MX Polyamide MXD6 Nylon

$$\text{-}\{\text{NHCH}_2\text{-}C_6H_4\text{-}\text{CH}_2\text{-NHCO-(CH}_2)_4\text{-CO}\}\text{-}_n$$

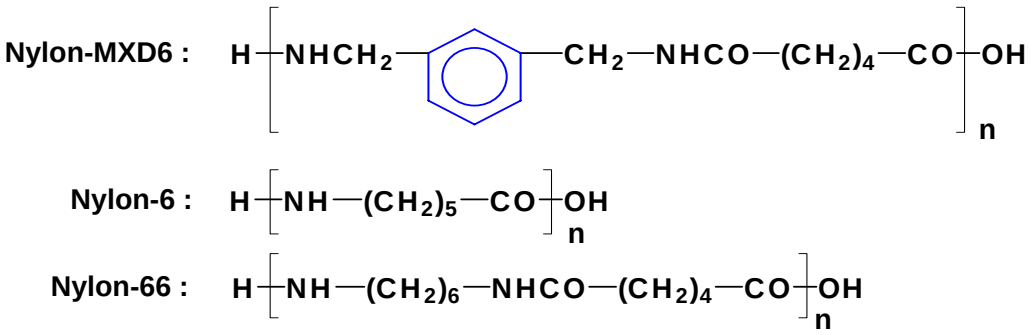
MITSUBISHI GAS CHEMICAL COMPANY, INC.

CONTENTS

1. NYLON-MXD6

NYLON－MXD6 is one of the crystalline polyamide resins，Which is produced through polycondensation of meta-xylylene diamine (MXDA) with adipic acid under MGC's own technology.

NYLON－MXD6 is a unique aliphatic polyamide resin which contains meta-xylylene groups in the molecule as shown below.



NYLON－MXD6 has following distinguished properties compared with other conventional polyamide resins such as nylon-6 and/or nylon-66.

-Higher tensile and flexural strength and modulus.
-Higher glass transition temperature.
-Lower water absorption.
-Wider processing window.
-Excellent gas barrier properties.

Based on these properties, NYLON-MXD6 has widely applied for packaging materials, molding compounds and monofilaments.

One of the most remarkable properties of NYLON-MXD6 is superior gas barrier properties against oxygen and carbon dioxide which are the best in commercial nylon plastics and better than those of ethylene-vinylalcohol copolymers (EVOH), acrylonitrile copolymers (PAN) and vinylidenchloride copolymers（PVDC） under a practical condition.

Additionally, because of the excellent heat stability and the wide processing window, NYLON-MXD6 can be easily applied for co-extrusion or co-injection in combination with other resins such as polyethylene terephthalate (PET)，polypropylene (PP) or polyethylene(PE) to produce multilayer containers，muitilayer sheets or films for packaging industry.

2. PROPERTIES

2-1. Physical properties

One of the distinctive physical properties of NYLON-MXD6 is high strength and modulus.
The physical properties of injection molded specimen and biaxially oriented film of NYLON－MXD6 are shown in Table-1 and Table-2.

Table 1　Physical properties of NYLON-MXD6 (injection molded specimen)

Items	Methods ASTM	Units	Nylon MXD6	Nylon 66	Nylon-6	PET
Specific gravity	D792		1.22	1.14	1.14	1.38
Water absorption (Equil. in water/20℃)	D570	%	5.8	9.9	11.5	
Moisture regain (Equil. 65%RH/20℃)	D570	%	3.1	5.7	6.5	
Heat distortion Temp.	D648	℃	96	75	65	85
Glass transition Temp.	DSC	℃	85	50	48	77
Melting point	DSC	℃	237	260	220	255
Thermal expansion	D696	cm/cm℃	5×10^{-5}	10×10^{-5}	8×10^{-5}	7×10^{-5}
Tensile strength	D638	MPa	99	77	62	79
		kgf/cm^2	1010	780	630	800
Tensile elongation	D638	%	2.3	60	200	5.8
Tensile modulus	D638	GPa	4.7	3.1	2.6	3.0
		kgf/cm^2	48×10^3	32×10^3	26×10^3	31×10^3
Flexural strength	D790	MPa	160	130	120	120
		kgf/cm^2	1600	1300	1250	1250
Flexural modulus	D790	GPa	4.4	2.9	2.4	3.4
		kgf/cm^2	45×10^3	30×10^3	24×10^3	35×10^3
Izod Impact (notched)	D256	J/m	20	39	59	39
		kg･cm/cm	2	4	6	4
Rockwell Hardness	D785	M Scale	108	89	85	106

Table 2　Physical properties of biaxially oriented NYLON-MXD6 films.

Items	Methods ASTM	Units	Biaxially oriented Films		
			Nylon-MXD6	Nylon-6	PET
Thickness		μ	15	15	15
Specific gravity			1.22	1.14	1.38
Haze		%	3.1	2.0	2.5
Tensile MD	D882	MPa(kgf/mm^2)	220 (22)	200 (20)	160 (16)
Strength TD			220 (22)	220 (22)	190 (19)
Tensile MD	D882	%	75	90	140
Elongation TD			76	90	60
Tensile MD	D882	GPa(kgf/mm^2)	3.8 (385)	1.7 (170)	3.4 (350)
Modulus TD			3.8 (390)	1.5 (150)	3.9 (400)
Impact strength		J (kgf･cm)	0.5 (5)	1 (10)	0.4 (4)
Water vapor Transmission	JIS-Z 0208(B)	g/㎡･24h	41	260	40

Note : stretch ratio of NYLOM-MXD6 : 4×4

2-2. Crystallization speed

The crystallization behavior of NYLON-MXD6 is similar to PET. It can stay in amorphous state easily if it is cooled immediately after the extrusion or the injection. The temperature range for the fastest crystallization of NYLON-MXD6 is around 150 to 170^{o}C

Because of the moderate crystallization speed of NYLON-MXD6, it has wider operation window than other polyamides in the thermoforming or the orientation process in order to manufacture containers or films.

Fig. 1 shows the relationship between the temperature and semi-crystallization time of NYLON-MXD6 in comparison with other polymers.

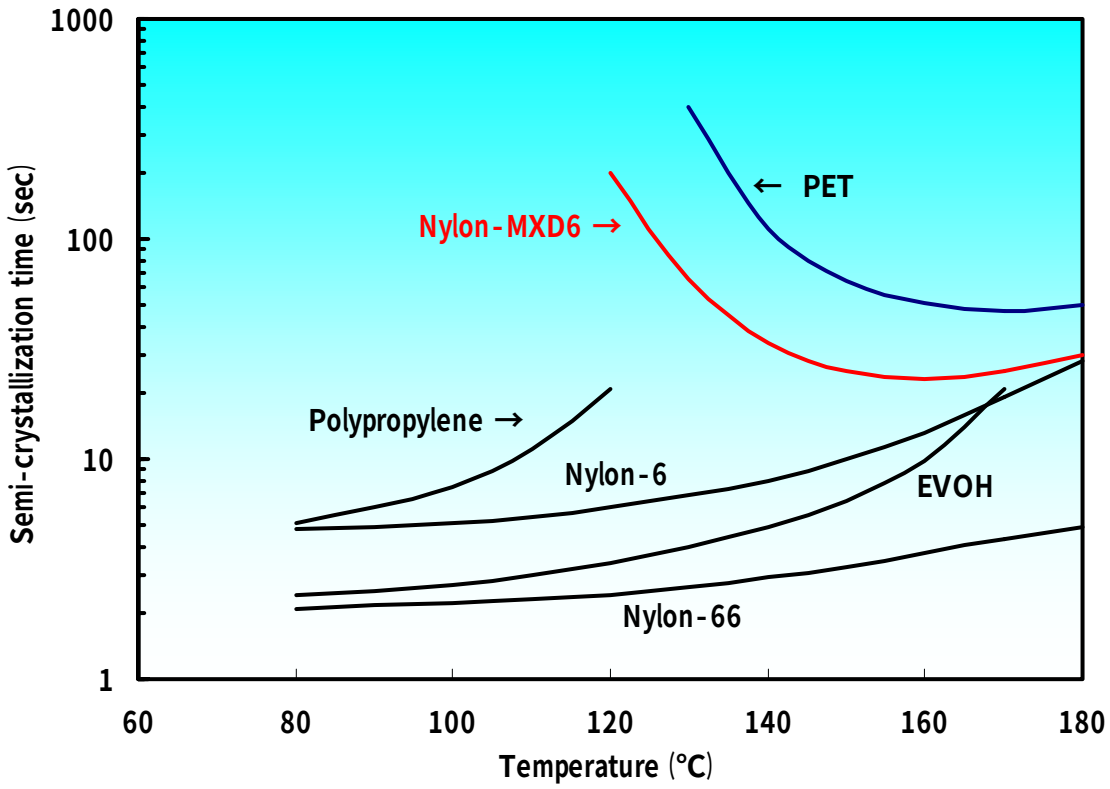


Fig. 1 Temperature dependence of semi-crystallization time for various polymers

2-3. Gas barrier properties

NYLON-MXD6 has excellent gas barrier properties compared with nylon-6 or PET.

The oxygen permeation rate of NYLON-MXD6 and other polymers are shown in Table 3.

The oxygen barrier property of NYLON-MXD6 is much less moisture sensitive than that of EVOH as shown in Fig. 2.

Table 3　Oxygen permeation rate of films

Films	Oxygen perameation rate (cc/m²·day·atm) 20μ, 23℃		
	60%RH	80%RH	90%RH
Nylon-MXD6 film (oriented)	2.8	3.5	5.5
Nylon-MXD6 film (non-oriented)	4.3	7.5	20
Ethylene vinylalcohol copolymer (Ethylen cont. 32mol%)	0.5	4.5	50
Ethylene vinylalcohol copolymer (Ethylen cont. 44mol%)	2.0	8.5	43
Acrylonitrile copolymer	17	19	22
Nylon-6 (oriented)	40	52	90
Nylon-6 (PVDC coated)	10	10	10
Polyethylene terephthalate (oriented)	80	80	80
Polypropylene (oriented)	2,500	2,500	2,500
Polypropylene (PVDC coated)	14	14	14

Nylon-MXD6 films : stretch ratio 4×4

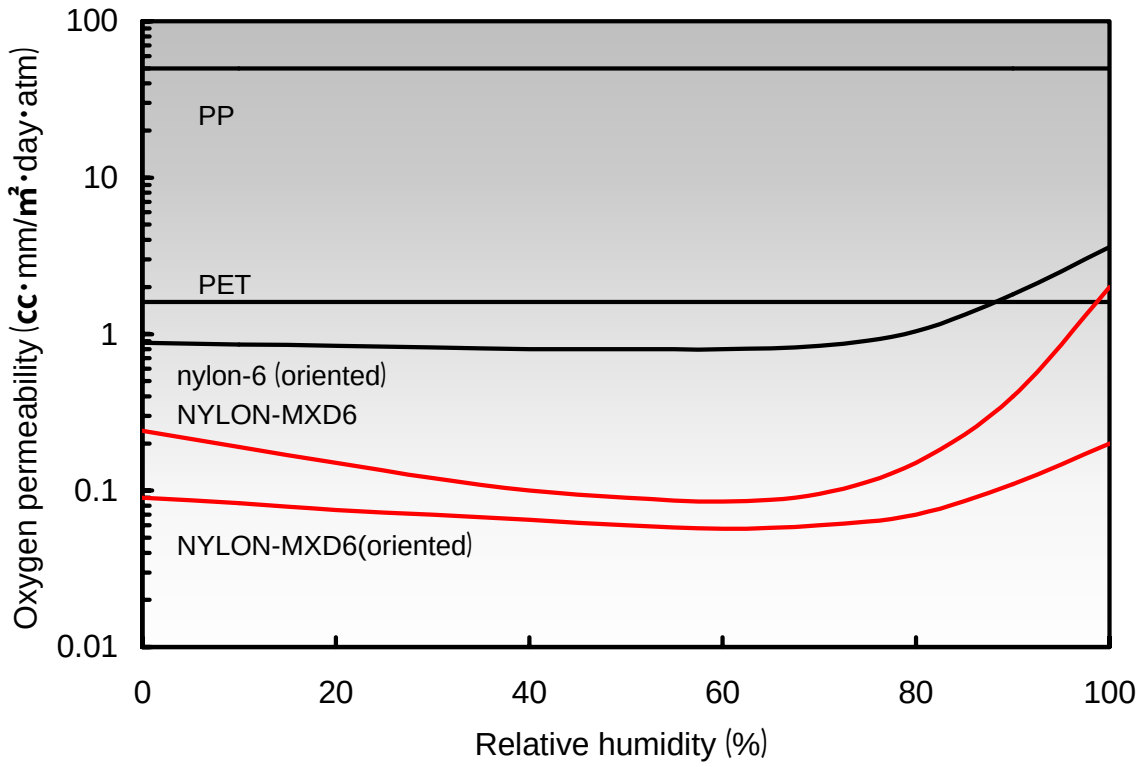


Fig. 2-1 Humidity dependence of oxygen permeability for various polymers

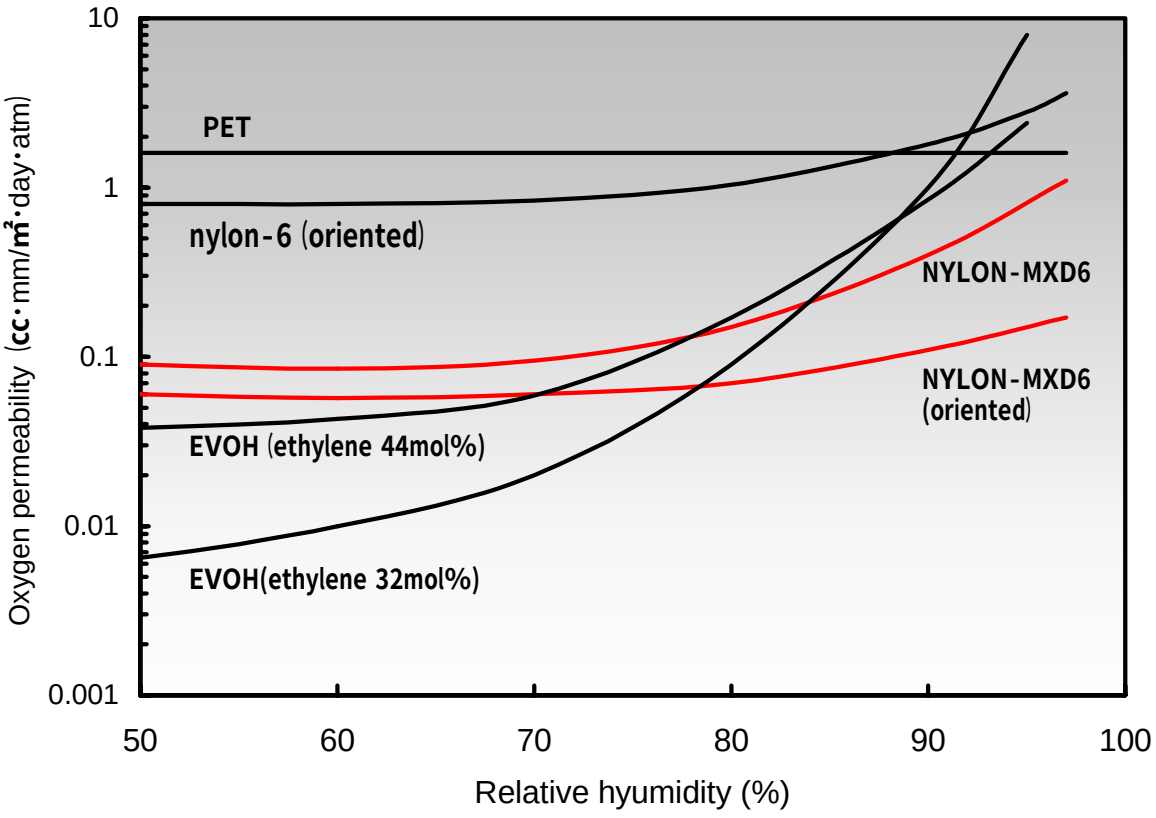


Fig2-2 Oxygen permeability for various polymers under high relative humidity condition.

2-4. Chemical Resistance

NYLON-MXD6 is fairly stable against various chemicals, except strong acid and phenols such as sulfuric acid, formic acid and m-cresol etc.
The chemical resistance of NYLON-MXD6 is shown in Table-4.

Table 4 Chemical resistance of NYLON-MXD6

Chemicals	Weight change (%)	Retention of tensile strength (%)
Water	0.7	87
methanol	1.4	87
8% Ethanol	0.6	93
50% Ethanol	0.9	87
n-Butanol	0	99
37% Formaldehyde	0.4	82
n-Heptane	0.1	98
30% Acetic acid (aq.)	0.7	89
30% H_2SO_4 (aq.)	0.9	92
10% HCl (aq.)	0.8	88
10% HNO_3 (aq.)	0.8	85
10% NH_4OH (aq.)	0.7	87

Note : Injection molded spesimens, immersion for 7 days at 20^{o}C

2-5. Rheological and thermal properties of each grades

The thermal properties and the melt viscosity of NYLON-MXD6 are shown in Table 5.
The relationship between the melt viscosity and the shear rate or the tempereture are shown in Fig. 3 and Fig. 4.

Table-5　Thermal properties and viscosity of NYLON-MXD6

Items		methods and conditions	Units	Grades		
				6001	6007	6121
Melting point		DSC	℃	237	237	237
Tg		DSC	℃	85	85	85
Processing temp.			℃	250～290	250～290	250～290
Melt viscosity	260℃	Capiraly rheometer Nozzle D：1.0mm L：10mm Shear rate 100 sec^{-1}	Pa･s	150	740	2000
	270℃			120	550	1500
	280℃			100	400	1200
Thermal expansion coeffisient		ASTM D696	cm/cm ℃	5.1×10^{-5}	5.1×10^{-5}	5.1×10^{-5}

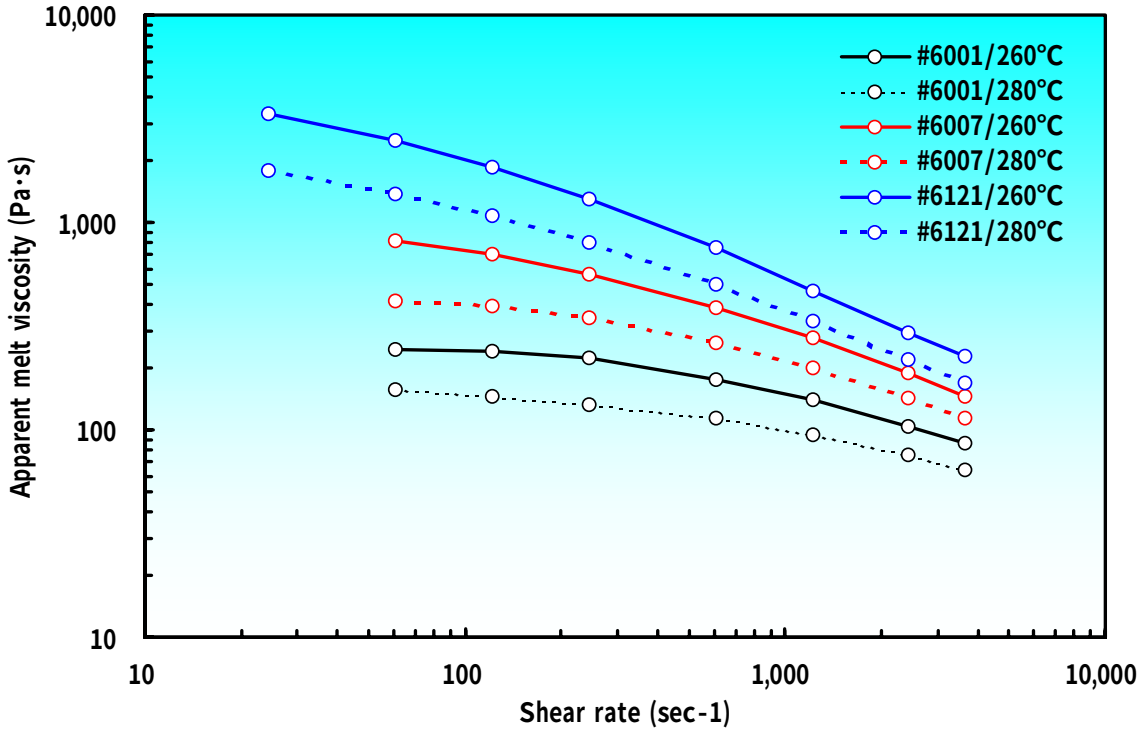


Fig. 3 Melt viscosity versus share rate

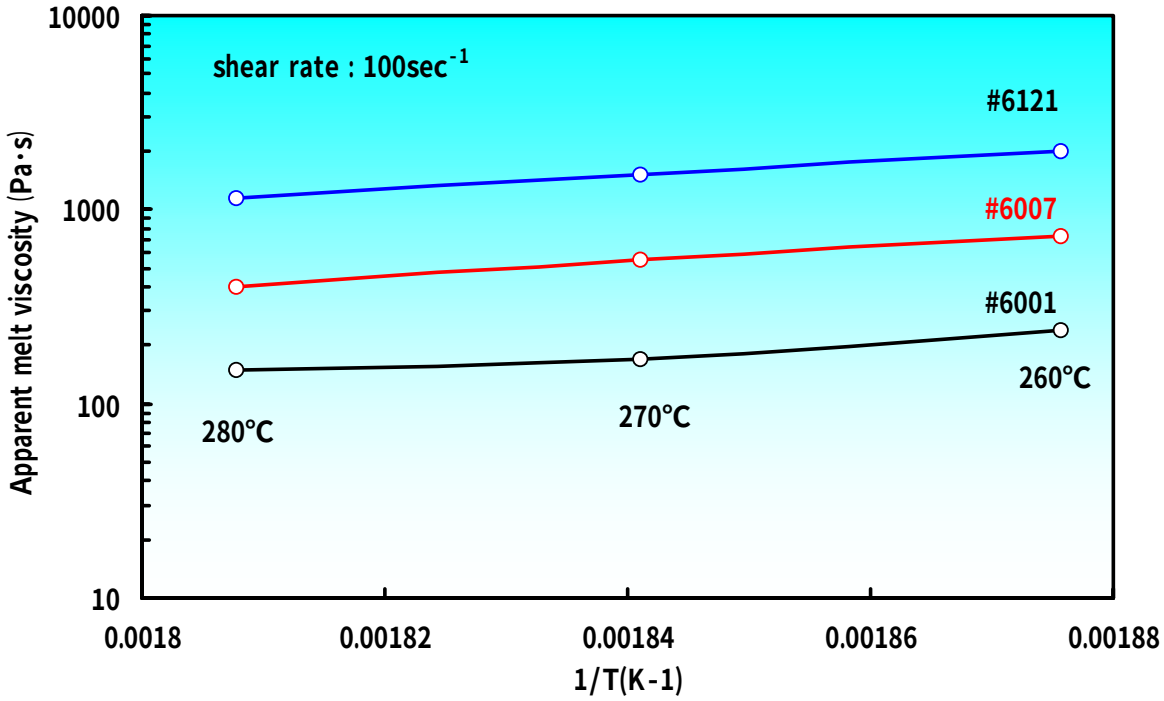


Fig. 4 Temperature dependence of melt viscosity

2-6. Thermal Stability

Thermal gravimetric curve of NYLON-MXD6 is shown in Fig. 5. Stability of the melt index is shown in Fig. 6. NYLON-MXD6 is more stable than the other gas barrier resins.

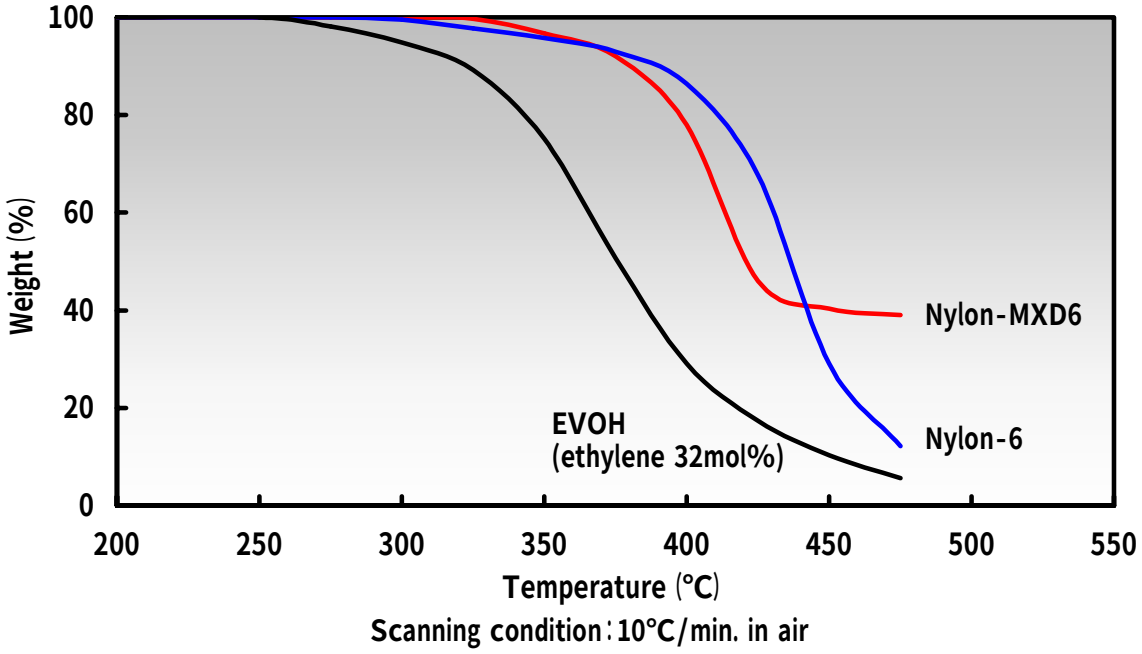


Fig-6 Thermal gravimetric curves of barrier resins

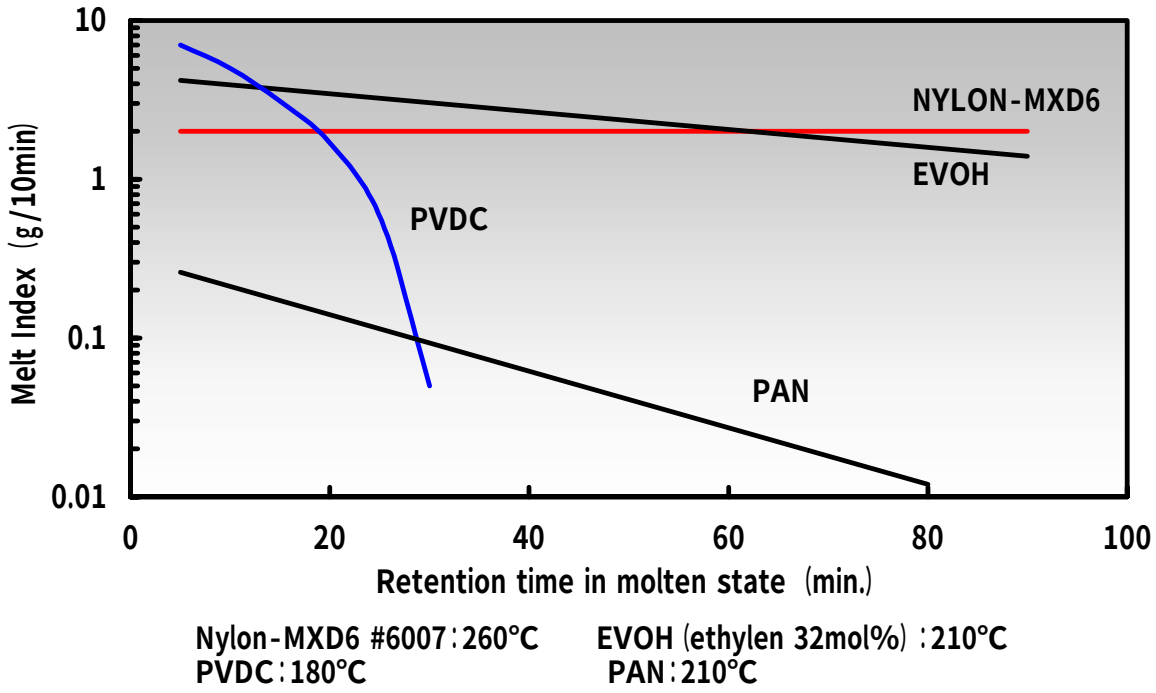


Fig-6 Stability of melt index of barrier resins

3. GRADES AND APPLICATIONS

NYLON-MXD6 can be easily applied for co-injection and/or co-extrusion in combination with other resins such as PET, nylon-6, polyolefines or other resins to produce various packaging. Additionally, it is suitable for monofilaments and molding compounds.

Applications

Grades

Grades and the applications of NYLON-MXD6 are shown in Table 6 and Table 7. Three grades with different molecular weight are available for several applications.

Table 6 Grades of Nylon-MXD6

Items	Grades		
	Nylon-MXD6 6001	Nylon-MXD6 6007	Nylon-MXD6 6121
Relative viscosity	2.1	2.7	3.5
MI (g/10min)	8	2	0.5
Moisture content (wt%)	< 0.15	< 0.15	< 0.15
Melting point (℃)	237	237	237

Table 7 Suitable grades for various applications

Applications	Grades
Monolayer or Multilayer films	6007
Multilayer sheets	6007,6121
Multilayer bottles and tubes (extrusion blow)	6007,6121
Monolayer blend bottles with PET (injection stretch blow)	6001,6007
Multilayer bottles with PET or PP (co-injection stretch blow)	6007
Monofilaments	6007

4. Applications

4-1. NYLON-MXD6/nylon-6 blend films

NYLON-MXD6 can be easily applied for the production of blend films with conventional nylons such as nylon-6 or nylon-66 because of the close solubility parameters.

NYLON-MXD6 has best gas barrier performance in commercial nylon plastics and useful for a modifier for conventional nylons to enhance the barrier performance.

For example, a small amount of NYLON-MXD6 effectively decreases the oxygen permeation rate of nylon-6 films as shown in Fig. 7.

On the other hand, NYLON-MXD6 can be modified the impact strength and the optical stability by blending with nylon-6 or nylon-66 especially in non-oriented application. A cast NYLON-MXD6 film blended with more than 10wt% of nylon-6 keeps good transparency even after boil or retort treatments.

The oxygen permeation rate of blend film composed of NYLON-MXD6 and nylon 6 is shown in Fig. 7.

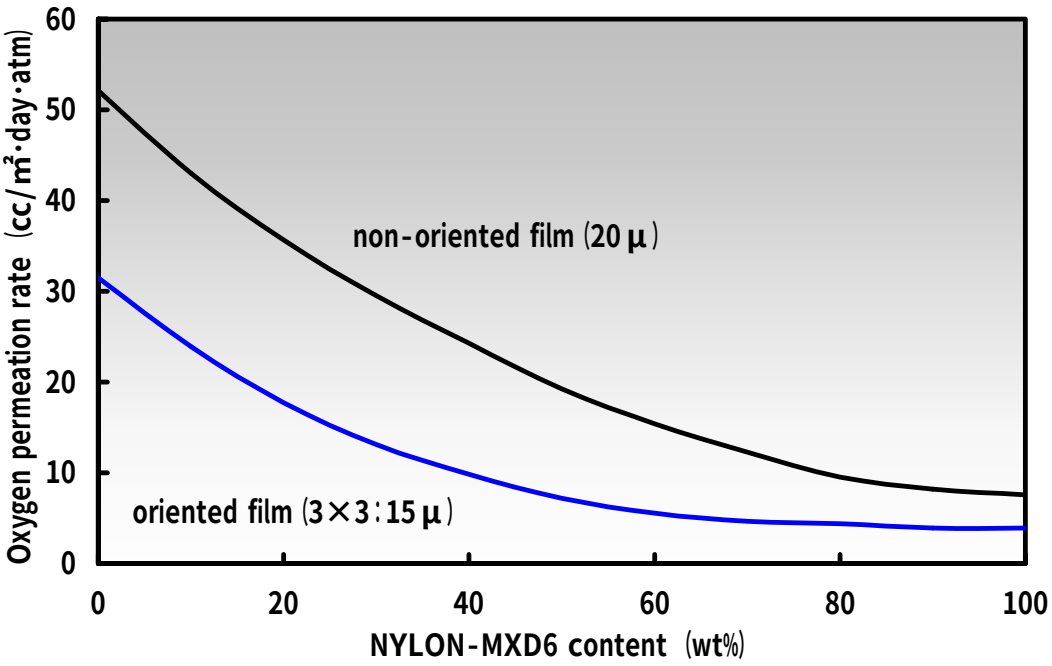


Fig. 7 Oxygen permeation rate of NYLON-MXD6/nylon-6 blend film (23°C, 60%RH)

In addition to the good transparency, multilayer films including NYLON-MXD6/nylon 6 blend layer shows excellent gas barrier properties even after boil or retort treatments. As shown in Table 8, the oxygen permeation rate of a multilayer film including the NYLON-MXD6/nylon 6 (90/10) blend layer recovers rapidly after the boil treatment. As a result, accumulated oxygen amount permeated through the film after the treatment is controlled at low level (Fig. 8).

Table 8 The oxygen permeation rate of multilayer film after boil treatment

Structure Thickness(μ)	Haze (%)		Oxygen permeation rate (cc/m²·day·atm)				
	Initial	After boiling	Initial	Time after boiling (hr)			
				1	10	24	72
LLDPE/Tie/Blend/Tie/LLDPE 30 / 10/ 15 /10 / 30	3.4	6.8	11	68	30	20	12
LLDPE/Tie/EVOH/Tie/LLDPE 30 / 10/ 15 /10 / 30	5.1	59	11	400	170	46	12

LLDPE: Linear low density polyethylene

Blend: NYLON-MXD6/nylon-6 = 90/10 boil treatment: 30min., 100℃.

Measurement condition: 23℃; inside:100%RH ; outside:60%RH

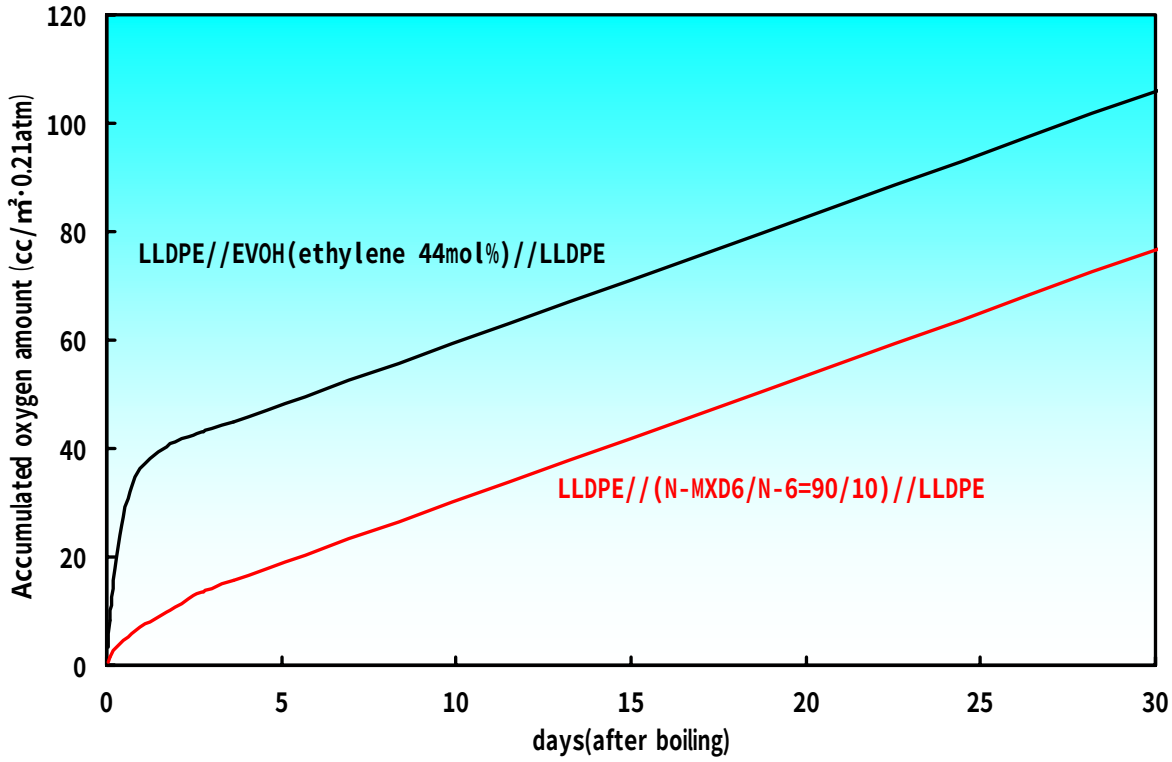


Fig-8 Accumulated oxygen amount of multilayer film after boiling

boil condition : 30min. 100℃

test condition：23℃ ; inside:100%RH ; outside:60%RH

NYLON-MXD6 film also has excellent aroma preserving and odor proof properties as shown in Table 9.

Table 9　Aroma preserving and odor proof properties of barrier films

Barrier materials Thickness : 15μ	Evaluated condiment		
	Soy sauce	Vinegar	Worceter sauce
NYLON-MXD6 (oriented)	◎(1 months)	○	◎(3 months)
NYLON-MXD6/nylon-6 blend (oriented)	◎(1 months)	○	○
Nylon-6 (Oriented)	○	▲	○
PVDC Coated Oriented Nylon-6	◎(1 months)	○	○
PET(oriented)	◎(1 months)	△	△
PE	▲	▲	▲

Barrier materials Thickness : 15μ	Evaluated flavor		
	d-Limonen	Vanillin	L-menthol
NYLON-MXD6 (oriented)	◎	◎	◎
NYLON-MXD6/nylon-6 blend (oriented)	○	△	◎
Nylon-6 (oriented)	○	▲	◎
EVOH	○	△	◎
PVDC coated oriented nylon-6	◎	◎	◎
PET (oriented)	○	◎	◎
PP (oriented)	▲	▲	○
PE	▲	▲	▲

NYLON-MXD6/nylon-6 blend (oriented) : NYLON-MXD6/nylon-6 = 30/70

Storage conditions : 23℃, 50%RH

Evaluation method : Sensory test

Oder proof time:

▲:Within 3 days, △:3 days to 1 week, ○:1 to 2 weeks, ◎:Longer than 2 weeks

4-2. NYLON-MXD6/PP multilayer rigid container

NYLON-MXD6/PP multilayer container produced by thermoforming has the excellent gas barrier property even after retort treatments.

The oxygen permeation rate of the multilayer container composed of NYLON-MXD6/PP is shown in Table 10 in comparison with EVOH/PP multilayer container. The accumulated oxygen amount in multilayer container after retort is shown in Fig. 9.

Table-10 Oxygen permeation rate of Nylon-MXD6/PP multilayer container

Structure	Average thickness (μ)	Oxygen permeation rate (cc/pkg·day·0.21atm)				
		Initial	Time after retorting (days)			
			1	7	14	30
PP/Tie/ Nylon-MXD6 /Tie/PP	140/10/ 40 /10/180	0.047	0.38	0.028	0.020	0.019
PP/Tie/ EVOH /Tie/PP (ethylene 32mol%)	140/10/ 40 /10/180	0.012	0.68	0.49	0.25	0.11

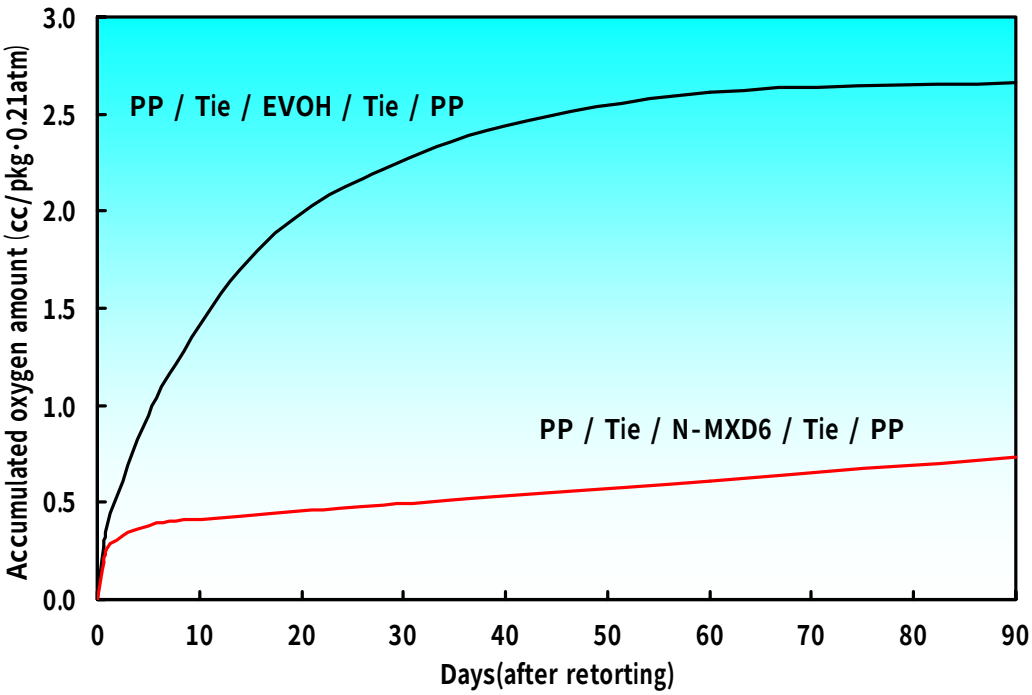


Fig. 9 Accumulated oxygen amount of multilayer container after retort

EVOH: ethylene 32mol%

Retort treatment: 121℃, 30min.

Container : surface area 310cm^2 , volume 350cm^3

PP/Tie/Barrier/Tie/PP: 140/10/40/10/180 μm (average thickness of container)

Measurement conditions: 23℃, inside 100%RH, outside 50%RH

4-3. NYLON-MXD6/PET multilayer and blend bottles

The properties of NYLON-MXD6/PET multilayer and blend bottles are shown in Table 11 and Table 12. The relationship between concentration of L-ascorbic acid and storage time of NYLON-MXD6/PET multilayer bottle is shown in Fig. 10. The carbonation retention of NYLON-MXD6/PET multilayer bottle is shown in Fig. 11. The carbonation permeation rate of NYLON-MXD6/PET blend bottle is shown in Fig. 12.

Table-11 Properties of NYLON-MXD6/PET multilayer bottle

Items	Units	Nylon-MXD6/PET multilayer bottle	PET bottle
Weight	g	50	50
Wall thickness	μm	330	330
PET	μm	306	330
NYLON-MXD6	μm	24	0
Haze	%	3.5	3.2
Oxygen permeation rate	cc/bottle·day·0.21atm	0.026	0.054

size：1500cc

condition：Temp. 20℃ , inside 100%RH , outside 65%RH

Table 12 Properties of NYLON-MXD6/PET blended bottle

Items	Units	NYLON-MXD6 content (weight %)	
		7	15
Weight	g	50	50
Thickness	μm	328	325
Haze	%	20	35
Oxygen permeation rate	cc/bottle·day·0.21atm	0.044	0.029

Size: 1500ml

Condition: 20℃, inside 100%RH , outside 65%RH

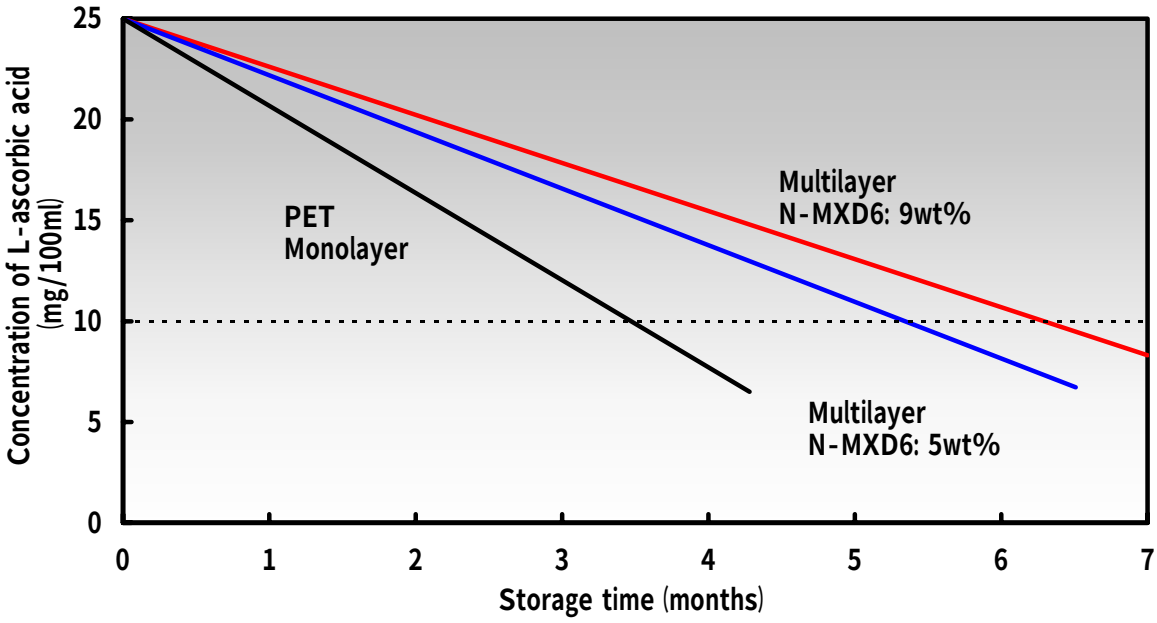


Fig. 10　Change of concentration of L-ascorbic acid in multilayer bottles with time

Bottle: 1500cc, 55g

Storage condition: 30℃, inside 100%RH, outside 65%RH

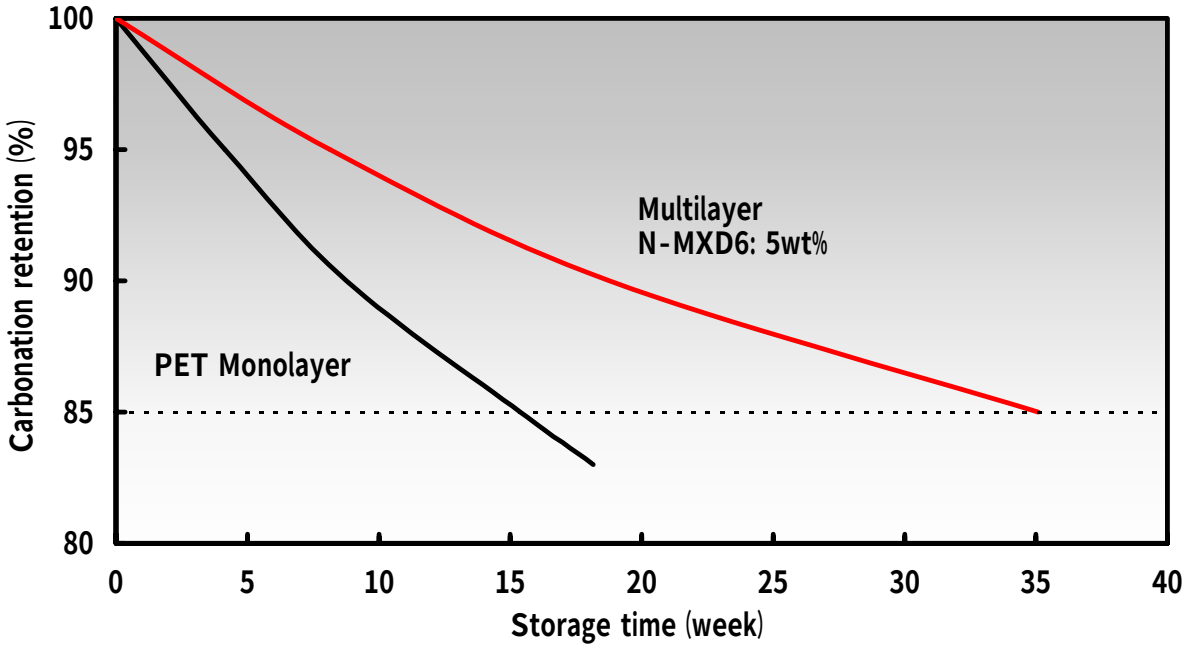


Fig. 11　Change of carbonation retention in multilayer bottles with time

Bottle: 1,000ml, wall thickness 350μm

Storage condition: 20℃, inside 100%RH, outside 65%RH

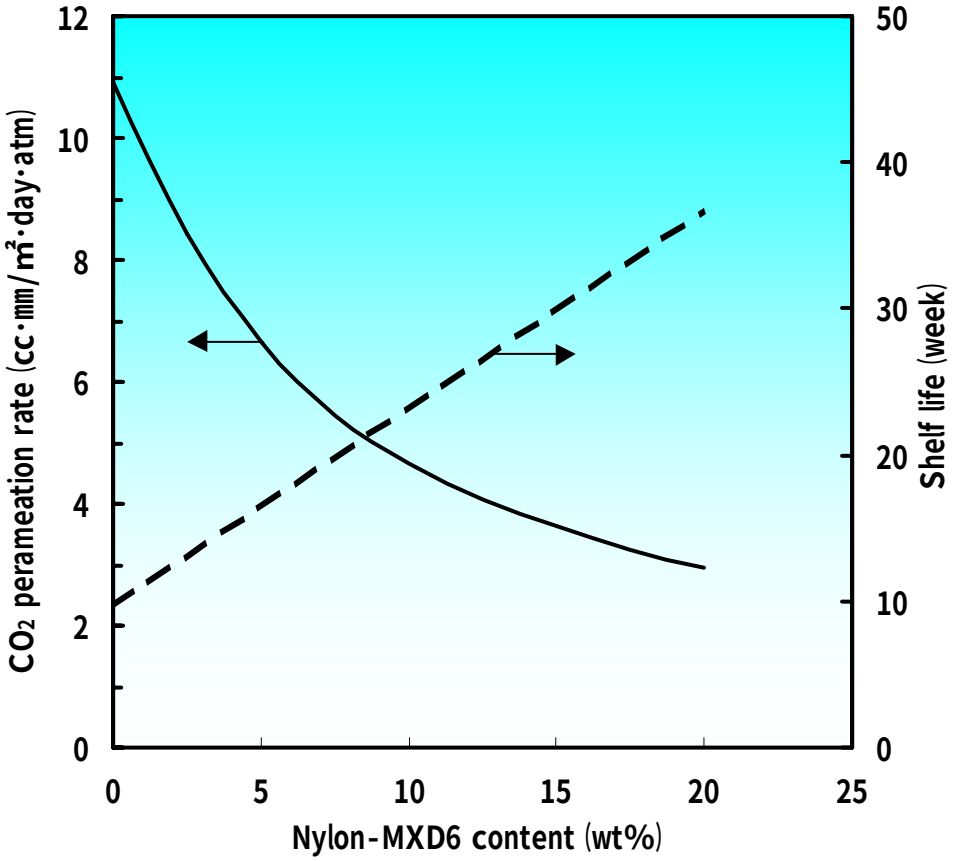


Fig. 12　CO_2 permeation rate of NYLON-MXD6/PET blend bottle

Bottle: 500ml

Measurement condition: 20℃, 60%RH

Shelf life: 15% loss from initial gas volume

4-4. Nylon-MXD6 monofilament

The mechanical properties of NYLON-MXD6 monofilament are shown in Table 13 in comparison with other polyamide and polyester monofilaments.

NYLON-MXD6 moofilament has higher tenacity and knot tenacity than nylon-6, nylon-66 and PET monofilaments. And the monofilament has higher Young's modulus than nylon-6 and nylon-66 monofilament.

NYLON-MXD6 monofilament keeps high tenacity and Young's modulus even in wet condition.

Table 13 Mechanical properties of NYLON-MXD6 monofilament

Resins		Nylon-MXD6	Nylon-6	Nylon-66	PET
Grade		#6007			
Relative viscosity		2.7	3.5	3.5	0.65[1)]
Total draw ratio		4.5	4.5	4.5	4.5
Denier	D	2000	2000	2000	2000
Diameter	μ	480	500	500	450
Properties of monofilament					
【Equilibrium23℃, 50%RH】					
Moisture content	%	1.7	2.6	2.4	0.5
Tenacity	gf/D	6.0	5.4	5.1	4.9
	(MPa)	(650)	(540)	(510)	(600)
Elongation	%	18	22	20	18
Young's modulus	kgf/mm^2	600	180	230	840
	(GPa)	(5.9)	(1.8)	(2.3)	(8.2)
Knot tenacity	gf/D	4.5	3.4	3.3	3.9
	(MPa)	(490)	(340)	(330)	(480)
【Equilibrium23℃, in water】					
Moisture content	%	5.8	10	8.5	0.7
Tenacity	gf/D	5.6	5.0	4.7	4.6
	(MPa)	(610)	(500)	(470)	(560)
Elongation	%	20	24	21	19
Young's modulus	kgf/mm^2	450	130	200	790
	(GPa)	(4.4)	(1.3)	(2.0)	(7.7)
Knot tenacity	gf/D	4.0	3.2	3.0	3.8
	(MPa)	(440)	(320)	(300)	(460)

1) intrinsic viscosity

Hydrolytic resistance

Tenacity of nylon-MXD6 monofilament after steam ambience treatment at 120℃ is shown in Fig. 13 in comparison with monofilaments of nylon-6 and PET.

NYLON-MXD6 monofilament keeps higher tenacity than the others even after the treatment.

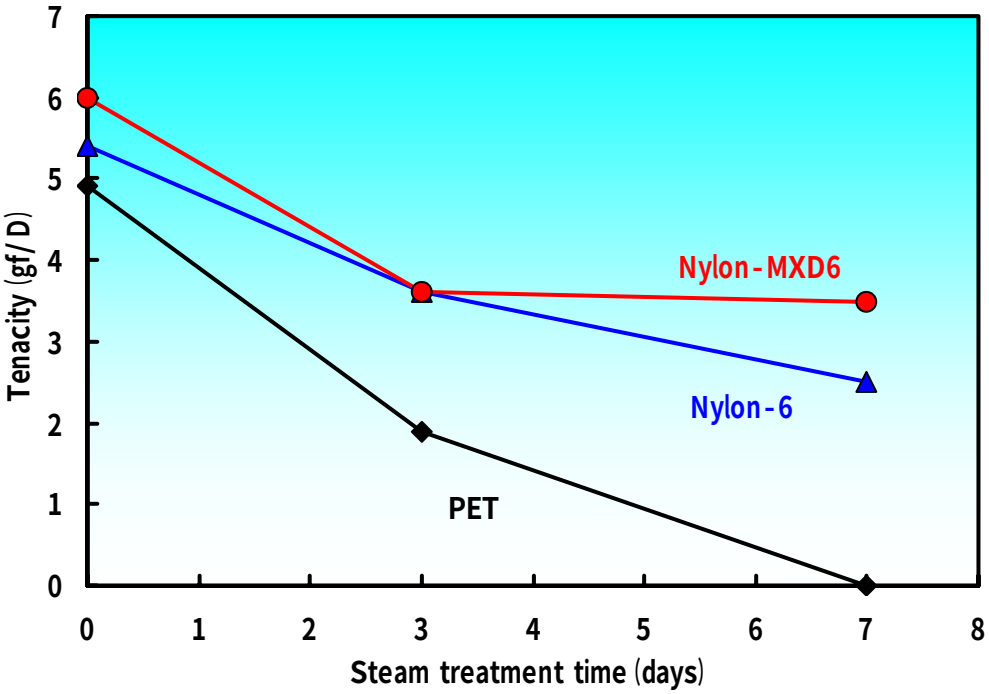


Fig. 13 Tenacity of NYLON-MXD6 monofilament after steam ambience treatment

Steam ambience treatment: 120℃, 1.1kgf/cm^2 (0.11MPa)

Diameter : 500μm

Hydrogen peroxide resistance

Mechanical properties of NYLON-MXD6 monofilament after immersion in hydrogen peroxide (3%aq., 90℃, 8hr.) are shown in Table 14 in comparison with monofilaments of Nylon-6 and PET.

NYLON-MXD6 monofilament keeps higher tenacity after the treatment.

Table 14 Mechanical properties of NYLON-MXD6 monofilament after hydrogen peroxide treatment (3%aq., 90℃, 8hr.)

Material	Nylon-MXD6	Nylon-6	PET
Total draw ratio	4.5	4.5	4.5
Denier (D)	4000	4000	4000
Diameter (μ)	680	700	640
Properties [a]			
Tenacity (gf/D)			
before treatment	6.0 [100]	5.4 [100]	4.9 [100]
after treatment	4.1 [69]	—[b]	2.9 [60]
Elongation (%)			
before treatment	18 [100]	22 [100]	18 [100]
after treatment	19 [109]	—[b]	26 [144]
Young's modulus (kgf/mm^2)			
before treatment	600	180	840
after treatment	470	—[b]	720

a) Figures in [ ]: retention of tenacity or elongation (%)

b) Impossible to test due to the brittleness

5. PROCESSING CONDITIONS

5-1. Processing temperature

NYLON-MXD6 can be easily used in extrusion and/or injection molding because of its good thermal stability in molten state. NYLON-MXD6 can be used in co-extrusion and co-injection with not only polyolefines but polymers with high processing temperature e.g. nylon-6, nylon-66, polycarbonate or PET. Suitable processing temperature of NYLON-MXD6 is 250 to 290℃.

The processing temperature range of NYLON-MXD6 compared with other polymers is shown in Fig. 14.

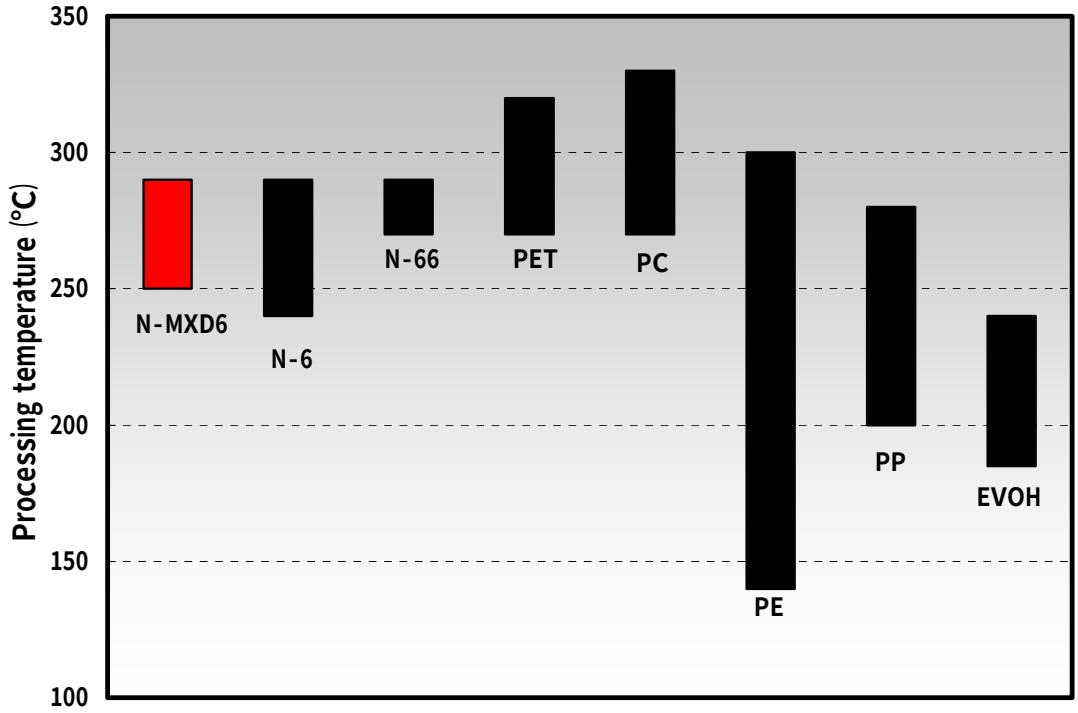


Fig. 14 Processing temperature of various polymers

5-2. Examples of screw design

Examples of screw design for NYLON-MXD6 are shown in Table 15 and Fig. 15.

Table 15　Examples of screw design

Items		Extruder diameter,D (mmϕ)	
		30	40
Types		full flight	full flight
L/D		24	26
Compression ratio		2.4	3.4
Pitch	(mm)	30	40
Feeding zone	(mm)	360	520
flight number		12	13
channel depth	(mm)	5.4	7.0
compression zone	(mm)	90	120
flight number		3	3
metering zone	(mm)	270	400
flight number		9	10
channel depth	(mm)	1.9	1.7

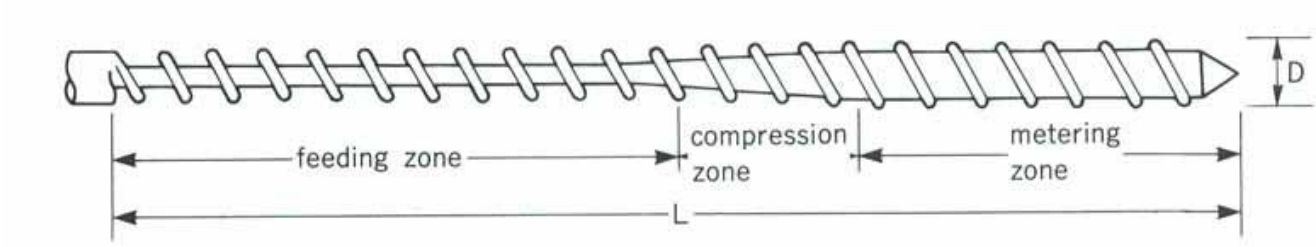


Fig 15　Example of screw figure

5-3. Processing conditions for co-extrusion

Examples of processing condition for co-extruded cast film with polyethylene, co-extruded sheet with polypropylene and co-extrusion blow-molded bottle are shown in Table 16, Table 17 and Table 18.

Please contact us if information regarding the selection of materials or detailed processing condition is necessary.

Table 16 Processing condition for multilayer film including NYLON-MXD6/Nylon-6 blend

Items		Unit	N-MXD6/N-6 Blend	LLDPE	Adhesive
MI of materials		g/10min		2.1	2.5
extruder	D	mm	30	45	30
	L/D		28	27	34
screw	type		full flight	full flight	full flight
	compression ratio		3.4	3.1	3.1
cylinder temp.	C1	℃	240	190	170
	C2		250	200	180
	C3		260	210	190
	C4			220	
	C5			230	
	head		260		
	adapter		260		
feedblock temp.		℃	250～265		
T-die temp.	D1	℃	250～265		
	D2		250～265		
	D3		250～265		
	D4		250～265		
	D5		250～265		
chill roll temp.		℃	20 ～ 40		

1) Blend ratio : NYLON-MXD6/nylon-6 = 70/30

NYLON-MXD6: #6007, nylon-6: relative viscosity 2.6

Table 17　Processing condition for Nylon-MXD6/PP co-extruded sheet

Items		Unit	Nylon-MXD6	PP	Adhesive
MI of materials		g/10min	0.5	0.8	1.5
extruder	D	mm	40	45	30
	L/D		24	27	34
screw	Type		full flight	full flight	full flight
	Compression ratio		3.4	3.0	2.9
cylinder temp.	C1	℃	240	210	180
	C2		250	220	190
	C3		260	230	200
	C4			240	
	C5			250	
	Head		260	250	200
	Adapter		260	250	200
feedblock temp.		℃	250～265		
T-die temp.	D1	℃	250～265		
	D2		250～265		
	D3		250～265		
	D4		250～265		
	D5		250～265		
chill roll temp.		℃	20 ～ 40		

Table 18　Processing condition for NYLON-MXD6/HDPE co-extrusion blow-molded bottles

Items		Unit	N-MXD6	HDPE	Adhesive
resin	M I	g/10min	0.5	0.3	1.0
extruder	D	mm	30	40	30
	L/D		24	24	24
screw	Type		full flight	full flight	full flight
	compression ratio		2.4	2.75	3.0
cylinder temp.	C1	℃	250	220	190
	C2		260	230	200
	C3		270	240	210
	head		270	240	210
	adapter			240	210
Die temp.	D1	℃	230		
	D2		250		
	D3		260		
	D4		250		
	D5		230		
	D6		220		
Blow air pressure		kg/cm^2	4.5		
Blow time		sec	20		
Mold temperature		℃	20 ～ 40		

6. Handling

It is not necessary to dry when you use N-MXD6 just after opening the damp-proof bags, because the pellets are dried enough for the processing (less than 0.1wt%) before the shipment.

In case the pellets have got moisture by exposing in atmosphere for a long time, it is necessary to dry under vacuum condition. In this case, the suitable drying conditions are at 120 to 140^{o}C, below 2mmHg, for 4 to 5 hours.

The moisture regain of NYLON-MXD6 under various humidities at 20℃ is shown in Fig.16. The relationship between moisture content of the pellets and drying time based upon above conditions is shown in Fig.17.

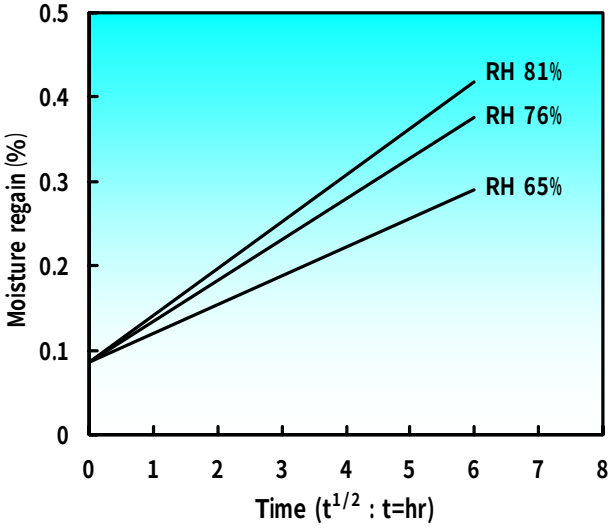


Fig.16 Moisture regain vs exposure time at 20℃

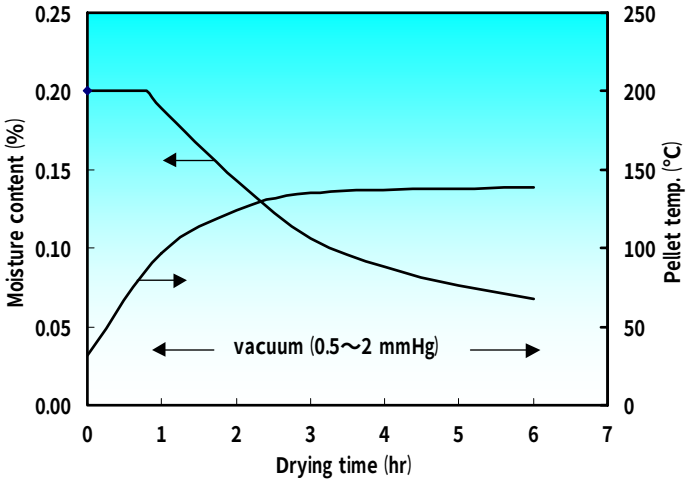


Fig.17 The behavior of moisture content of pellets

7. Safety and hygiene

A) FDA

FDA has approved the use of NYLON-MXD6 for indirect food additives. Please refer the corresponding articles of the code of federal regulation (CFR).

For a direct contact: 21 CFR Part 177.1500 (a) (10) (ii), (b) 10.1

For an indirect contact: 21 CFR Part 177.1390 (c) (1) (i) (e), Part 177.1500 (b) 10.3

For a modifier of PET: 21 CFR Part 177.1630 (e) (4) (v) “hexanedioic acid polymer with 1,3-benzenedimethanamine”

Additionally, no objection letters for the safe use of PET bottles modified with NYLON-MXD6 have been submitted from FDA for the both of multilayer bottles and blend bottles.

B) EC Directive

Our NYLON-MXD6 is in compliance with EC-Directives for food packaging materials.

C) Cas. Reg. No.

#25718-70-1

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