JSR RB®

Syndiotactic 1,2-Polybutadiene

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Attention for processing JSR RB

1. Process and mold JSR RB below 150°C (resin temperature).
   When it is processed between 150~180°C, do not keep it in the extruder for more than 10 minutes.
   There is a possibility of gelation or fire when resin temperature is above 150°C.
2. Do not keep JSR RB in the extruder for more than two hours, even if resin temperature is below 150°C.
   In case of discontinuation of manufacturing, purge the extruder with polyethylene, and stop heating.
3. After processing, purge the extruder with polyethylene.

1-1 What is JSR RB?

JSR RB is the world's first low molecular weight, low crystallinity syndiotactic 1,2-polybutadiene which was developed by the proprietary technology of JSR Corporation.

It possesses more than 90% of 1,2-bonds and it is a unique thermoplastic elastomer which has an average molecular weight of around 120,000, and a crystallinity of 15 ~ 30%.

High molecular weight 1,2 polybutadienes that had appeared in patents up to then, were either amorphous polymers or high crystallinity polymers having a crystallinity of 50% or above.

The high crystallinity polymers have a high melting point, and at such a high melting point, it already exceeds the limit of thermal stability.

Thus, it has the disadvantage that it cannot be processed by general processing machines for plastics.

Contrary to this, JSR RB is a 1,2 polybutadiene which has its crystallinity adjusted to 15 ~ 30%, and the melting point is suitable.

Thus, it can be processed easily by polymer processing machines used in general.

※ JSR RB has not been approved for any medical or food contact applications by the Food and Drug Administration (FDA) of the United States, Bundesgesundheitsmat (BGA) of Germany or any other similar authorities in any other countries except Japan.

1-2 Outstanding Features and Typical Applications of JSR RB

JSR RB is a thermoplastic elastomer which possesses the properties of both plastics and rubber.

«Outstanding Features as a Thermoplastic Elastomer»

(1) It is light, rubber-like, and slip resistant, so it is suitable for fields such as footwear and industrial goods.

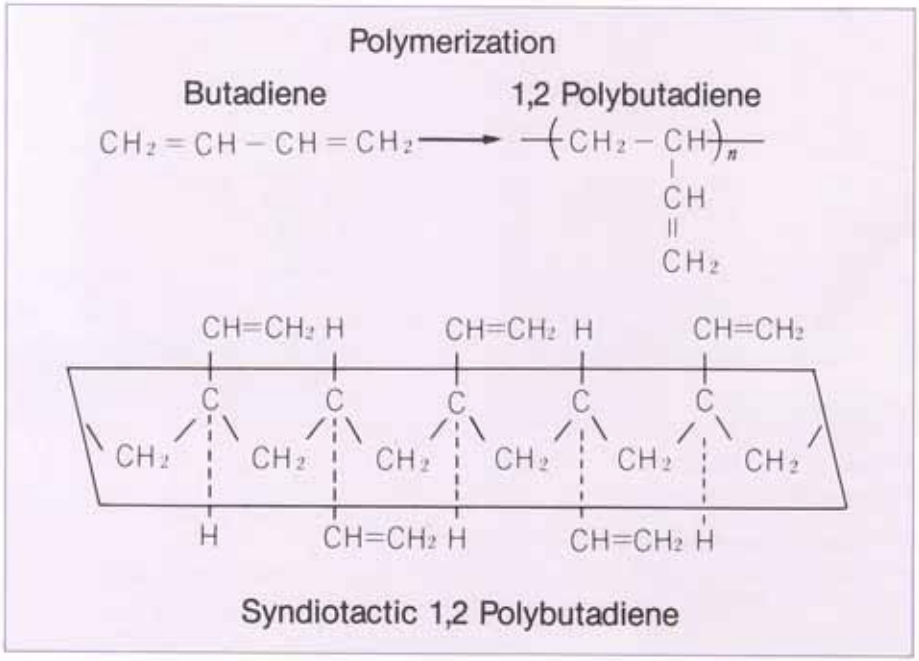
(2) It has a low melting point and can be cured by sulfur, so it is suitable for melting bags.

(3) Gas permeability and transparency are good, and it can be molded or formed without any plasticizers.
In addition, it is flexible and possesses adequate self-adhesion, so it is suitable for films and sheets.

«Outstanding Features as a Rubber for Curing»

(1) The melt viscosity is lower than those of other rubbers for curing, so it is suitable for making sponges.

(2) The green strength is high in comparison with other rubbers for curing, and it possesses high hardness and high flow.
Thus, it is suitable as a rubber modifier.
Besides the above, since it is susceptible to peroxide crosslinking reaction, it is suitable as auxiliary reaction agent for EVA and other curable rubbers.



Syndiotactic 1,2 Polybutadiene

2 Basic Properties of JSR RB

2-1 Dynamic Properties of JSR RB

2-1-1 Tensile Properties

Similar to polyethylene, the Stress-Strain Curve of JSR RB has a yield point.
However, even above the yield point, the stress keeps on increasing with elongation, then it breaks. This kind of Stress-Strain Curve is very similar to that of EVA, and it indicates a characteristic property lying somewhere between crystalline polymer and amorphous polymers.
Among the 3 grades of JSR RB, RB810 which has lower crystallinity strongly shows the properties of amorphous polymers.
Consequently, the yield point becomes vague, and the break point becomes low.

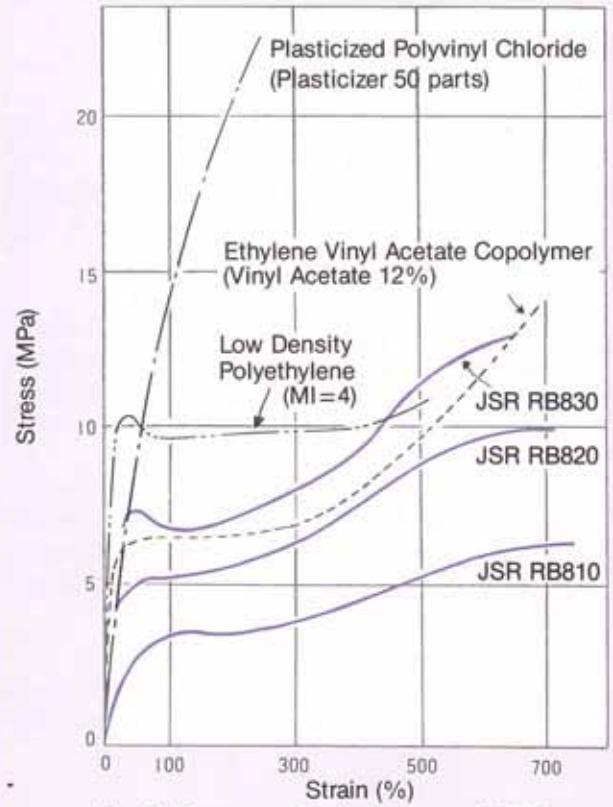


Fig. 1. Stress — Strain Curves of JSR

(Press Sheet Thickness 21mm)

2-1-2 Changes in Tensile Properties

Similar to polyethylene and polypropylene, the dynamic properties of JSR RB can be improved by stretching it.
As an example, Stress-Strain Curves of biaxial expansion films, which were stretched in the longitudinal direction and the transverse direction 2.5 times each with different stretching temperatures, is shown in Fig. 2.
The dynamic properties of the stretched film receive the influence of the setting temperature at the time of maximum expansion, and if it is stretched at a temperature 10~20°C below the melting point, a film with high strength can be formed.

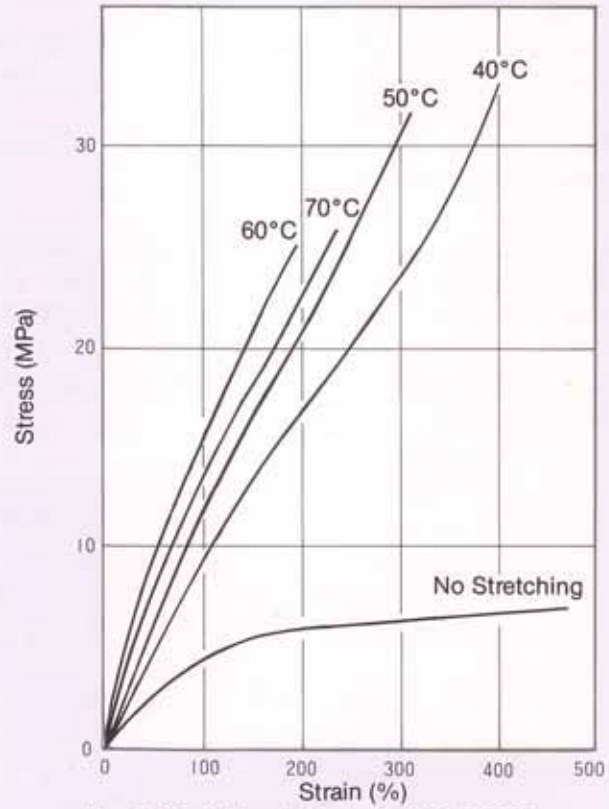


Fig. 2 Stretching Effect of JSR RB820

Stretching of 2.5 times in Longitudinal Direction
Transverse Direction at each Temperature

2-1-3 Modulus

In Fig 3, the modulus of JSR RB, plasticized PVC, LDPE and EVA, are shown.
As it is evident from this figure, the modulus of JSR RB is almost the same as that of EVA within the range of measuring temperatures, and it shows lower modulus than LDPE.
However, JSR RB has a higher brittle point than LDPE or EVA, and the modulus will become higher than those of these polymers at low temperatures.

2-2 Thermal Properties of JSR RB

In Fig. 4, the Differential Scanning Calorimetry Curves (DSC Curve) are shown.
The Vicat softening point which is a typical value to indicate the heat resistance of JSR RB820, is 50°C and approximately same as that of EVA.
It is 10°C to 40°C lower than plasticized PVC (50 parts of plasticizer) which is 60°C, and that of LDPE which is 90°C.
Thus, it is necessary to pay sufficient attention when using RB820 at high temperatures.
The brittle point of JSR RB820 is −37°C, and it is slightly higher than plasticized PVC or LDPE. Thus, attention must be paid when using it under low temperatures.

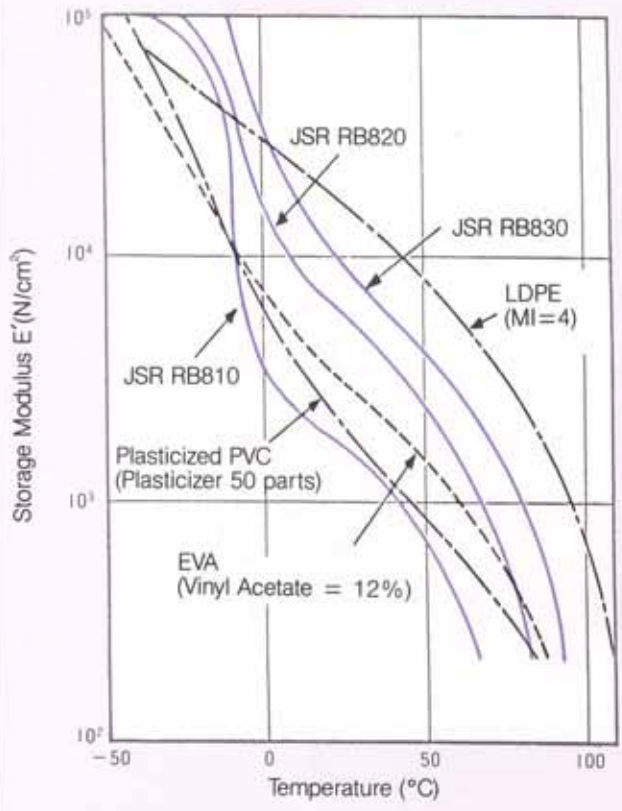


Fig. 3 Temperature-Modulus Curves of JSR RB

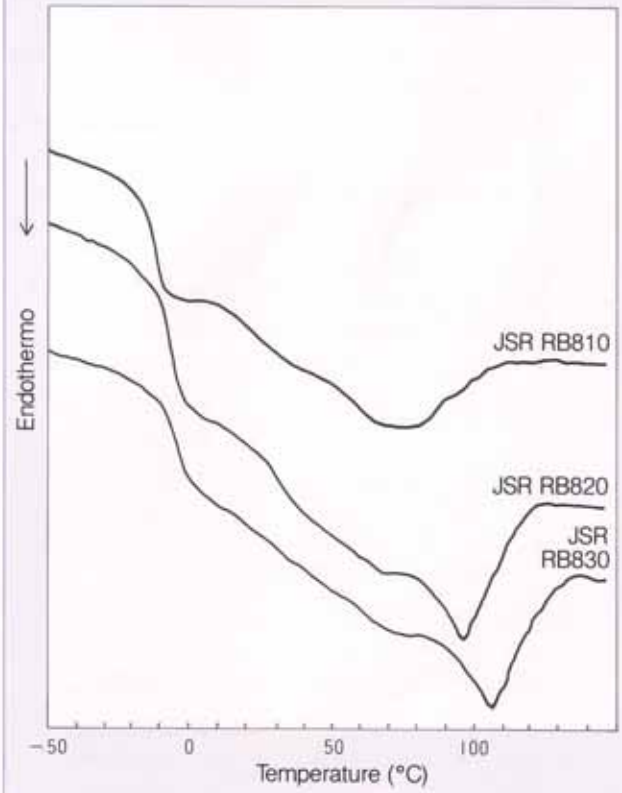


Fig. 4 DSC Curves of JSR RB

2-3 Molten Properties of JSR RB

2-3-1 Flow Curve · Viscosity Curve

The Flow Curves and Viscosity Curves of JSR RB820 and LDPE at 150°C are shown in Fig. 5 and Fig. 6. From Fig. 5, it is evident that the pressure dependency of JSR RB820 flow is much less than that of LDPE.

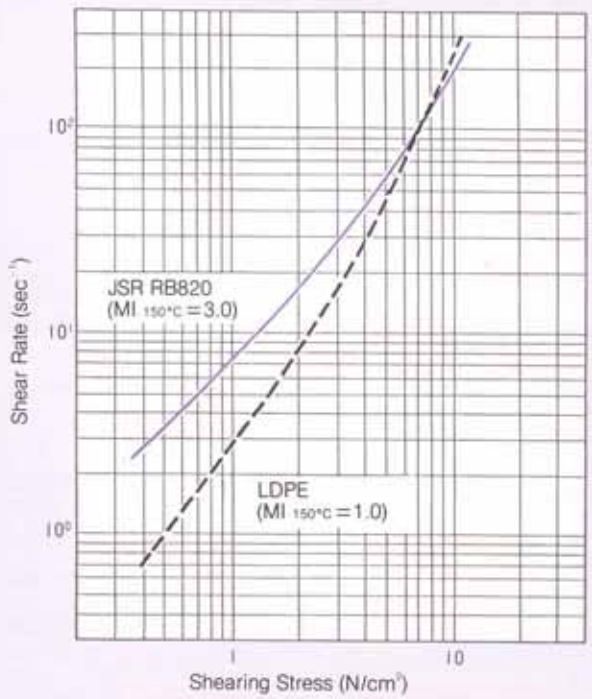


Fig. 5 Flow Curve of JSR RB

Temperature: 150°C

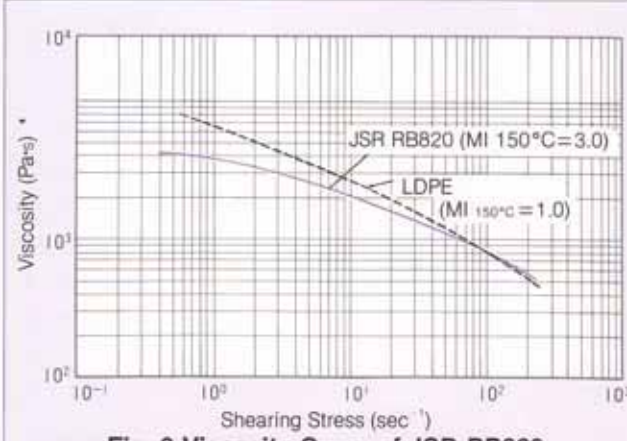


Fig. 6 Viscosity Curve of JSR RB820

Temperature: 150°C

2-3-2 Temperature Dependency of Flow

Fig. 7, the temperature dependency of the JSR RB820 flow is shown.

This drawing shows a typical example of the case of flow at a creeping stress of 10 N/cm², and comparison with that of LDPE.

The change of flow in JSR RB820 based on temperature is smaller than that of LDPE.

At temperatures of 130°C or below, it is almost the same, but as the temperature rises, polyethylene flows more easily.

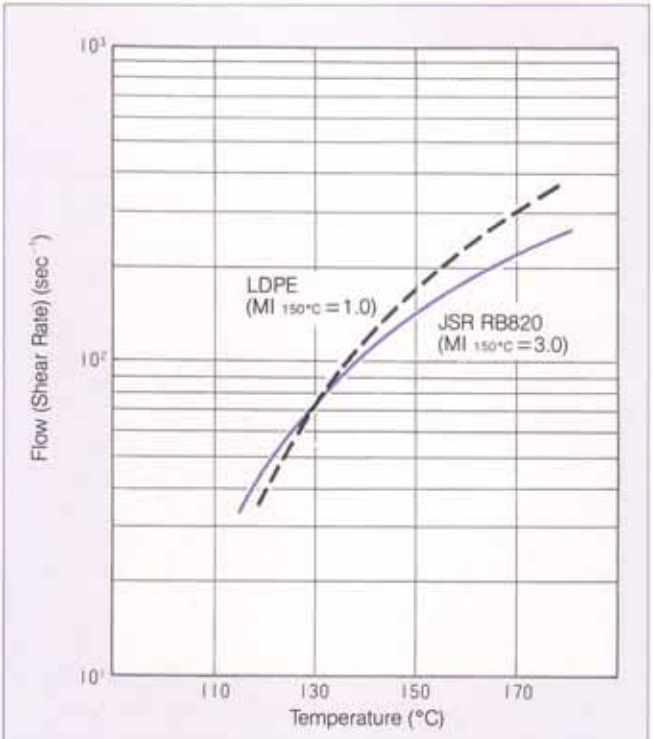


Fig. 7 Temperature Dependency of JSR RB820 Flow

2-3-3 Barus Effect

When molten polymers are extruded through a slit of a die, if they expand larger than the slit when they are extruded, such a phenomenon is called the Barus Effect.

This is a phenomenon which cannot be neglected when polymers are actually processed in various forming machines.

In Fig. 8, the results of the measurements made on this expansion by the use of melt indexer is shown. From this drawing, it is clear that the expansion ratio of JSR RB820 will be about 10% less than LDPE.

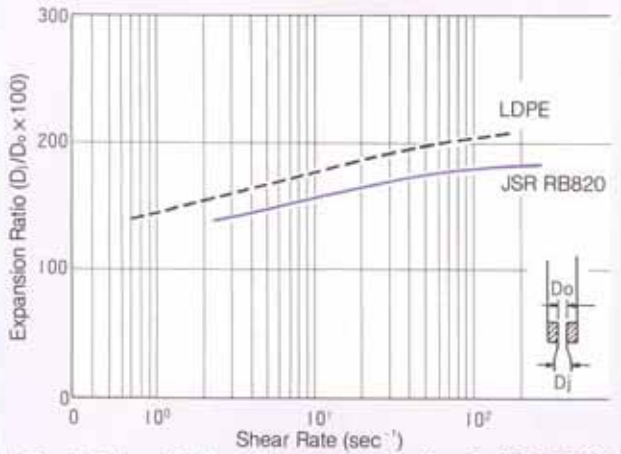


Fig. 8 Shear Rate • Expansion Ratio of JSR RB820

Temperature: 150°C

2-4 Optical Properties of JSR RB

It is possible to obtain molded products with good transparency by JSR RB.

However, similar to other crystalline polymers, it will be influenced by cooling speed. Molded products which are cooled slowly will have low transparency in comparison with the ones which are cooled rapidly. Thus, in order to obtain molded products with good transparency, it is necessary to cool the molten polymer rapidly.

As an example, Table 1 shows the relation between the cooling speed of JSR RB820 and its transparency.

Table 1 shows the Haze values of JSR RB, molten at 140°C and cooled into sheets having a thickness of 1mm, using different cooling speeds.

The cooling speed of slow cooling (2) is lower than that of slow cooling (1).

In the case of slow cooling, both have low transparency in comparison with that of rapid cooling. (i.e. The haze value is high.), and it is evident that transparency and cooling speed are related.

Table 1 Influence of Cooling Speed on the Transparency of JSR RB820

Cooling Method	Transmission Rate of Parallel Light (%)	Haze Value (%)
Quenching	91	1
Slow Cooling (1)	73	9
Slow Cooling (2)	62	20

The results of the above Table were obtained by melting JSR RB820 at 140°C, and molding press sheets having a thickness of 1 mm.

Cooling Method	Cooling Condition
Quenching	10°C×5 min.
Slow Cooling (1)	25°C×8 min.
Slow Cooling (2)	50°C×10 min.

2-5 Electrical Properties of JSR RB

The electrical properties of JSR RB820 are shown in Table 2. JSR RB820 has the same electrical properties as polyethylene with the exception of dielectric loss tangent, and it can be used in those fields where high breakdown voltage is not necessary. In addition, since it is a hydrocarbon polymer, it possesses a better insulating property than plasticized PVC.

Table 2. Electrical Properties of JSR RB820

Properties	Test Method	Unit	JSR RB820	Plasticized PVC	Polyethylene
Volume Resistivity (60%R.H., 20°C)	ASTM D 257	Ω·cm	2×10^{17}	$10^{11}\sim10^{14}$	$>10^{16}$
Dielectric Strength (40%R.H., 25°C)	ASTM D 149	kV/mm	46	10 ~ 30	18 ~ 28
Dielectric Constant (60%R.H., 20°C)	ASTM D 150				
60Hz			2.6	5.0 ~ 9.0	2.2 ~ 2.4
10^6Hz			2.6	3.3 ~ 4.5	2.2 ~ 2.4
Dielectric Loss Tangent (60% R.H., 20°C)	ASTM D 150				
60Hz ($\times10^{-3}$)			2.5	80 ~ 150	< 0.5
10^6Hz ($\times10^{-3}$)			4.5	40 ~ 140	< 0.5

The values in the above figure were measured by using press sheets (For Dielectric Strength, Thickness: 1 mm, for all other tests, Thickness 2 mm) for JSR RB820, and "Plastics Processing Technology Handbook" (IV §4) was referred to for polyethylene)

2-6 Chemical Resistance of JSR RB

The chemical resistance of JSR RB820 is shown in Table 3.

Table 3. Chemical Resistance of JSR RB820

Solvent \ Temperature	25°C	35°C	60°C
Carbon Tetrachloride	VS	VS	VS
Chloroform	VS	VS	—
Carbon Disulfide	VS	VS	—
Benzene	VS	VS	VS
Toluene	VS	VS	VS
Cyclohexane	S	VS	VS
Chlorobenzene	S	VS	VS
Ether	▲S	—	—
Petroleum Ether	▲SS	—	—
Isopropyl Ether	▲SS	▲SS	—
n-Heptane	▲SS	▲SS	—
Methyl Ethyl Ketone	▲IS	▲IS	▲SS
Acetone	IS	IS	—
n-Butanol	IS	IS	IS
Methanol	IS	IS	IS

The chemical resistance of JSR RB820 will vary with the degree of crystallinity.
In general, it is stable against diluted solutions of hydrochloric acid, sulfuric acid, and caustic soda. However, under high concentration, for instance, in case of concentrated sulfuric acid, the hardening will be promoted, and it is necessary to pay attention to it.
As for the dissolution in various solvents, it will dissolve in aromatic hydrocarbon, halogenated hydrocarbon, and hydrogen disulfide, but it will not dissolve easily in aliphatic hydrocarbons. It will not dissolve in ketones and alcohols regardless of the temperature.

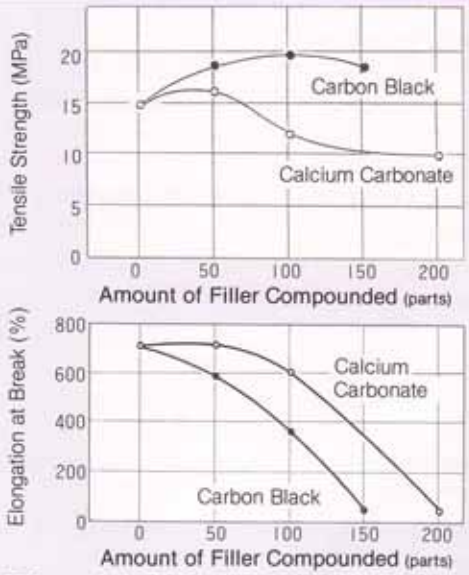
Test Method
After immersing in the chemicals at 25°C for 24 hours, the specimens were left at the temperatures for 30 minutes each, then after vibrating for 30 minutes at 25°C, the specimens were filtered with 200 mesh screens and the undissolved portions were measured.
Explanation of the Symbols:
VS: Easily soluble (Insoluble portion 1 wt% or less)
S: Soluble (Insoluble portion 10 ~ 60 wt%)
SS: Not easily soluble (Insoluble portion 90 ~ 95 wt%)
IS: Insoluble (Insoluble portion 99 wt% or above)

2-7 Chemical Properties of JSR RB

Since JSR RB820 possesses hydrogen repeatedly bonded to the tertiary carbon in the allyl position, it will be easily activated by high energy sources such as heat and/or light.
In addition, JSR RB will easily cause chemical reaction with various chemically reactive reagents. The chemical reaction of 1,2-polybutadiene has been reported in large number of literatures related to liquid 1,2-polybutadienes, and similar reactions are also possible with JSR RB.
As for chemical reactions of JSR RB which are useful industrially, there are crosslinking, "ene" addition reaction, graft polymerization, etc.

2-8 Ease of Combustion of JSR RB

JSR RB which is degraded by light will have cross-links among the molecules. Thus, when it is burned, unlike normal polyolefins, it will not melt.
In Table 4, a comparison of combustion test results between JSR RB and polyethylene blends is shown. In addition, as shown in Fig. 9, by adding fillers, it is possible to control the amount of heat generation.



9 Effect of Filler Compounding in JSR RB820 Film

Table 4. Combustion Test of JSR RB*

1. Self-Sustained Combustion Test

	Specimen LDPE / JSR RB	Self-sustained Combustion Amount (%)	Residual Amount (%)	Amount of Molten Specimen Falling (%)
Stored in dark place for 4 months	0/100	92.4	0	7.6
	25/75	82.6	0	17.4
	50/50	68.3	18.4	13.3
	75/25	61.7	25.0	13.3
	100/0	35.4**	51.6	13.0
Exposed outdoors for 4 months	0/100	99.4	0.6	0
	25/75	98.5	1.5	0
	50/50	99.1	0.9	0
	75/25	98.1	1.9	0
	100/0	25.4**	63.4	11.2

*In accordance with "Testing Methods of Plastics" by Terada. (Page 98, 1969)

**Self-sustaining combustion did not take place, and the combustion stopped.

Specimen: JSR RB820

Test Specimen: 145 mm × 10 mm × 2 mm

2. Combustion Test

	Specimen LDPE / JSR RB	Combustion Amount (%)	Falling Amount of Molten Specimen (%)
Stored in dark place for 4 months	0/100	100	0
	25/75	100	0
	50/50	93.8	6.2
	75/25	91.9	8.1
	100/0	61.1	38.9
Exposed outdoors for 4 months	0/100	100	0
	25/75	100	0
	50/50	100	0
	75/25	100	0
	100/0	66.7	33.3

Test Method:

A method in which the specimen placed on 200 mesh screen tilted at an angle of 45 is burned continuously with a Bunsen burner from below the mesh.

3 Typical Physical Properties of JSR RB (Non Crosslinked)

Properties	Test Method	Unit	Measured Value		
			JSR RB810	JSR RB820	JSR RB830
Density	ASTM D 1505 modify (at 20°C)	10^3kg/m^3	0.901	0.906	0.909
Microstructure Percentage of 1, 2 Bonds	Infrared Spectrum (Morero Method)	%	90	92	93
Refractivity	ASTM D 542		1.510	1.512	1.517
MFI (Melt Flow Index) 150°C, 21.2N	ASTM D 1238	g/10min	3	3	3
Thermal Properties					
Vicat Softening Point	ASTM D 1525	°C	39	52	68
Melting Point	ASTM D 3418	°C	71	95	105
Brittle Point	ASTM D 746	°C	−40	−37	−35
Tensile Properties	ASTM D 412				
300% Modulus		MPa (kgf/cm^2)	3.9 (40)	5.9 (60)	7.8 (80)
Strength at break		MPa (kgf/cm^2)	6.4 (65)	10.3 (105)	12.7 (130)
Elongation at Break		%	750	700	670
Hardness	ASTM D 2240				
Shore D		Points	32	40	47
Shore A		Points	82	95	99
Izod Impact Strength (With notch, at room temperature)	ASTM D 256	N-cm/cm (kgf-cm/cm)	Doesn't Break	Doesn't Break	Doesn't Break
Transmittance of Parallel Light*	ASTM D 1003	%	91	89	82
Haze Value*	ASTM D 1003	%	2.6	3.4	8.0
Mold Shrinkage**	JSR method	%	0.7 ~ 0.9	0.3 ~ 0.5	0.3 ~ 0.6

*Values measured with 2 mm thickness sheet molded by injection molding machine set at cylinder temperature 150°C, mold temperature 20°C.

**130°C Medium Speed Injection Molding. Mold Temperature 20°C. ASTM No. 1 Dumb-bells were used.

Application of JSR RB 4

JSR RB is a thermoplastic elastomer which has outstanding physical properties lying between plastics and rubber, and it also has characteristics such as possessing high reactivity which cannot be observed with other thermoplastic polymers. The applications are broadly diversified.

The typical applications of JSR RB are summarized in Table 5. However, these applications are only a part of its broad field of applications.
For more intormation on tne applications shown in Table 5, please contact your JSR representative or one of the offices of JSR Corporation. Iisted on the back cover of this brochure.

Table 5. Applications and Outstanding Features of JSR RB

Applications			Outstanding Features
Applications as Thermoplastic Elastomers	Film	Film for indurstrial use. Melt Bags	Transparency, self sticking property, flexibility, piercing strength, gas permeation, low temperature heat sealing properties.
	Various footwear soles.	Unit soles, inner soles, outer soles based on injection molding	Lightweight, hard, rubber-like feeling, no flatting, snappiness, fine reproduction of mold design, paintability, adhesion, crack resistant.
	Others	Blow Molding Injection Molding Plastics Modifier	Flexibility, rubber-like feeling
Applications as Rubber	Variety of Sponge Products	Microcellular sponge, Hard sponge, semihard sponge, soft sponge, crepe-like sponge.	One-step cure, broad curing condition range, enables high filling, elasticity, snappines, no flatting, weather-ability, ozone resistance, heat resistance, tear resistance, paintability, adhesion, slip resistance, abrasion resistance.
	Various High Hardness Products	Footwear Industrial Goods Sports Goods Miscellaneous Goods	Elongation, tensile strength, high hardness, snappiness, flowability, cross-linking properties, weatherability, ozone resistance, heat resistance, slip resistance, abrasion resistance.
	Injection Cured Product	Industrial Goods	Flowability, crosslinking property, weatherability, ozone resistance, heat resistance, slip resistance, abrasion resistance, snappiness, injection moldability.
	Various Rubber Modifiers	Various Rubber Products	High green strength, flowability, extrudability, weatherability, ozone resistance, heat resistance, snappiness.
	Others	Transparent Cured Rubber Products	Transparency, weatherability, heat resistance.
Other Applications	Modifiers	Blends with SBS	Improvement in appearance of molded goods. (Elimination of flow marks and scratch marks) Improvement of flowability.
	Crosslinking Co-agent	Crosslinking Co-agent for polyolefins	Reduction amount of crosslinking agent, good mechanical properties
	Photosensitive Materials	Printing Materials	Photosensitivity (Photocrosslinking), flowability, low solution viscosity
	Thermosetting Resin Product	Resin Vibration Insulator	High hardness

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