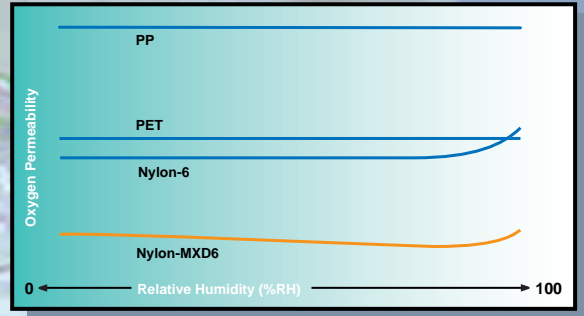


Nylon-MXD6

Superior performance
in barrier
packaging



MITSUBISHI GAS CHEMICAL COMPANY, INC.

Nylon-MXD6

STRONG, SAFE AND EASY TO USE

Nylon-MXD6's properties give it advantages in many areas important in food packaging. Co-extruded, co-oriented films of Nylon-MXD6 have been proven to provide excellent gas barrier properties, pinhole resistance, heat resistance and environmental compatibility. It is tough and highly transparent. In addition, it is highly rated for aroma retention, and odor proofing.

Given Nylon-MXD6's excellent gas barrier properties compared to conventional nylons, and its other advanced properties, it has emerged as a highly regarded option for food packaging and other multifunction packaging.

ADVANTAGES



Provides superior protection for foods. Nylon-MXD6 has excellent gas barrier and aroma preserving properties, keeping oxygen out and flavor and aroma in. It offers the best gas barrier property among nylon resins even under high humidity. Nylon-MXD6 is also excellent in preserving aroma as shown in *Table 2*. One of the key characteristics of barrier packaging is to protect food from oxygen, and Nylon-MXD6 offers immediate recovery of oxygen barrier after retorting or boiling treatment.

Easy to work with. The moderate crystallization speed means that Nylon-MXD6 provides good processability. It is easy to be stretched and/or thermoformed. The processing temperature range of Nylon-MXD6 overlaps with that of other packaging materials which makes it possible to co-extrude with not only polyolefins but nylon 6, nylon 66, PET, polycarbonate and other materials with a relatively high processing temperature range. (*Figure 1*)

This processing temperature range allows for diverse combination with other resins and various combinations with other polymers. It is easy to manufacture multilayered containers by co-extrusion or co-injection combination with other polymers and it improves properties and/or processing window for the other polyamides. Nylon-MXD6 has excellent thermal stability in the melting condition in comparison with other gas barrier resins, which enables stable processing. (*Figure 2*)

Easy on the environment. Nylon-MXD6's superior recyclability occurs because it recycles without any gel formation and decomposition, and it does not contain any halogens that could give rise to acid rain or dioxin upon incineration. Its thermal stability also enables users to recycle the trimming scraps resulting from film and sheet production. Nylon-MXD6, compared to other available packaging options, is an environmentally friendly material.

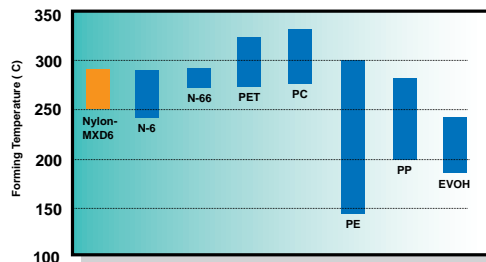


Figure 1 - Processing Temperature Range

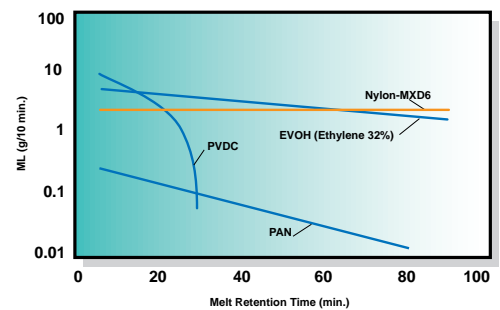


Figure 2 - Stability of Melt Viscosity

Nylon-MXD6:	260°C
PVDC (Polyvinylidene chloride):	180°C
EVOH (Ethylene 32%):	210°C
PAN (Polyacrylonitrile):	210°C

**EXAMPLES
OF APPLICATIONS**



Oriented films. Due to their good adhesion properties, Nylon-MXD6 and nylon 6 can be laminated without the use of an adhesive agent. Several manufacturers of oriented nylon 6 films are marketing co-extruded, co-oriented films that make use of this characteristic.

The co-extruded, co-oriented films of Nylon-MXD6 with nylon 6 are excellent in gas barrier properties, pinhole resistance, transparency, heat resistance, environmental compatibility and take printing well. They are becoming popular as substitutes for PVDC coated oriented nylon, and these characteristics make it ideal for use in cooked food, liquid food and lid material packaging. Blended, oriented films of Nylon-MXD6 with other nylons, also exhibit easy tearing and linear cutting properties and have been gaining acceptance as multifunctional packaging materials coming to be used in easy-to-open retort pouches and stand-up pouches.

Co-extruded, non-oriented, multilayer films. The blending of nylon 6 with Nylon-MXD6 improves the properties of nylon 6. The gas barrier property of nylon 6 can be effectively improved (Figure 3), the impact and pinhole resistance of Nylon-MXD6 are improved, and the gas barrier layer exhibits better thermoformability.

With all of these favorable characteristics, packaging manufacturers around the world have adopted the use of films having a blend of Nylon-MXD6 and nylon 6 as the gas barrier layer.

Multilayer sheets and multilayer containers. With multilayered sheets of Nylon-MXD6 and PP (polypropylene), the increase of oxygen permeability after retort treatment is small compared with sheets of EVOH and PP. Multilayered sheets of Nylon-MXD6 and PP are also quick to recover after retort treatment, and the amount of oxygen that permeates into a container is held at a low level. (Figure 4)

Nylon-MXD6 type multilayered sheets are easier to thermoform and exhibit better processability than multilayered EVOH sheets. Also, since Nylon-MXD6 has excellent thermal stability, co-extruded sheets made by combining Nylon-MXD6 and PP can be recycled readily. (Table 3)

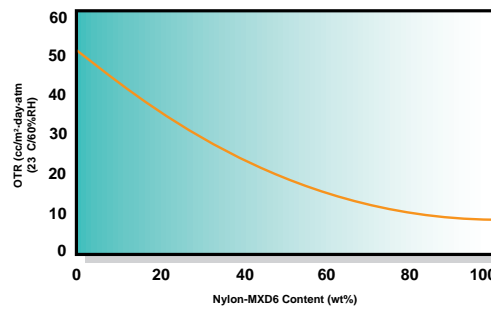
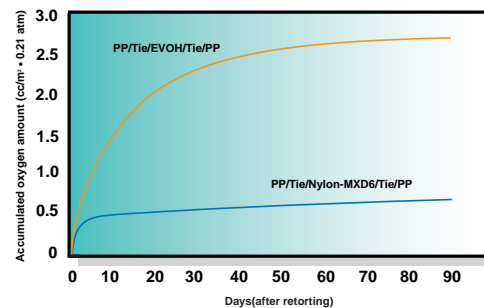


Figure 3 - Oxygen Transmission Rate of Nylon-MXD6/N-6 Blend Film (Thickness: 20µm)



EVOH: ethylene 32 mol%
Retort treatment: 121°C, 30 min.
Container: surface area 310 cm², volume 350 cm³
PP/Tie/Barrier/Tie/PP: 140/10/40/10/180 µm (average)
Measurement conditions: 23°C, inside 100% RH, outside 50% RH

Figure 4 - Cumulative Oxygen Transmission of Retorted Multilayer Containers

CO-INJECTION MOLDED, STRETCHED MULTILAYERED BOTTLES



Nylon-MXD6/PET multilayered bottles, made by co-injection molding and stretch blow molding, improve on the gas barrier properties of stretched PET bottles which have a mechanical strength, pressure resistance and transparency equivalent to those of single-layer PET bottles. (Figures 5,6)

Nylon-MXD6/PET multilayered bottles can be made thinner and achieve equal protection of a single-layer PET bottle. Nylon-MXD6/PET multilayered bottles can thus be compacted readily and are anticipated to contribute to volume reduction and resource savings in the recycle stream.

These bottles are currently being used for carbonated beverages, juices, salad dressings, condiments, bottled water and beers worldwide. The demand for these bottles has been expanding rapidly due to the properties and functionality of Nylon-MXD6.

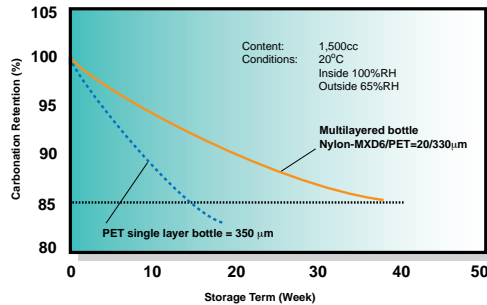


Figure 5 - Carbonation Retention of Nylon-MXD6/PET Multilayered Bottle

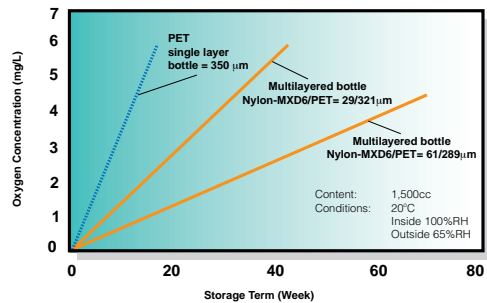


Figure 6 - Oxygen Concentration of Nylon-MXD6/PET Multilayered Bottle

FDA STATUS

Nylon-MXD6 has FDA approvals in a variety of packaging applications.

FUTURE PROSPECTS

The demand for Nylon-MXD6 as packaging material has expanded steadily during the 10 years since MITSUBISHI GAS CHEMICAL COMPANY started developing Nylon-MXD6 into packaging material.

With the ever-increasing safety-consciousness about foods, it is expected that the need for gas barrier packaging that enables long-term storage without damaging the freshness of foods will become higher in the future. Coupled with its barrier properties, improved processing options and reduced harm to the environment, it is easy to see why Nylon-MXD6 is the packaging material for the new millennium.

Advanced Properties of Nylon-MXD6

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 (immersion 24 hr/20°C)	D570	%	5.8	9.9	11.5	0.1
MOISTURE REGAIN (Equilibrium 65% RH/20°C)	D570	%	3.1	5.7	6.5	
HEAT DISTORTION TEMP.	D648	°C	96	75	65	85
GLASS TRANSITION TEMP	DSC	°C	85	50	48	77
MELTING POINT		°C	237	260	220	255
THERMAL EXPANSION	D696	cm/cm°C	5x10 ⁻⁵	10x10 ⁻⁵	8x10 ⁻⁵	7x10 ⁻⁵
TENSILE STRENGTH	D638	kg/cm ²	1,010	780	630	800
TENSILE ELONGATION	D638	%	2.3	60	200	5.8
TENSILE MODULUS	D638	kg/cm ²	48x10 ³	32x10 ³	26x10 ³	31x10 ³
FLEXURAL STRENGTH	D790	kg/cm ²	1,600	1,300	1,250	1,250
FLEXURAL MODULAS	D790	kg/cm ²	45x10 ³	30x10 ³	24x10 ³	35x10 ³
IZOD IMPACT (notched)	D256	kg-cm/cm	2	4	6	4
ROCKWELL HARDNESS	D785	M Scale	108	89	85	106

Table 2 - AROMA PRESERVING AND ODOR PROOF PROPERTIES OF BARRIER FILMS

BARRIER MATERIAL (Thickness: 15µm)	EVALUATING FLAVOR		
	d-Limonen	Vanilla Essence	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	▲	▲	▲


Odor Proof Time

- ⊙ Excellent (longer than 2 weeks)
- Good (1 to 2 weeks)
- △ Fair (3 days to 1 week)
- ▲ Poor (within 3 days)

Nylon-MXD6/Nylon 6 Blend (Oriented): Nylon-MXD6/Nylon 6 = 30/70 Storing conditions: 23°C, 50% RH (Shaded)
Evaluation method: Organoleptic test

Table 3 - Recyclability of Nylon-MXD6

MATERIAL	Nylon-MXD6	EVOH Type
	PP/ mod. PP/ Nylon-MXD6	PP/ mod. PP/ EVOH
BLENDING RATIO	90 / 5 / 5	90 / 5 / 5
EXTRUSION TEMPERATURE (°C)	270	210
GEL GENERATION		
NUMBER OF RECYCLING		
0	No	No
1	No	No
2	No	Yes
3	No	Yes



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MITSUBISHI GAS CHEMICAL COMPANY, INC.

Mitsubishi Gas Chemical America, Inc.
520 Madison Avenue, 17th Floor, New York, NY 10022 USA
Phone: 212-752-4620 Ext. 104, Fax: 212-758-4012, www.mgc-a.com

Mitsubishi Gas Chemical Europe, GmbH
Immermannstrasse 43, 40210 Dusseldorf 1 Germany
Phone: 49-211-363088, Fax: 49-211-354457

Mitsubishi Gas Chemical Company, Inc.
5-2, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100 Japan
Phone: 81-3-3283-4812, Fax: 81-3-3214-0938