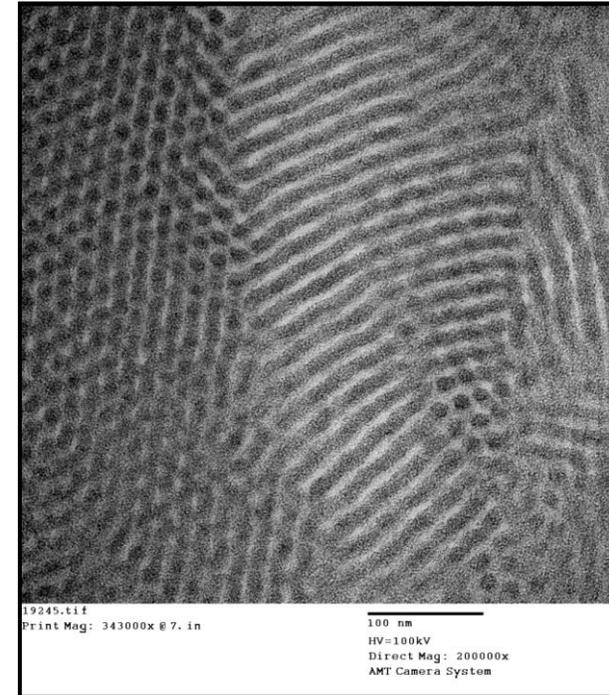
TEM Image

- SEPTON™ BIO-series has sphere polystyrene domain, although SEBS with same styrene content has cylinder type domain.

HSFC (SEPTON™ BIO-series: St=30wt%)



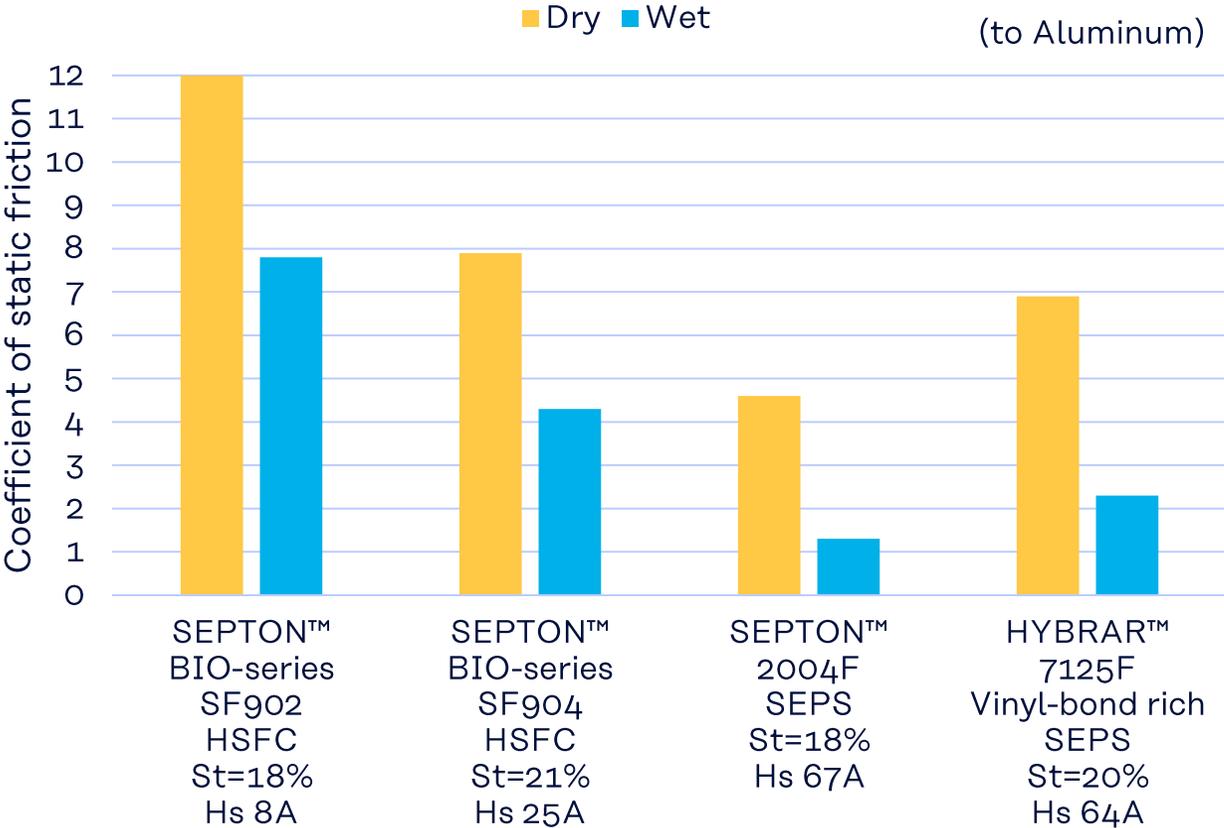
SEBS (St=30wt%)



* cast sheet (from 10wt% cyclohexane solution)

Grip performance

- SEPTON™ BIO-series show high grip performance compared with general HSBCs.
- SEPTON™ BIO-series show high grip performance in wet conditions.

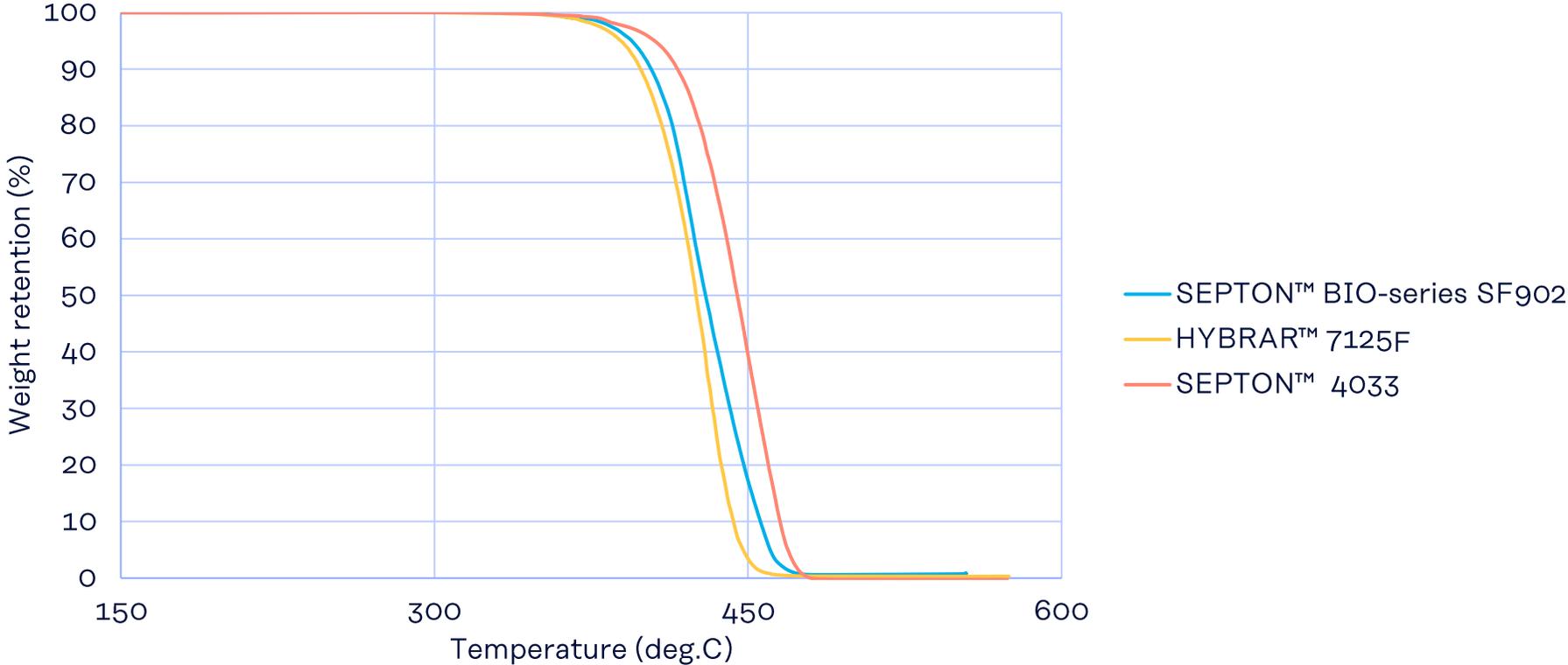


Aluminum



Specimen: Compression molded sheet (0.5 mmt)

Heat Resistance



Test conditions : Thermo-balance Heat Degradation, Heat rate 10 deg. C/min., Nitrogen Atmosphere

Line-up

	Adhesive	Protective Film	Sealant	Resin Modifier	Compound	Jelly	Nonwoven
<u>SEPTON™ BIO-series SF902</u> Middle Mw Low St content	✓	✓ Solvent coating	✓	✓		✓	
<u>SEPTON™ BIO-series SF904</u> Low Mw Low St content	✓	✓ Co-extrusion & Solvent coating	✓	✓	✓		✓

Adhesive

Features

- High adhesiveness and tackiness without tackifier
- Low bleeding
- High adhesiveness to PE, Glass with tackifier
- Good heat resistance (SEPTON™ BIO-series SF902)
- Good film extrusion mold-ability (SEPTON™ BIO-series SF904)

Adhesive Properties of Solvent Coated Film

		Units	SEPTON™ BIO-series SF904	SEPTON™ BIO-series SF902	HSBC-1	SEPTON™ BIO-series SF904 + TF*3	SEPTON™ BIO-series SF902 + TF*3	HSBC-2 + TF*3	Test Method
SAFT*1	to SST*2	(deg. C)	145	202	188	132	190	159	
Ball tack		(Ball No.)	5	6	2	6	8	5	JIS Z0237
Rolling ball tack		(cm)	> 37.5	11	> 37.5	36.7	17	> 37.5	ASTM D3121
180° Peel strength	to Glass	(N/25 mm)	0.1	0.3	0.03	4.9	8.9	10	
	to SST*2	(N/25 mm)	8.1	5.7	12	13	15	11	
	to PE	(N/25 mm)	0.5	0.7	0.05	2.8	2.7	0.2	
	to PMMA	(N/25 mm)	11	9.8	18	15	14	14	

*1: 0.5kgf, sample size 25 mm x 25mm, temperature increment 0.5 deg. C/min

*2: Stainless steel

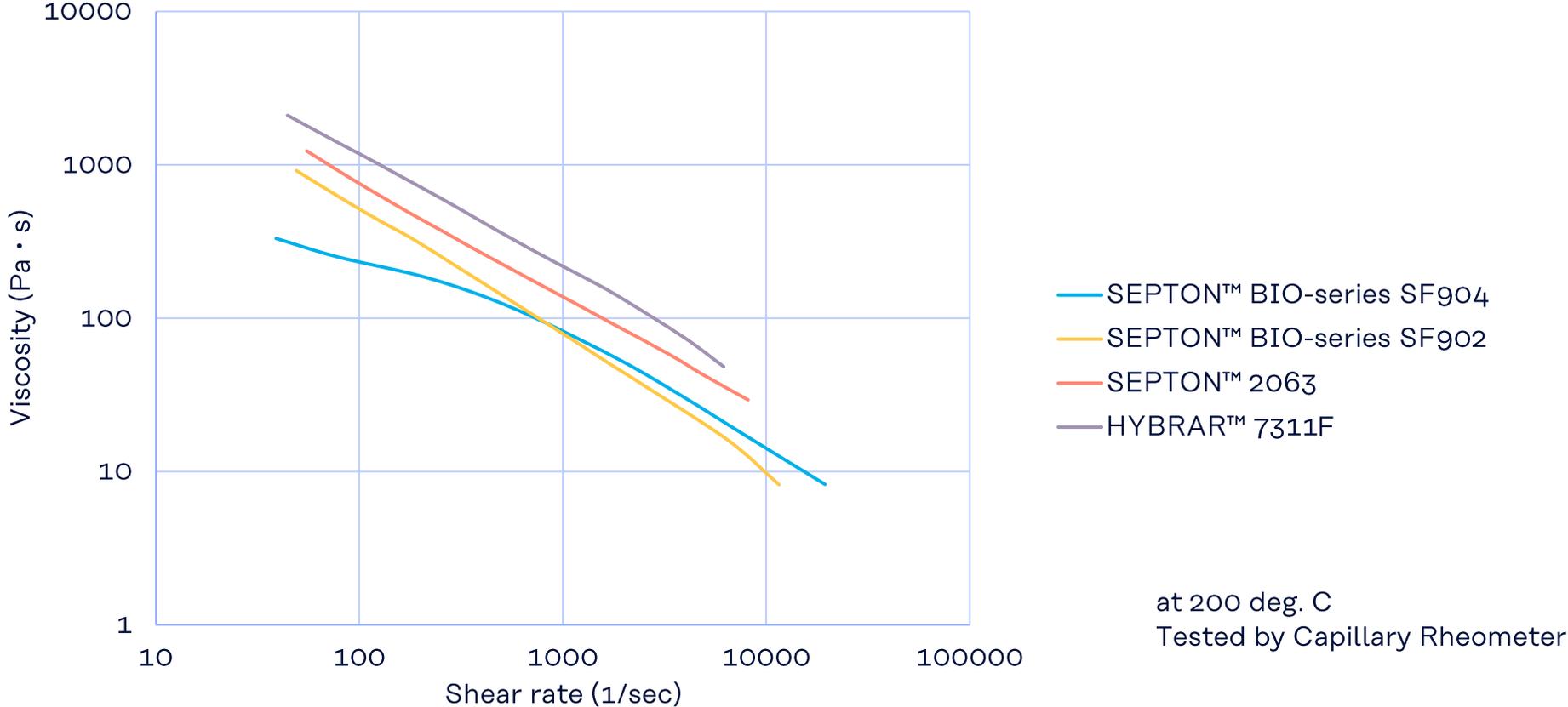
*3: Tackifier; Arkon P-125 (Arakawa Chemical Industries, Ltd.)

Formulation; SEPTON™ BIO-series/TF or HSBC-2/TF (80/20, by wt)

Test Specimen; Cyclohexane solvent (TS=25wt%) coating to PET film(50 μm)

Melt Viscosity

- SEPTON™ BIO-series SF904 shows similar shear dependency to HSBCs with lower viscosity.



T-die Cast Film

- SEPTON™ BIO-series SF904 shows good T-die film casting mold-ability and co-extrusion with polyolefin.

SEPTON™ BIO-series SF902



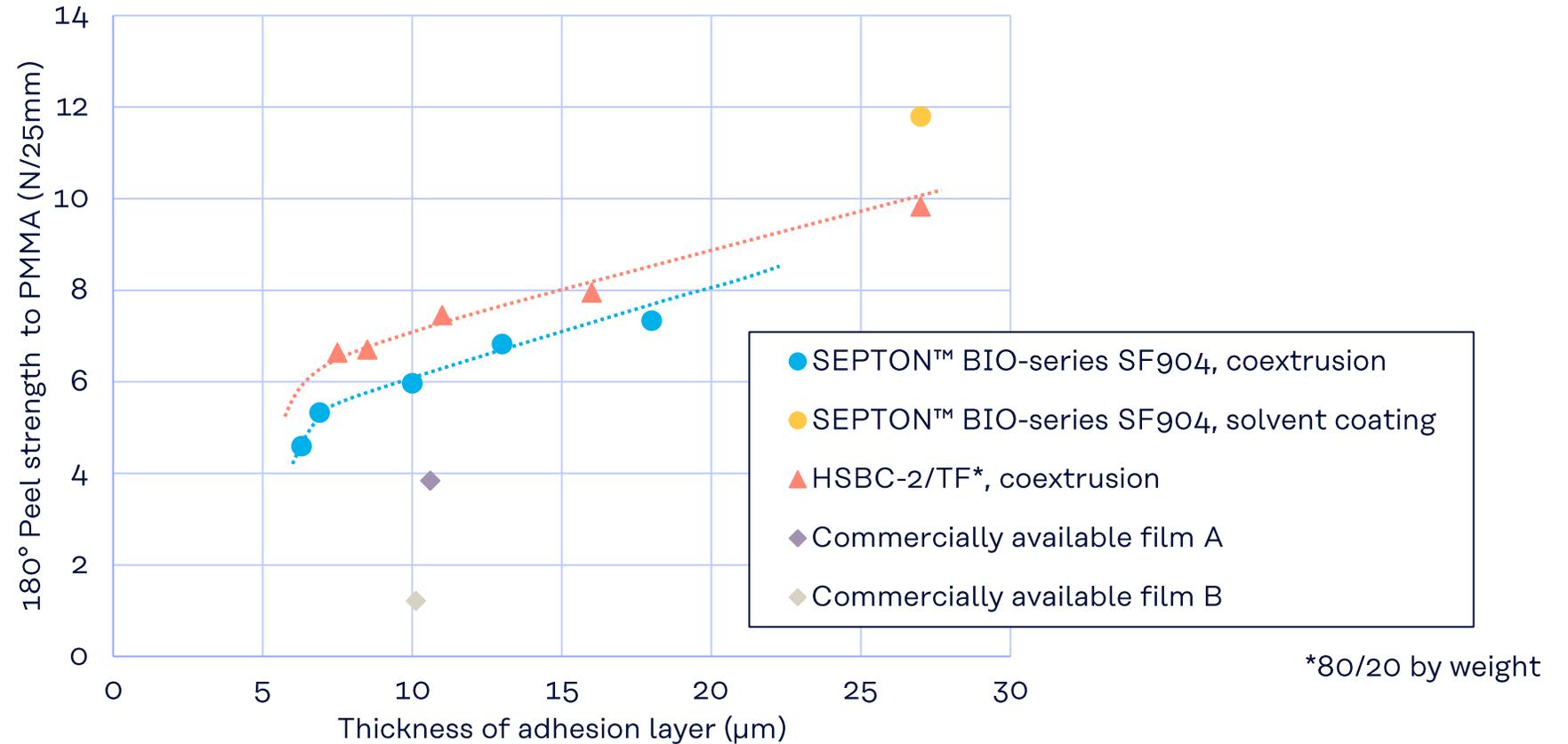
SEPTON™ BIO-series SF904



@ 200 deg. C

Adhesive Properties of T-die Cast Film

- SEPTON™ BIO-series SF904 shows good adhesiveness equivalent to HSBC/TF.



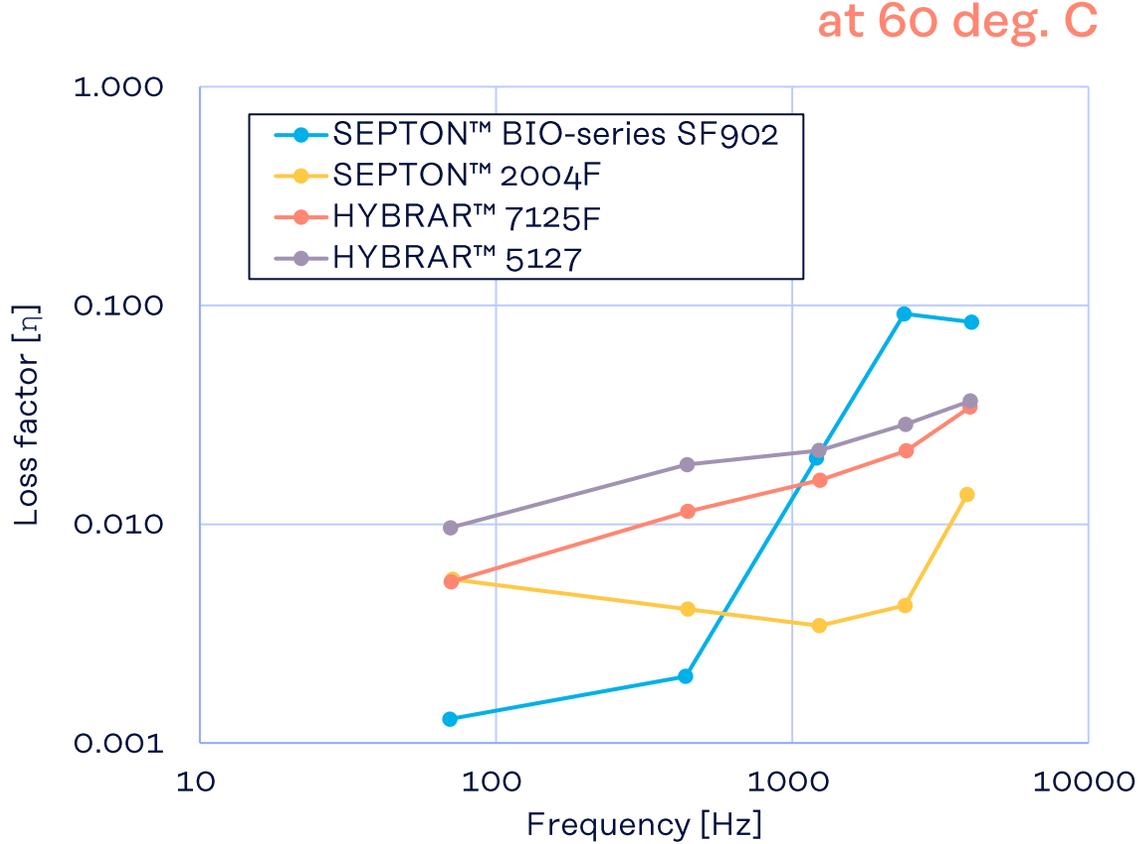
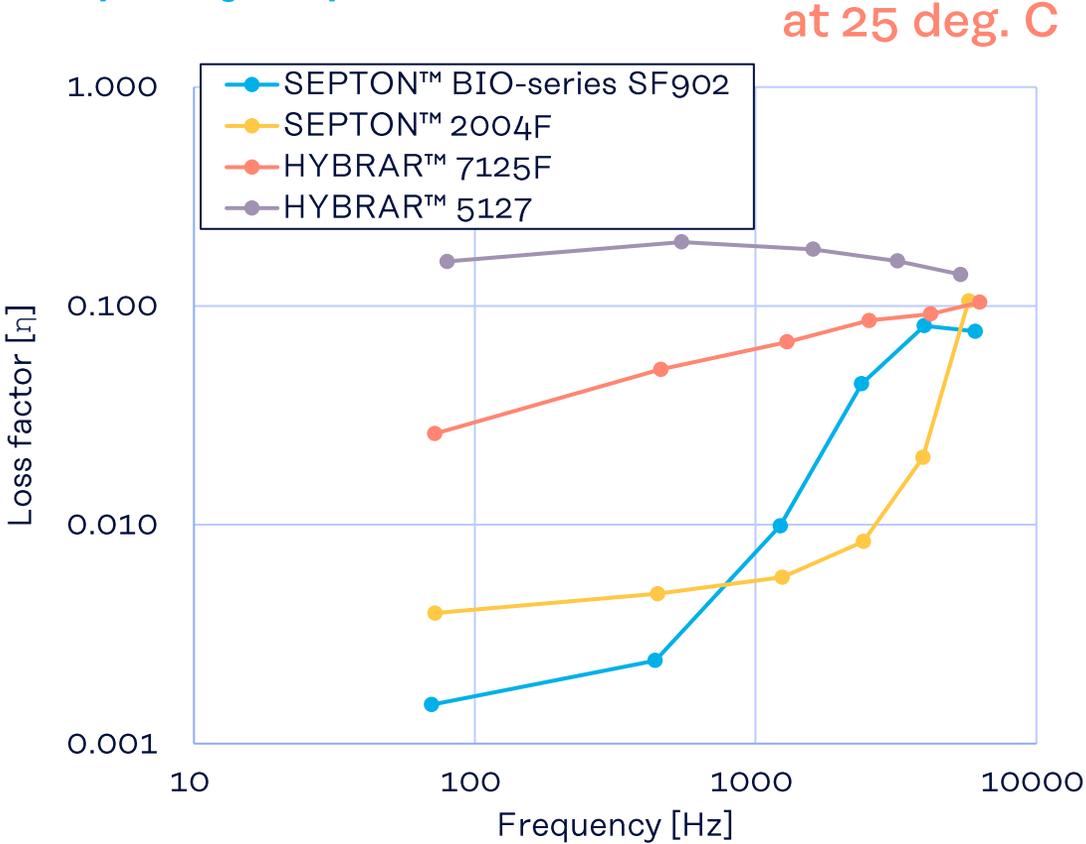
Sealant

Features

- SEPTON™ BIO-series shows good damping property to high frequency sound at any temperature.
- Softness without oil

Sound Damping

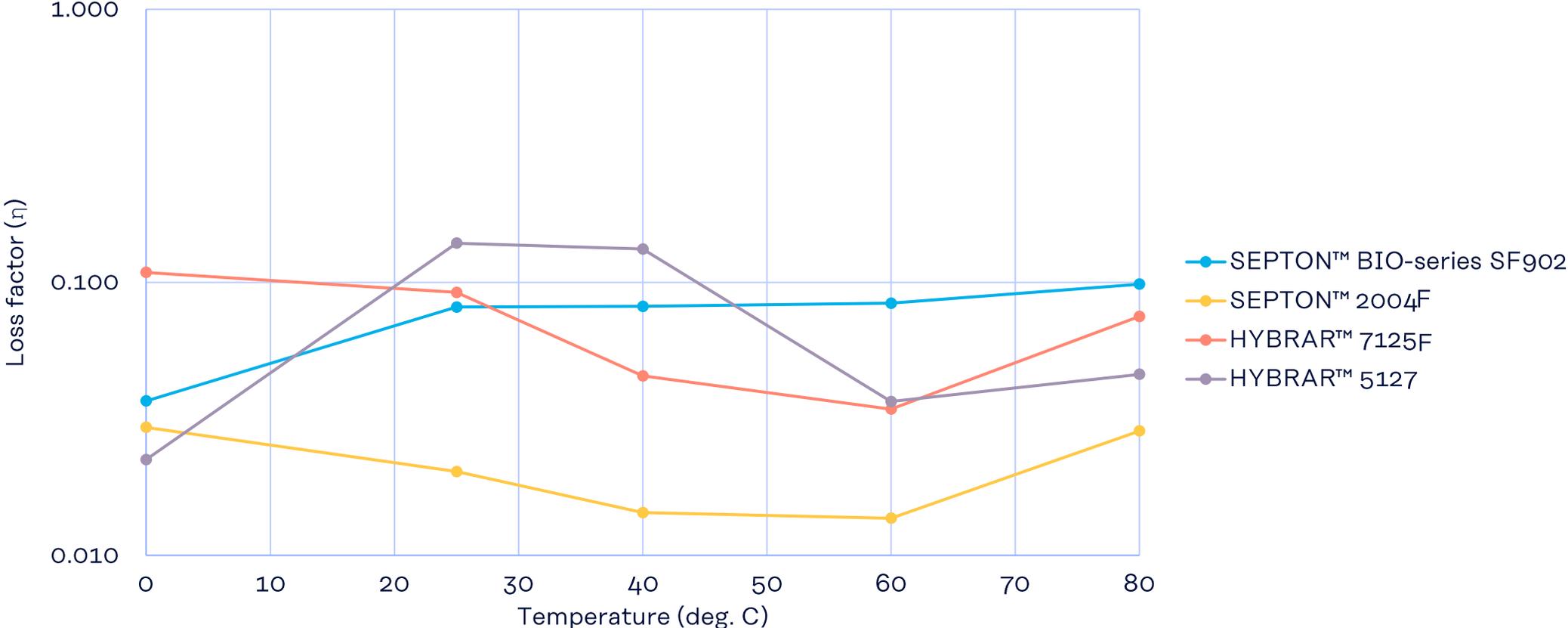
Frequency Dependence



Sound Damping

Temperature Dependence

Frequency; 4 kHz



Compounds

Features

- Adhesive compounds show good adhesion to various polar and non-polar adherent with extrusion molding.
- Adhesive compounds show good adhesion to various polar adherent with insert injection molding.
- Compounds using thermoplastic vulcanizates (TPV)/SEPTON™ BIO-series show good extrusion mold-ability.
- For weather seal applications, compounds using TPV/SEPTON™ BIO-series show good softness and adhesion to EPDM.
- Compounds using SEPTON™ BIO-series/Oil/PP show good softness.

Adhesive Compound for extrusion molding

- Adhesive compounds using SEPTON™ BIO-series show good adhesiveness to various polar and non-polar adherent.

Formulation; SEPTON™ BIO-series/EMA/MAh-PP (70/20/10)
 Adherent; 1 mm thickness plate
 Bonding condition; Pre-heating at 160 deg. C, 0.5 min
 Compression at 160 deg. C, 2 MPa, 2.5 min

EMA; ELVALOY® AC1820 (DuPont de Nemours, Inc.), MAh-PP; ADMER™ QF551 (Mitsui Chemicals, Inc.)

	Thickness [mm]	Hs [Type A]	180° Peel strength [N/25 mm]					
			PC	PMMA	ABS	PA6	PP	Al
SEPTON™ BIO-series SF902 Compressed sheet	1.0	37	34	30	31	21	30	34
SEPTON™ BIO-series SF904 Compressed sheet	1.0	41	55	30	6.2	56	68	90

Adhesive Compound for insert injection molding

- Excellent Adhesive strength to polar materials by insert injection

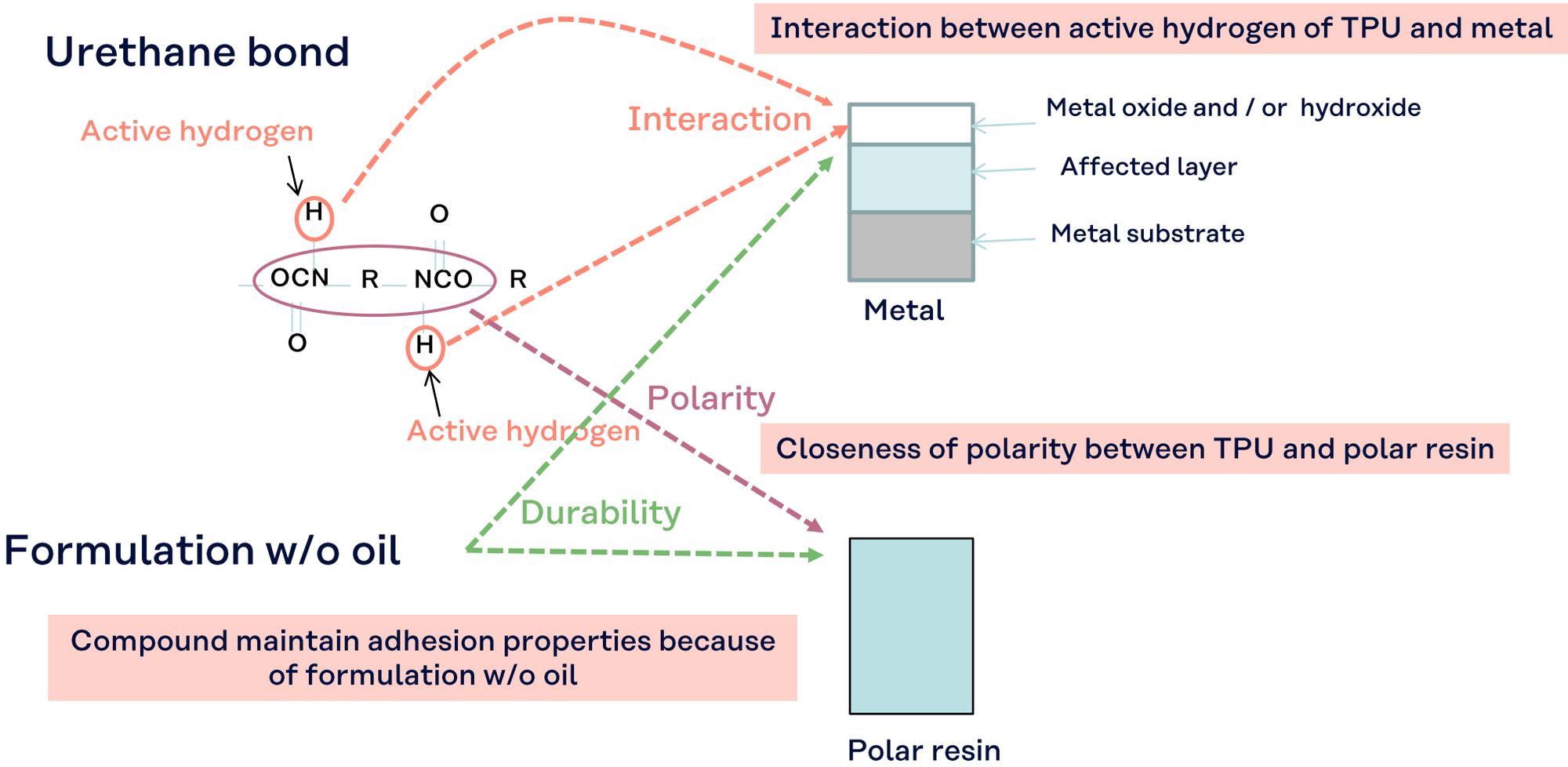
		HSFC	HSBC
SEPTON™ BIO-series SF904		100	-
SEPTON™ 8006		-	100
TPU (Elastollan® C80a: BASF SE)		200	200
TU-S5265 (Kuraray Co., Ltd.)		50	50
Paraffin oil (Kinetic viscosity=96 mm ² /s@40 deg. C)		-	100
Antioxidant (ADKSTAB AO-60, ADEKA Corporation)	to compound (wt%)	0.1	0.1
Antiblocking agent: Talc FFR (Asada Milling Co., Ltd.)	to compound (wt%)	0.1	-
Mixing condition: Barrel temp.	¹⁾ deg. C	220	240
Moisture (Pellet)	²⁾ ppm	453	479
MFR (230 deg. C, 2.16 kg)	g/10 min	22	5.2
Hardness	Type A	65	55
Tensile strength	Mpa	7.4	2.9
Elongation	%	260	480
Molding condition: Cylinder temp./Mold temp.	³⁾ deg. C	260/40	260/40
Substrate		180° Peel strength (N/25 mm)	
PC		96	50
ABS		87	50
PMMA		64	46
PA6		70	26
Aluminum		48	6.1
Magnesium alloy		52	5.6

1) ZSK26Mc: φ26mm, L/D=56 (Coperion GmbH)

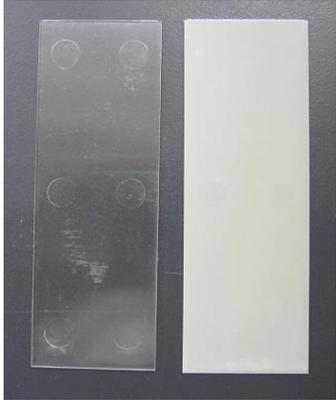
2) Drying condition: 80 deg. C, 4 hrs

3) EC75SX: 75ton (Shibaura Machine Co., Ltd.)

Estimation of adhesive mechanism



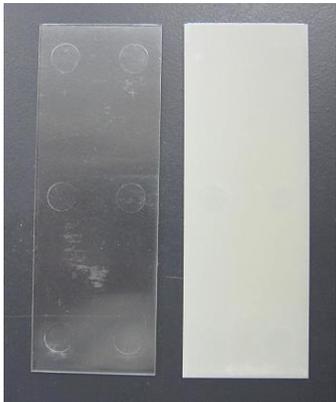
Substrate washing



Polar resin

Just wiping surface with methanol

Polar resin



Metal

- 1) Washing the surface by mixed solution
Clean ace S / distilled water = 20 / 80 (v / v)
- 2) Then washing the surface by distilled water with ultrasonic for 10 min
- 3) Drying the metal at 100 deg. C for more than 1 hr
Clean ace S : Neutral detergent (AS one Corporation)

Metal

Compounds using thermoplastic vulcanizates (TPV)/SEPTON™ BIO-series (extrusion)

				Hardness 60A		Hardness 40A	
TPV-1			100		70		
TPV-2				100			70
TPV-3						100	
SEPTON™ BIO-series SF904					30		30
MFR	(210 deg. C, 2.16 kg)	g/10 min	-	-	22	-	29
	(210 deg. C, 5 kg)	g/10 min	1.5	0.6	94	14	148
Compression set	(70 deg. C, 22 hrs)	%	29	27	74	25	59
	(120 deg. C, 22 hrs)	%	25	29	62	27	85
Properties							
Hardness		(Type A)	76	60	56	40	35
100% Modulus		MPa	4.6	2.0	1.9	0.9	0.7
Tensile strength		MPa	8.9	5.3	3.1	2.9	1.7
Elongation		%	450	380	318	320	337
Tear strength		N/mm	16.0	8.7	9.5	3.9	5.0
Resilience		%	46	54	42	55	52
Extrusion Moldability			Good	Fair	Excellent	Bad	Good

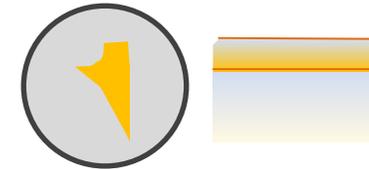
Compounds using TPV/SEPTON™ BIO-series (extrusion)

- SEPTON™ BIO-series SF904 improves extrusion mold-ability of TPV.

	Hardness	MFR 210 deg.C, 5 kg			Moldability (Garvey die)
TPV-1	76	1.5			Good
TPV-2	60	0.6			Fair
TPV-1/SF904 (70/30)	56	94			Excellent
TPV-3	40	14			Bad
TPV-2/SF904 (70/30)	35	148			Good

Garvey die test

Excellent



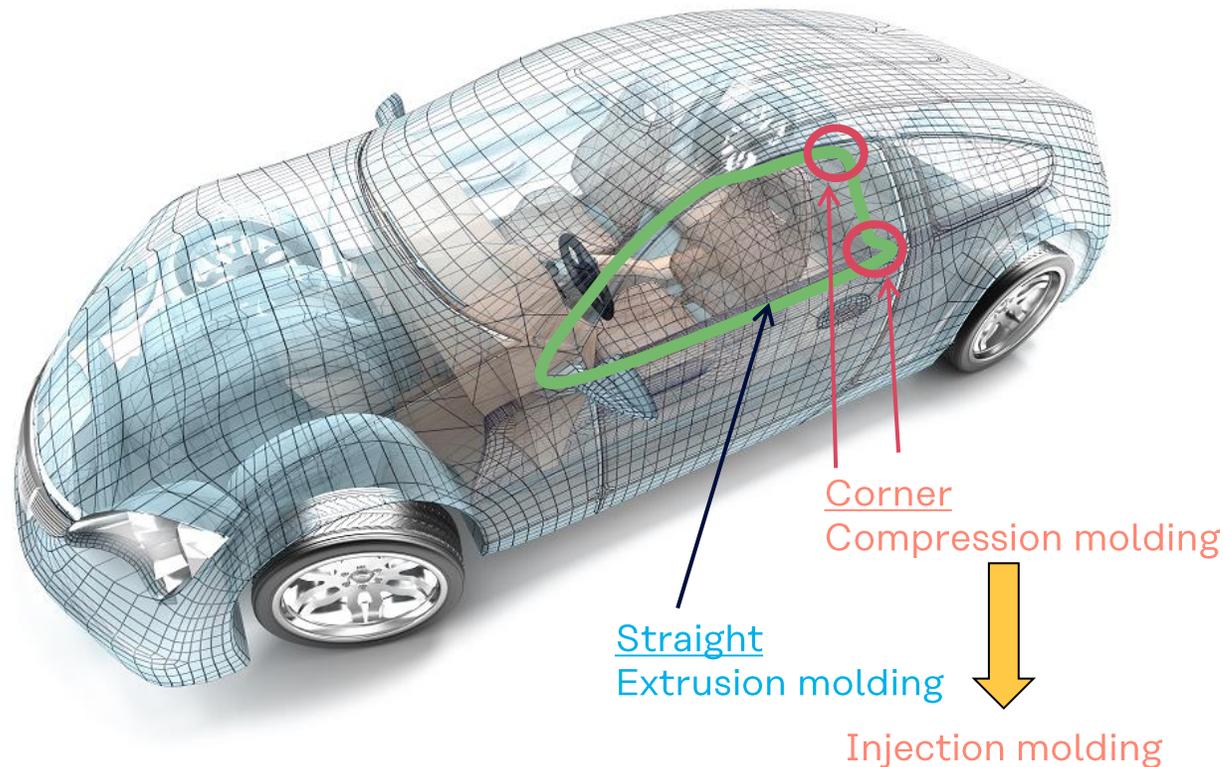
Bad



Weather Seal (Compounds using SEPTON™ BIO-series/PP)

Formulation; SEPTON™ BIO-series/Random-PP/Erucamide (75/25/0.2)

Random PP; MFR=20 g/10 min @ 230 deg. C, 2.16 kg
Erucamide; (DIAMID L-200, Nippon Kasei Chemical Co., Ltd.)



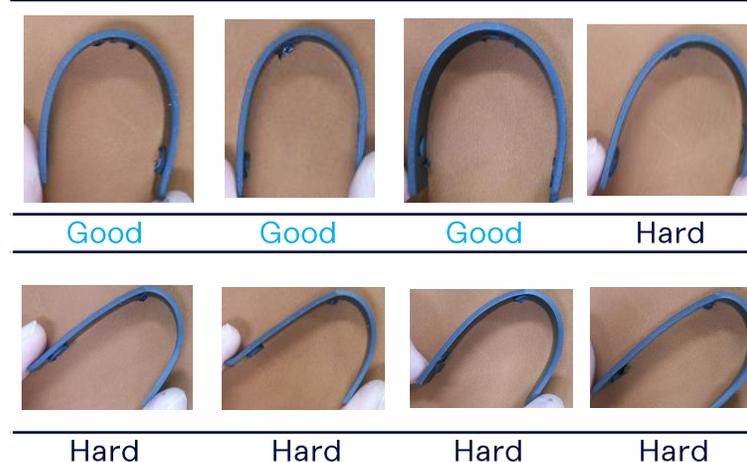
		SEPTON™ BIO-series SF902	SEPTON™ BIO-series SF904	TPV
Hardness	Type A	70	75	62
Adhesion	N/cm ²	169	198	105

Insert injection molding to EPDM



Window seal (Compounds using TPV/SEPTON™ BIO-series)

Glass-run corner (Window seal)						
TPV-4			100	75	75	75
SEPTON™ BIO-series SF902				15		
SEPTON™ BIO-series SF904					18.75	15
r-PP (MFR 20 g/10 min)				10	6.25	10
Hardness	Type A		71	76	67	76
Adhesive force	to TPV	N/cm ²	310	288	243	286
	to EPDM	N/cm ²	239	246	222	283
MFR (230 deg. C, 2.16 kg)		g/10 mim	9.4	16	67	61
Flexibility	to TPV		Good	Good	Good	Hard
	to EPDM		Hard	Hard	Hard	Hard



Window seal (Compounds using TPV/SEPTON™ BIO-series)



Door seal corner					
TPV-5			100	75	75
SEPTON™ BIO-series SF904				18.75	15
r-PP (MFR 20 g/10 min)				6.25	10
Hardness	Type A		42	48	54
Adhesive Force	to TPV	N/cm ²	140	120	135
	to EPDM	N/cm ²	100	115	150
MFR (230 deg. C, 2.16 kg)		g/10 mim	3.6	134	107
Flexibility	to TPV		Good	Good	Hard
	to EPDM		Hard	Soft	Good



Compounds using HSBC/Oil/PP

Physical properties of HSBC based compound with process oil

SEPTON™ BIO-series SF902		HSFC	100			
SEPTON™ BIO-series SF903		HSFC		100		
SEPTON™ 4033		SEEPS			100	
SEPTON™ 4055		SEEPS				100
Process Oil			50	50	50	50
Polypropylene			20	20	20	20
Antioxidant			0.1	0.1	0.1	0.1
MFR						
	(200 deg. C, 2.16 kg)	(g/10 min)	8.1	3.5	2.4	No flow
	(200 deg. C, 5 kg)	(g/10 min)	115	82	9.7	No flow
Properties (Press molding, 230 deg. C)						
Hardness		(Type A)	18	20	67	62
100% Modulus		(MPa)	0.4	0.4	2.4	1.4
Tensile strength		(MPa)	1.1	3.1	21	20
Elongation		(%)	340	590	690	740
Compression set	(23 deg. C, 22 h)	(%)	4	10	18	12
	(70 deg. C, 22 h)	(%)	66	20	100	30
	(100 deg. C, 22 h)	(%)	100	46	-	43
	(120 deg. C, 22 h)	(%)	-	60	-	Broken
Permanent set	(100%, 10 min – 10 min)	(%)	2.3	2.3	1.8	4.8

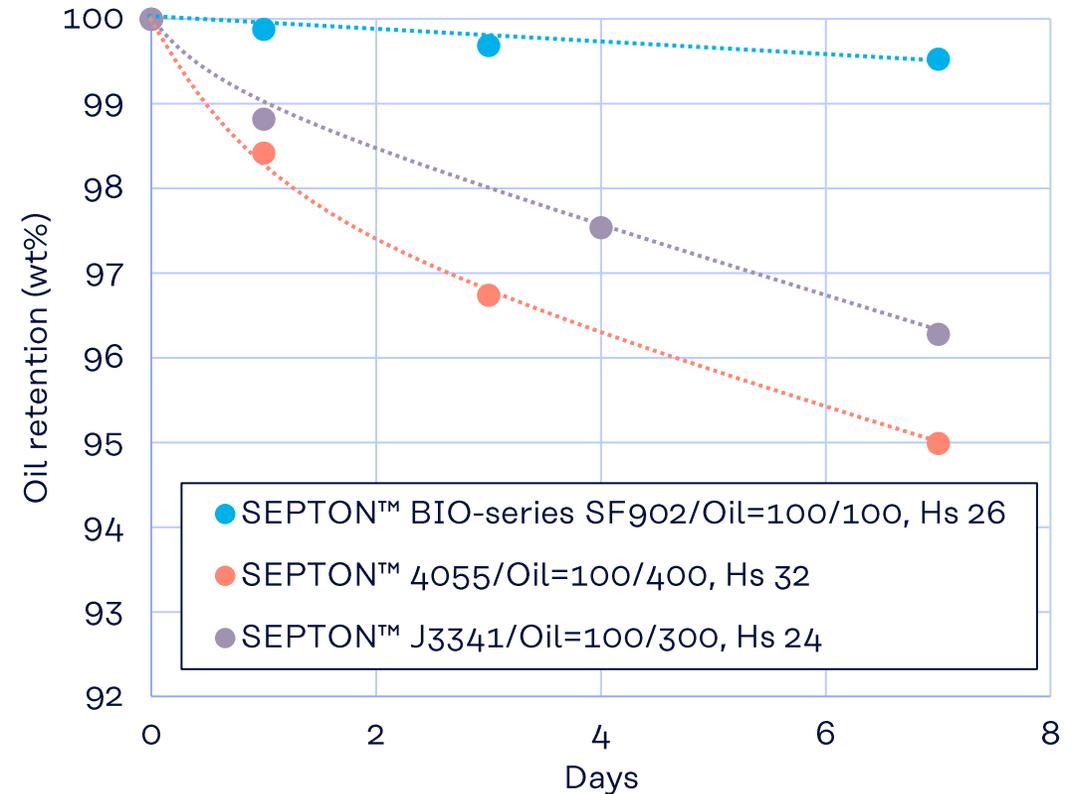
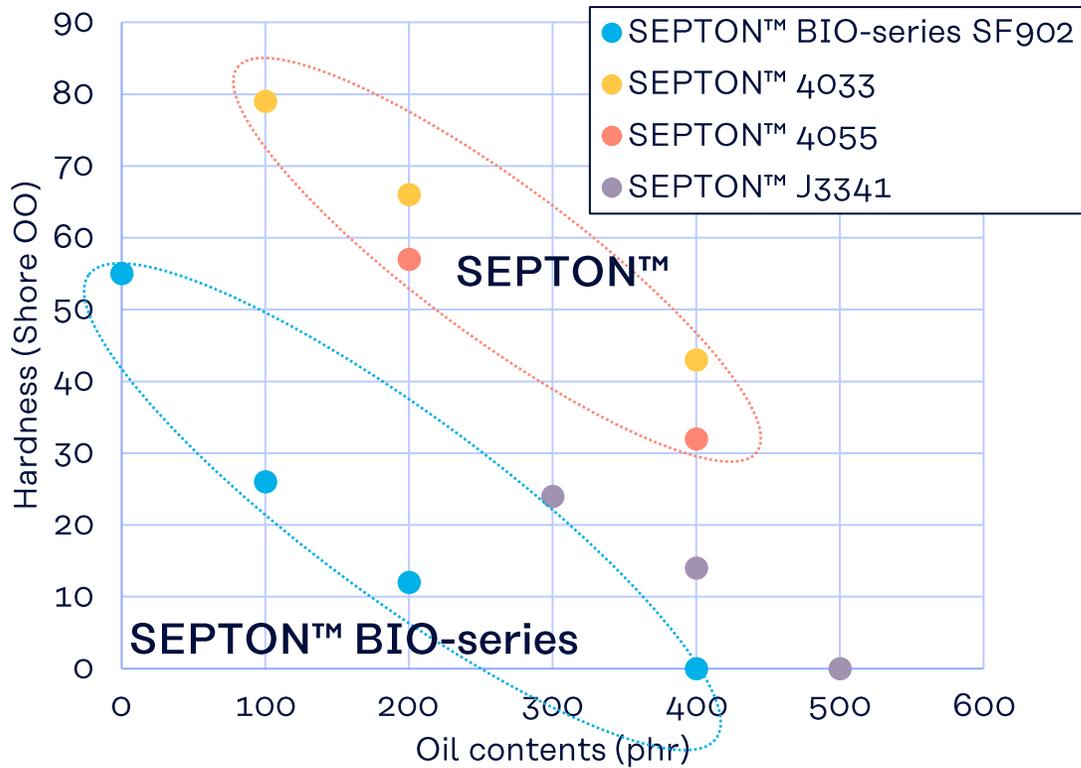
Jelly

Features

- Excellent softness with low amount of oil
- Low bleeding
- Good compression set
- High flow-ability

Jelly

- Jelly using SEPTON™ BIO-series shows excellent softness with lower oil amount.



Jelly

SEPTON™ BIO-series SF902		100	100						
SEPTON™ 4033				100	100	100			
SEPTON™ 4055							100	100	
SEPTON™ J3341									100
Paraffin Oil		100	200	100	200	400	200	400	400
Hardness	(SHORE OO)	26	12	79	66	43	57	32	14
MFR (160 deg. C, 2.16 kg)	g/10 min	68	> 700	8.5	> 700	> 700	No flow	2.7	44
Compression set (40 deg. C, 22 hrs)	%	43	80	74	96	100	15	15	8
Oil Retention (wt%)	1 day	99.9	99.4	99.9	99.9	97.7	99.8	98.4	97.5
	3 days	99.7	98.7	99.9	99.7	95.4	99.4	96.7	94.9
	7 days	99.5	98.1	99.9	99.3	93.1	98.9	95.0	92.6

Nonwoven

Features

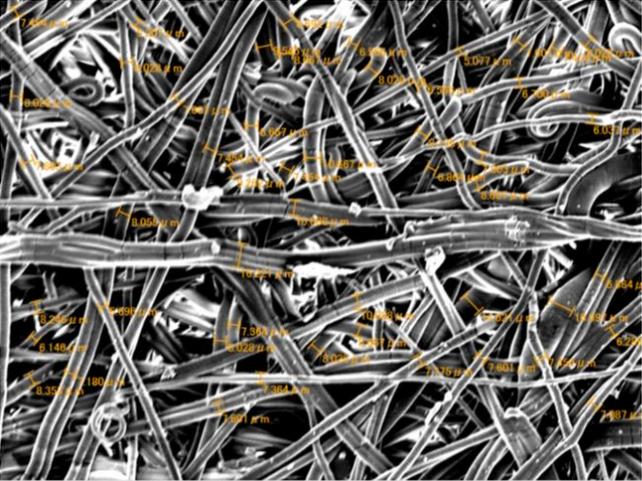
- Good melt blow mold-ability by controlling molecular structure (SEPTON™ BIO-series SF904)
- Excellent elastic recovery compared to conventional HSBC
- Good drape-ability

Nonwoven

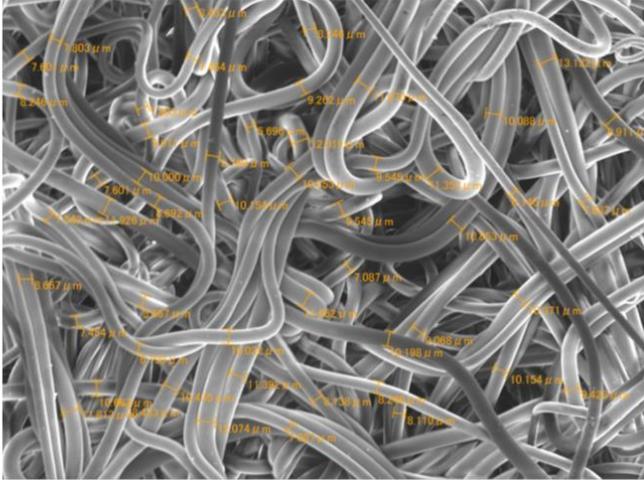
- SEPTON™ BIO-series SF904 shows good melt blow mold-ability.

SEM Image

SEPTON™ BIO-series SF904



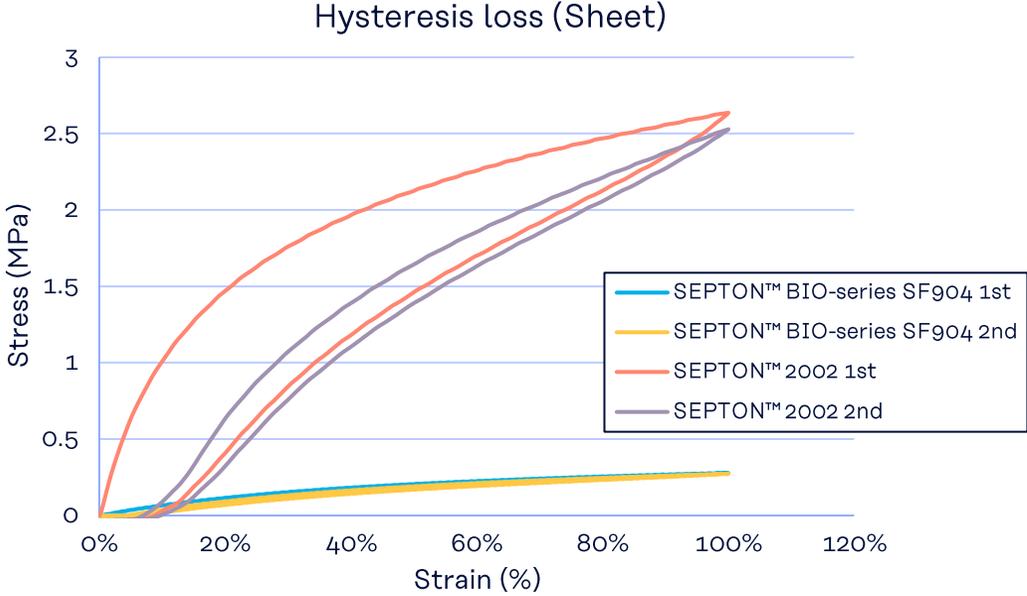
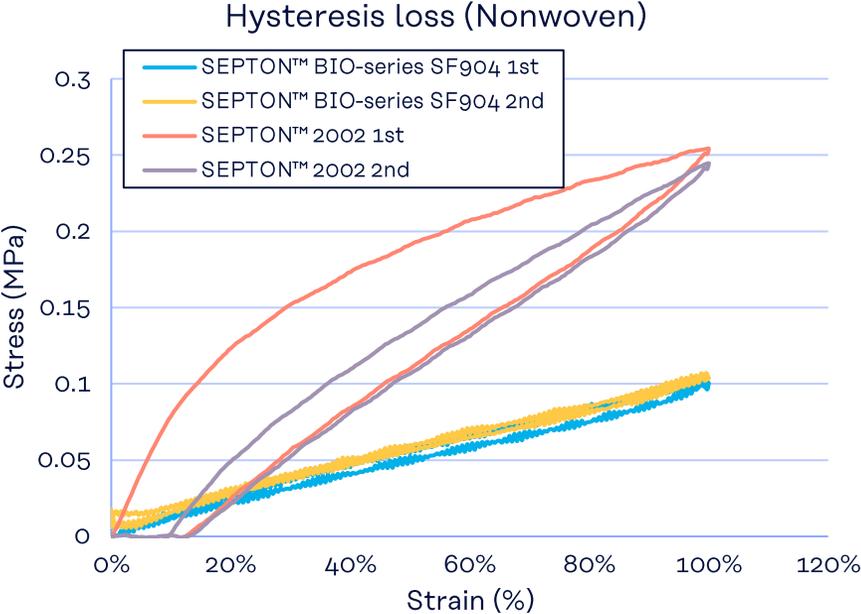
SEPTON™ 2002



	SEPTON™ BIO-series SF904	SEPTON™ 2002
Fiber Diameter [μm] (average of 50 points)	8.2	9.2
Thickness [μm]	260	520

Nonwoven

- SEPTON™ BIO-series SF904 shows excellent elastic recovery.



		Hysteresis loss 1st cycle	Hysteresis loss 2nd cycle
		(%)	(%)
SEPTON™ BIO-series SF904	Nonwoven	11	4
	Sheet	15	10
SEPTON™ 2002	Nonwoven	39	17
	Sheet	33	11

Composite molded article based on SEPTON™ BIO-series SF904

Features

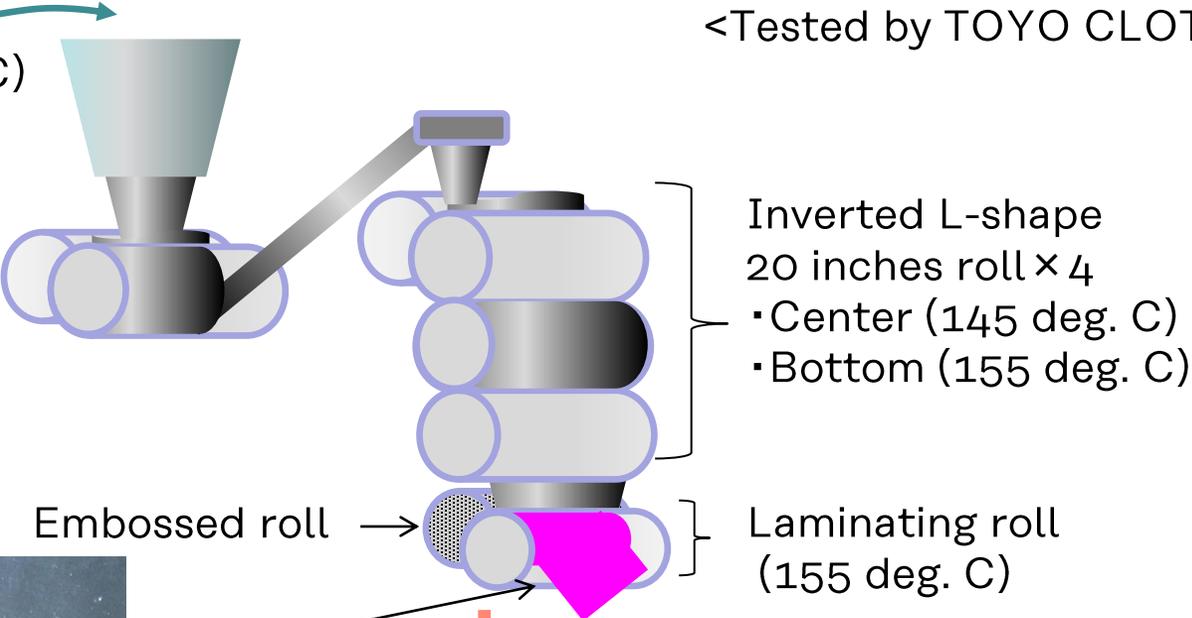
- Good foam-ability and cell uniformity
- High peel strength between fabric and foamed layer without primer

Calendaring process

- 1) 2-layer: Fabric / SEPTON™ BIO-series SF904 (100) + SEPTON™ 2002 (20)* *Reduction of tack
- 2) 3-layer: Fabric / SEPTON™ BIO-series SF904 / Fabric

100L of banbury mixer (140 deg. C)

- SF904 (+2002)
- Foaming agent
- Foaming auxiliary
- Antioxidant
- Carbon M.B.



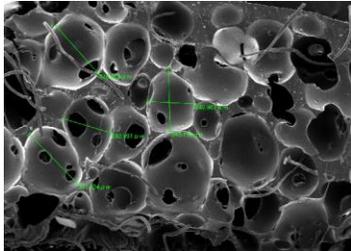
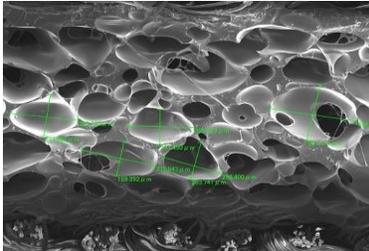
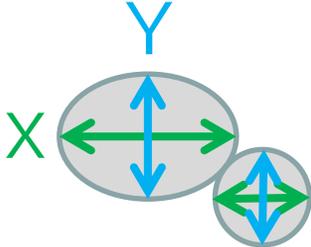
<Tested by TOYO CLOTH CO., LTD.>



Foam oven
210-220 deg. C, 10 m (line speed: 5 m/min.)

Foaming process

- Good foam-ability and cell uniformity
- High peel strength between fabric and foamed layer without primer

Configuration	2-layer			3-layer		
Foam cells						
						
	Foam cells (μm)			Foam cells (μm)		
	X	Y	X/Y	X	Y	X/Y
Average	318	253	1.26	354	224	1.58
Expansion ratio*	2.64			2.39		
Peeling strength (To fabric)	N/3 cm			N/3 cm		
	4.7 Material break			8.8 Material break		

Expansion ratio*: After foaming / Before foaming

Foaming condition: 210-220 deg. C, 10 m (line speed: 5 m/min.)

Which would you like to evaluate, SEPTON™ BIO-series itself or the composite molded articles?

Potential applications

		Strength	Potential applications
Grip compound	Injection molding (Non-vulcanized)	High grip, High bio-cont.	Grip (Golf, Bicycle, Jet ski)
	Compression molding (Vulcanized)	High wet-grip, Lightweight, High tear strength	Shoe sole (Hiking, Bouldering) Fisheries for boots
Adhesive compound	Injection molding	Softness, High adhesive force, Plasticizer less, High flowability	Cross car beam (Automobile)
	Compression molding Extrusion molding	Excellent chipping resistance	Decoration film (Adhesive layer)
Adhesive	Coating	Excellent high adhesion to the substrate, Tackifier less, Excellent moldability	Protective film (Strong adhesive)
	Co-extrusion		
Jelly	Injection molding	Softness, High flowability, Less oil bleeding, High bio-cont.	Cushion gel (Shoes)
Composite molding	Calendering	Softness, Good foamability, Excellent adhesion to the substrate	Wet suit, Sports supporter
Emulsion	Coating	Softness, Plasticizer less, High friction resistance, Low hysteresis loss	Protective film (Weak adhesive), Coating of gloves (ex) Golf gloves
	Dipping	Softness	Disposable gloves
TPV modifier	Injection molding	Softness, High flowability	Window seal (Automobile)
Nonwoven	Melt blow	Softness, High flowability, Low hysteresis loss	Diaper, Mask
Plastics modifier	Injection molding 3D printing	High impact strength, High flowability, Good low-temperature characteristics, High bio-cont.	3D printing filament, Trays, Housings of home electric appliances, Automotive parts

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kuraray **Septon™** **BIO-series**