

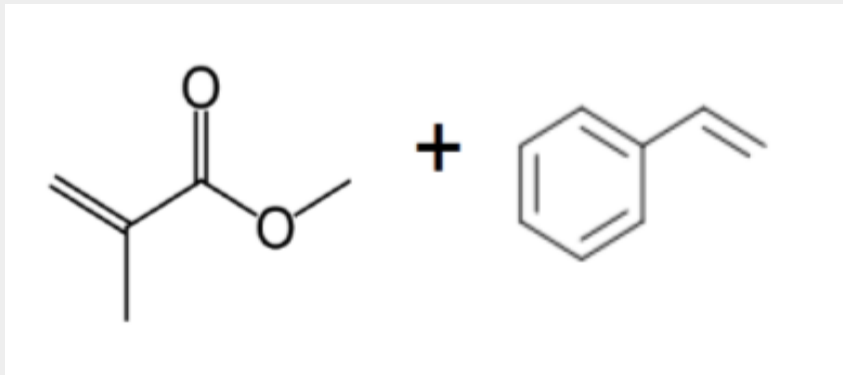
Introduction of **LG SMMA**



SMMA



SMMA (Styrene-co-methyl methacrylate)



MMA(methyl methacrylate)

Styrene

Features

- Excellent optical properties
 - similar to acrylic resin
 - high transmission rate and low haze
- Low moisture absorption rate (0.12%)
- Outstanding weatherability
- Excellent processability
- Low specific gravity (1.15g/cm³, 1.11g/cm³)

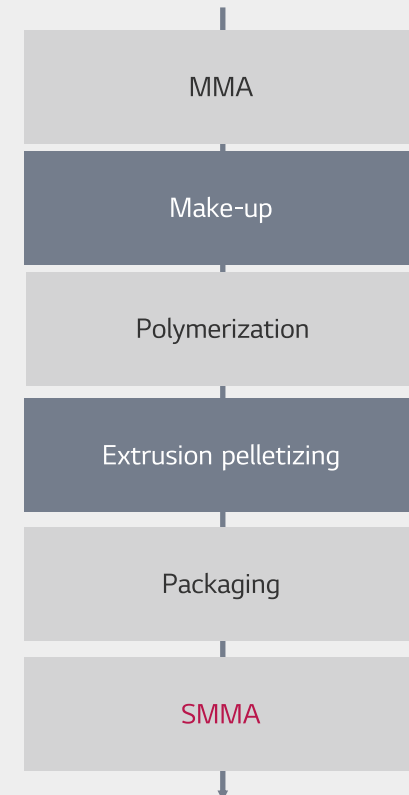
SMMA production

SMMA products come from Polymer Plant No. 2, Continuous Polymerization process.



Production Process

Continuous Process



① SM 30%

Injection grade : HX700, HX500

It is also appropriate for food and cosmetic containers due to outstanding chemical resistance to solvents, such as alcohol. SGS's test results for 'FDA, EU Food contact, Korean domestic food safety standards'



② SM 50%

Extrusion(optical) grade : HX238, HX208

In particular, low moisture absorption rate compared to general acrylic resin allows for application to high temperature and humidity. This material is appropriate for various purposes including light guide plate and lighting cover.



SMMA Features



Styrene Strength

- (+) Moisture Absorption
- (+) Dimension stability
- (+) Alcohol resistance

MMA Strength

- (-) Transmittance
- (-) Surface hardness
- (-) Weatherability

Items	Method	Unit	MMA 100%	MMA 70%	MMA 50%
			PMMA IF850	SMMA HX700	SMMA HX500
Water absorption	ASTM D570, 24hr	%	0.3	0.18	0.12
Shrinkage			-	↓	↓↓
Alcohol resistance	-	-	-	↑	↑↑
Specific Gravity	ISO 1183-1	g/cm ³	1.19	1.15	1.11
Refractive index	ISO 489	nd	1.49	1.53	1.55
Light transmittance	ISO 13468-1	%	92	91	91
Rockwell Hardness	ISO 2039-2	M-scale	92	87	75
Pencil hardness	-	-	3~4H	1~2H	F

SMMA

Background



Narrow Bezel, Bezel-less?

MOISTURE
ABSORPTION

Thermal
Expansion
behavior

Moisture Absorption → weaken interchain hydrogen bonding → swelling → volume increased → Result in an increase in thermal expansion.

JOURNAL OF MATERIALS SCIENCE 24 (1989) 3137-3140

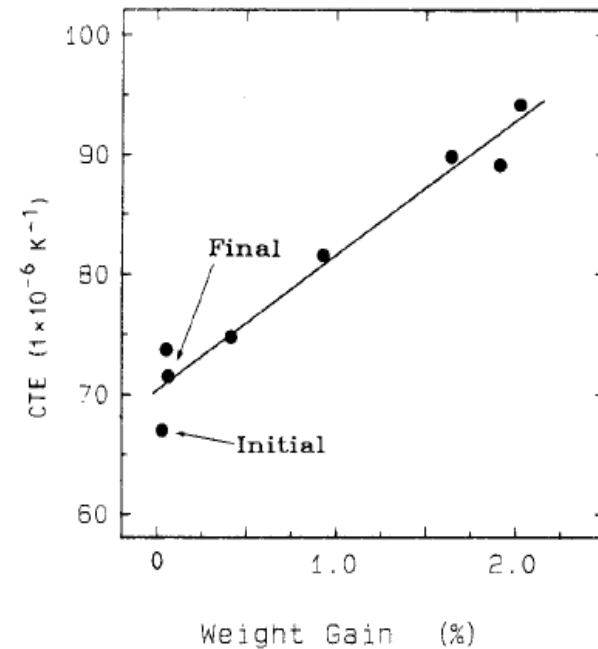
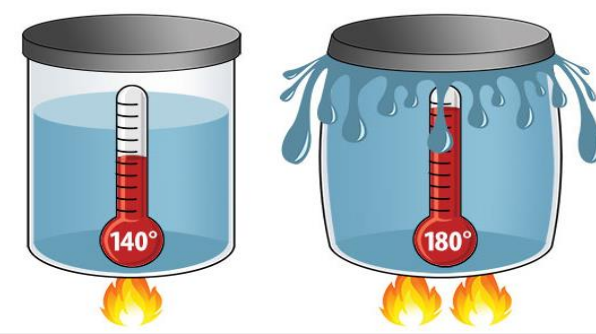


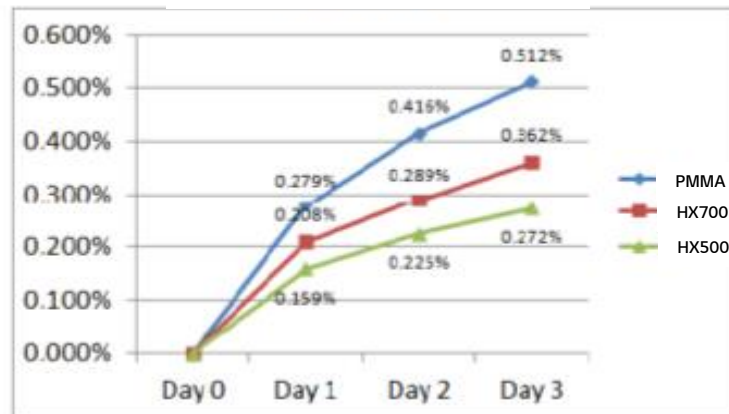
Figure 4 CTE (evaluated at 50°C) plotted against per cent weight gain for a single V811 specimen, moisture conditioned by immersion as in Fig. 3. Initial and final dried states demonstrate reversibility.

SMMA

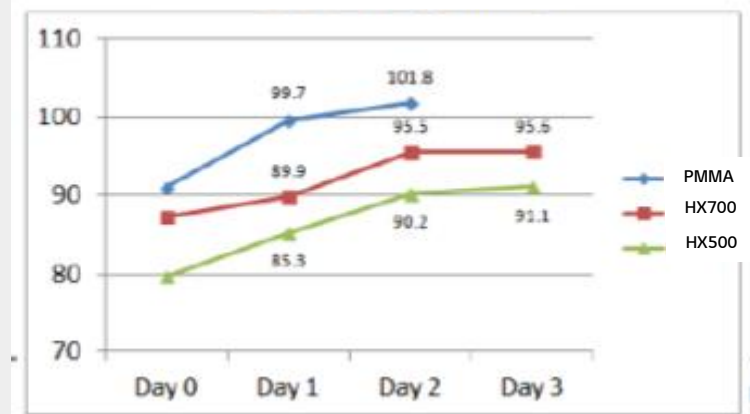
Moisture Absorption



Water absorption (%)



CLTE (um/m°C)

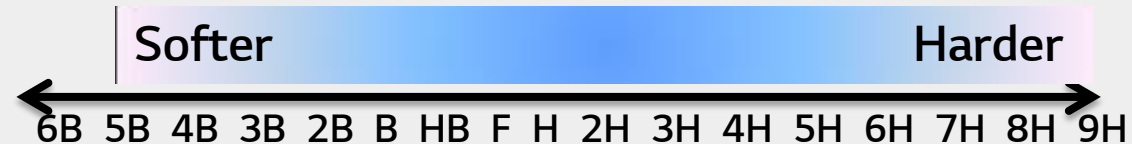


The moisture absorption rate and CLTE values in the high temperature and high humidity environment are lower than that of PMMA, and the dimensional stability is relatively good.

SMMA Surface hardness

SMMA HX700 1~2H pencil hardness
HX500 F pencil hardness

PC << SAN << SMMA < PMMA



► Comparison in pencil harness.

Material	Injection-processed	Extrusion sheet
PMMA	3~4H	2H
SMMA	1~2H, F	H~F
SAN	1~2B	-
PC	< 2B	6B

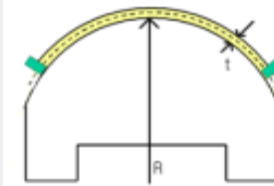
Pencil Hardness (ASTM D3363, 1kgf)

SMMA Alcohol resistance (ESCR)

SMMA outlasts PMMA in ESCR testing

ESCR (Environmental stress crack resistance) condition

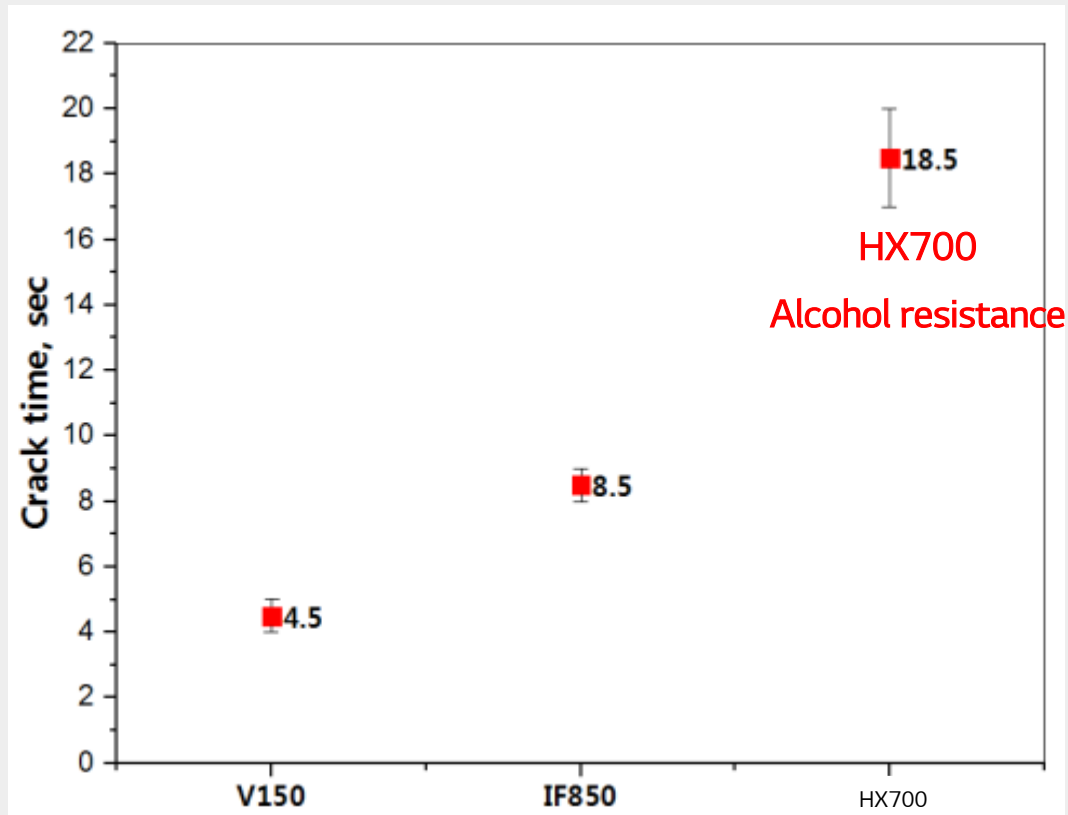
- Strain : 1.0 %
- Solvent : Ethyl alcohol (80vol%)
- Elapsed time till it breaks



$$\text{Strain(\%)} = t / (2R + t) * 100$$

t : specimen thickness
R : Jig Radius

► Results



SMMA outperforms PMMA in chemical resistance

► Applying a moisture cream over cosmetic containers and

SMMA Chemical Resistance (Cosmetics)

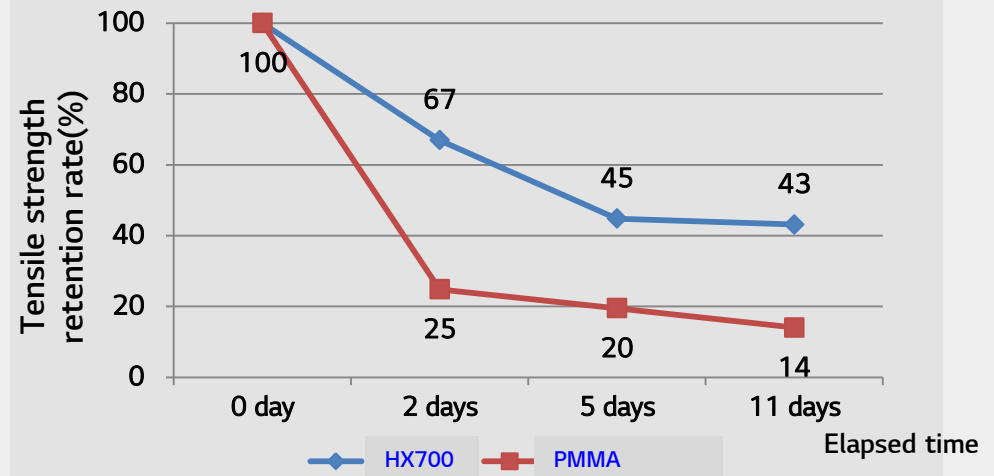
1) Cosmetic container (50°C, in 10 days)

SMMA
HX700

PMMA



2) Tensile strength retention rate
- speed : 5mm/min



SMMA Chemical Resistance (Cosmetics)

➤ Three major transparent polymer : SMMA, SAN, PET-G

: PET-G > SAN ≥ SMMA (※ Left : better → Right : C)

No.	Product name (cosmetics)	Grade		
		SMMA	SAN	PET-G
1	Body & Family sun lotion for the whole family (SPF42/PA+++)	C	C	B
2	Ohui, Absolute UV Master 100+(SPF50+/PA+++)	C	C	B
3	Majesta Protective Cream	C	A	A
4	Second Skin Foundation (SPF35/PA++)	B	A	A
5	X2D2 fresh double deep cream (moisture cream)	A	A	A
6	Hyobidam sun cream(SPF50+/PA+++)	A	A	A

Criteria

Results	ΔL^* ①	Injection molded product (Cosmetic container) Appearance change
A	0~6	Minor damage
B	7~10	damage
C	25~	Heavy damage

① L* (Brightness)

L* indicates the brightness in CIE L* a* b* color space.

L*=0 black, L*=100 white

L* value goes up when specimens are damaged

SMMA

Light Transmittance

Light transmittance 91% or more (at 3mm thick)

: It is similar to PMMA in light transmittance, and it is comparable or even higher than other transparent resin

Transparent polymer	PMMA	SMMA	PC	MABS	PS	SAN	Glass
Tt(%)	> 92	> 91	87-89	87-90	88-90	90	89-90

➤ Tt (150mm long path)

PC	SMMA	PMMA
30~55%	89%	89%

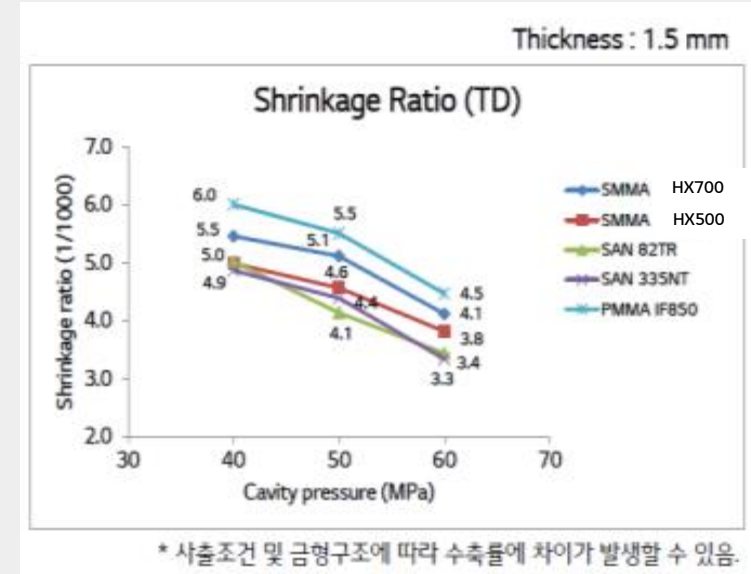
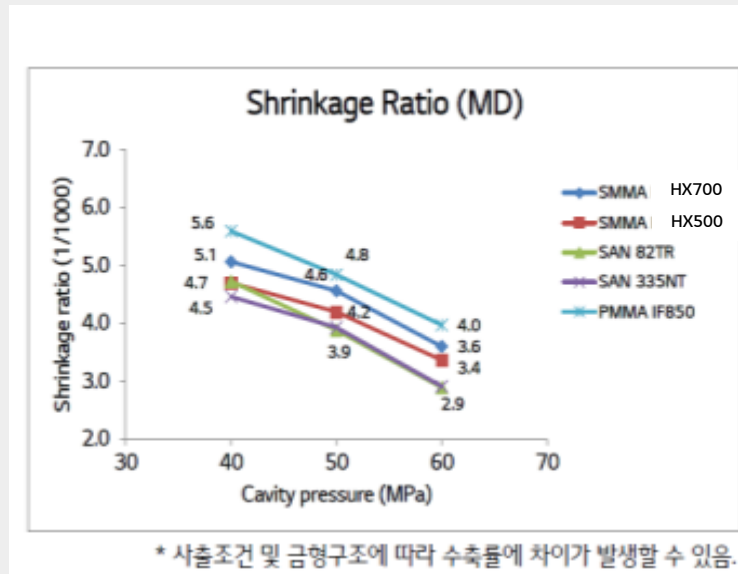


SMMA Mold shrinkage

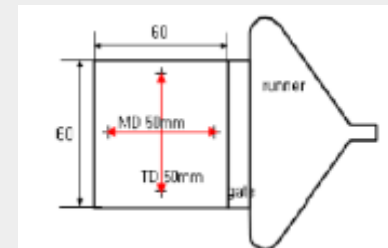
■ Mold shrinkage

1) Polymer : PMMA → SMMA → SAN

2) Flow direction : TD → MD



사출기	사출온도	금형온도	사출속도	냉각시간
Woojin 110	230 ℃	75℃	60 mm/s	30 sec



$$\text{수축률 } S = \frac{\text{금형치수} - \text{제품치수}}{\text{금형치수}} \times 1000$$

Holding Pressure & Time ↑, Mold Temp. ↓, Thickness ↓

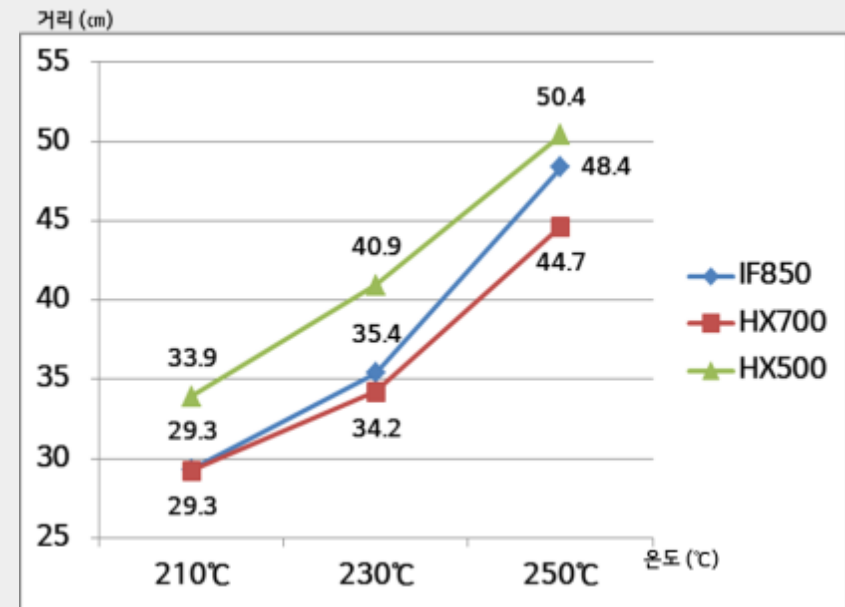
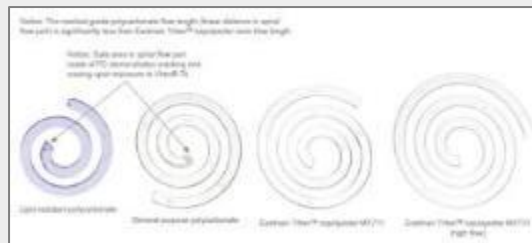
■ Melt flow index

		Injection Grades					Remarks
Grade		HX700	HX500	IF850	SAN 335NT	SAN 82TR	
MFI (g/10min)	230°C, 3.8kg	7.9	8.0	13	10	19	Standard for PMMA
	220°C, 10kg	20	27	27	28	49	Standard for SAN

■ Spiral flow path

Holding pressure / time

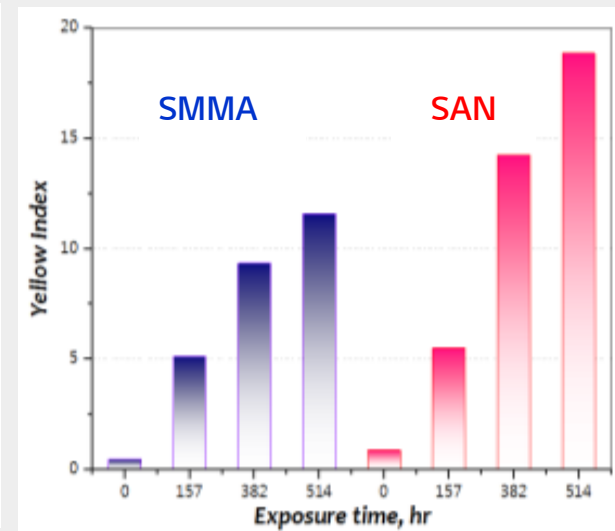
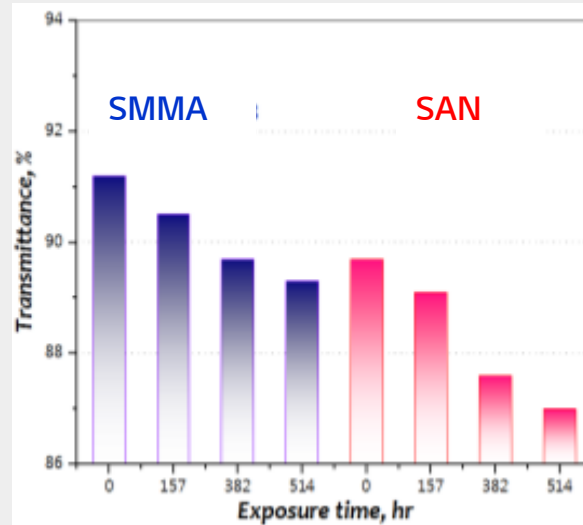
- ✓ Holding pressure 1,050kgf/cm²
- ✓ Holding time 10sec.
- ✓ Clamp tonnage 170톤



SMMA outperforms SAN

: similar to that of PMMA, and better than SAN in a UV-CON comparison

SMMA
Weatherability



SMMA Miscibility

PMMA/SMMA blend generates haze.
Immiscible between the two.

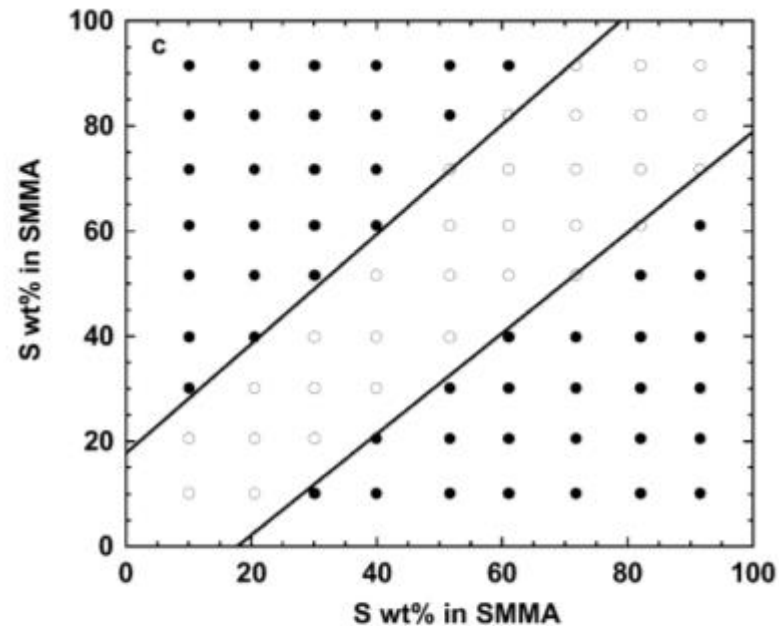
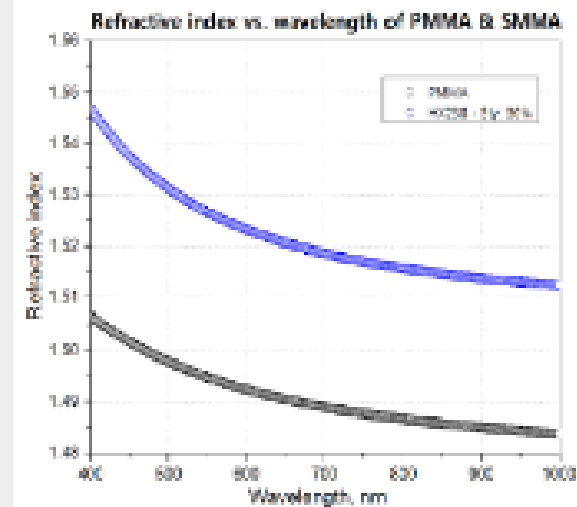


Fig. 4. Copolymer isothermal miscibility maps at (a) 120 °C; (b) 150 °C; (c) 180 °C for 50/50 blends of $S_x\text{MMA}_{1-x}/S_y\text{MMA}_{1-y}$ copolymers: (○) miscible; (●) immiscible. The $B_{S/\text{MMA}}$ values obtained from the best fit of these miscibility maps were: $B_{S/\text{MMA}} = 0.20 \text{ cal/cm}^3$ at 120 °C, $B_{S/\text{MMA}} = 0.21 \text{ cal/cm}^3$ at 150 °C, $B_{S/\text{MMA}} = 0.23 \text{ cal/cm}^3$ at 180 °C. The solid curves were calculated from these $B_{S/\text{MMA}}$ values, respectively.



→ 굴절률 상이
혼입 시 백탁 이슈

Source : Re-examination of the miscibility behavior of SMMA copolymers
using various techniques, S. Zhu, D.R. Paul

SMMA Defect (Injection molding)

▪ Bubble, void

Cooling shrinkage, Inadequate pre-drying, normally occur in thick part

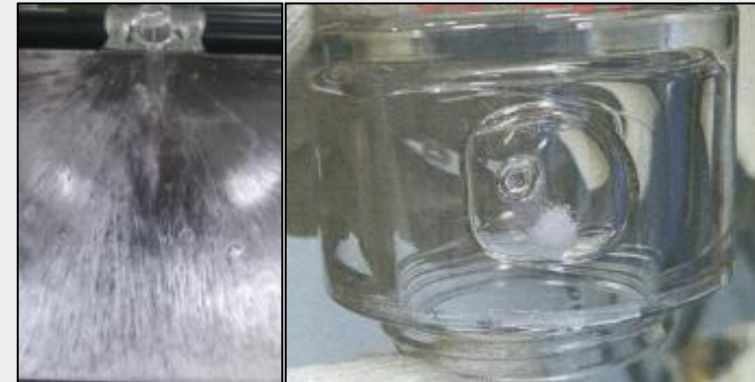
- ✓ Mold temp. ↑ (up to 80°C)
- ✓ Melt temp. ↑
- ✓ Holding pressure and time ↑
- ✓ Injection speed ↑
- ✓ Backpressure ↑
- ✓ Adequate pre-drying (70~80°C, 4hrs.)



▪ Bubble + white streak

Thermal degradation of material

- ✓ Melt temp. ↓
- ✓ Injection speed ↓
- ✓ Screw RPM ↓
- ✓ Residence time in a heated cylinder ↓
(Avoid over-cushion)



▪ Streaks

Inadequate pre-drying (moisture) or thermal degradation

- ✓ Adequate pre-drying (70~80°C, 4hrs)
- ✓ Injection speed ↓
- ✓ Screw RPM ↓
- ✓ Residence time in a heated cylinder ↓

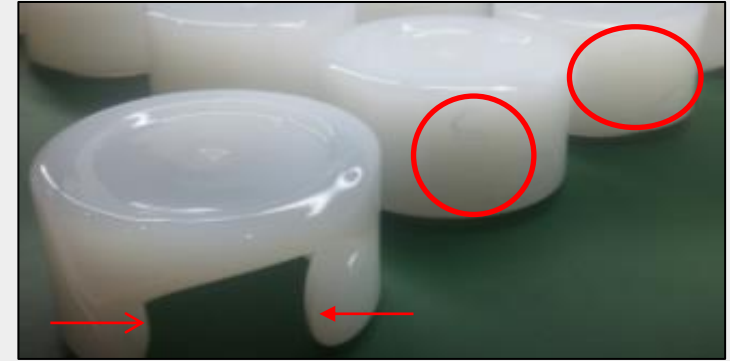
SMMA Defect

(Injection molding)

▪ Weld lines

Two melt streams meet

- ✓ Mold temp. ↑ (up to 80°C)
- ✓ Melt temp. ↑
- ✓ Injection speed ↑
- ✓ Efficient vent



▪ Insufficient Cavity filling

Insufficient melt flow

- ✓ Injection speed & pressure ↑
- ✓ Mold temp. (up to 80°C) ↑
- ✓ Melt temp. ↑
- ✓ Holding pressure ↑
- ✓ Back pressure ↑



▪ Black streaks

Air is compressed at the end of the flow path or introduction of air into the feed and subsequent carbonization when the polymer is injected into mold. (diesel effect)

- ✓ Screw RPM ↓
- ✓ Back pressure ↑
- ✓ Injection speed ↓



SMMA Defect

(Injection molding)

- Surface grooves ('record' effect)

Stick/slip effect

- ✓ Mold temp. ↑
- ✓ Melt temp. ↑
- ✓ Injection speed ↑



- Breakage during demolding

Cavity overfilling or too low temp. during demolding

- ✓ Injection pressure & holding pressure ↓
- ✓ Mold temp. ↑
- ✓ Mold opening and ejection speed ↓

- Noise during metering

Too low temp. in the feed zone

- ✓ Temp. in the feed zone ↑
- ✓ Melt temp. ↑
- ✓ Add external lubricant

- Warpage

Too high melt temp., inadequate cooling. irregular shrinkage

- ✓ Cooling time ↑
- ✓ Mold & melt temp. ↓

SMMA
Food
Safety

US FDA 21 CFR 177.1010
(Acrylic and Modified Acrylic Plastics)



Test Report

No.: T31620211425SC

Date: MAY 16, 2016

Page 1 of 3

LG MMA CORP.
58, YEOSUSANDAN-4RD, YEOSU-CITY, JEONNAM, KOREA

The following samples were submitted and identified on behalf of the client as:

HK298/SGS REF NO. AYAA16-15603

SGS Case No.	: CAS16201628729	
Sample Receiving Date	: MAR 16, 2016	
Test Performing Date	: MAR 16 ~ 24, 2016	
Last Information Date	: MAY 04, 2016	

Test Requested : Please refer to the result summary.

Test Method & Results : Please refer to next page(s).

Result Summary :

Test Requested	Conclusion
US FDA 21 CFR 177.1010 (Acrylic and Modified Acrylic Plastics)	-
a) Total Nonvolatile Extractives	PASS
b) Potassium Permanganate Oxidizable Extractives	PASS
c) Ultraviolet-absorbing Extractives	PASS

Signed for and on behalf of
SGS Hong Kong Ltd.



She Wai Leuk, Jerry
Technical Manager

a) Total Nonvolatile Extractives → Pass
b) Potassium Permanganate Oxidizable Extractives → Pass
c) Ultraviolet-absorbing Extractives → Pass

20

Bisphenol A free, Butadiene free, Acrylonitrile free

SMMA Food Safety

EU AYAA16-15699

SGS **INSTITUT FRESenius**

SGS INSTITUT FRESenius GmbH, Steinbach 109 - 4030 Tübingen

LG MMA CORP.
58, Yeosu-sandan-4ro
Yeosu-City, Jeonnam
KOREA

Taususotain, 18/04/2016

Electron Nidenthal / IT
Project Manager
Tel.: +49 69 20 744 104, Fax: +49 6123 744 504
Electron.Nidenthal@sgs.com
Consumer and Retail
Non Food

Test-report no. 2903051
Test-report version < 1 >

Original Sample ID	Sample Description	Sample Receipt Date
18028409	18028	14/03/2016

General Information

SGS-Client's ID : 13008109
SGS-Client's Order : 9891808
Ordering date : 12/03/2016
Testing period : 18/03/2016 - 07/04/2016
Order no. : AYAA16-15699
Testing scope : Test according to client's requirements

Assessment

Overall assessment : **pass**

The sample meets the requirements of LFGB and Regulation (EC) No. 1831/2003 in the tested items.

SGS INSTITUT FRESenius GmbH

L.A. Chen-Niemer (Project Manager)

L.A. Electron Nidenthal (Project Manager)

European EU AYAA16 - 15699 conforms to the requirements of food processing equipment and packaging standards.

California proposition 65

SGS

Evaluation Screening Report No. 18000167-CTANWAD-0000 Issued Date: 2016-04-26 Page 1 of 4

LG MMA CORP.
58, Yeosu-sandan-4ro, Yeosu-City, Jeonnam, Korea

The following complete assessment submitted and identified upon behalf of the client as:

SGS File No. : 18016-10000
Product Name : 18016
Brand/Trade Name : 18016
Material : 18016
Received Date : 2016-03-23
Test Period : 2016-03-23 - 2016-04-26
Buyer :
Manufacturer :
Inspector :
Country of Origin : 18016
Test Requested :
Test Method :
Test Result :
Summary :

AA requested by client, following client's 28 substances relevant for the product based on chemicals known to cause cancer or reproductive toxicity listed by State of California environmental protection agency, Office of Environmental Health Hazard Assessment with drinking water and food enforcement act of 1986.

Please refer to test pages.

Please refer to test pages.

According to the submitted sample and evaluation screening, chemicals from this Proposition 65 list were / were detected in the submitted product please refer to test pages. Further risk hazard assessment by toxicologist under existing data measurement is required.

SGS Korea Co., Ltd.
Alon Kim
Alon Kim / Project Manager

Over 900 chemical substance are listed. Major 28 chemical substance are tested.
(EA, Styrene detected)

Physical properties

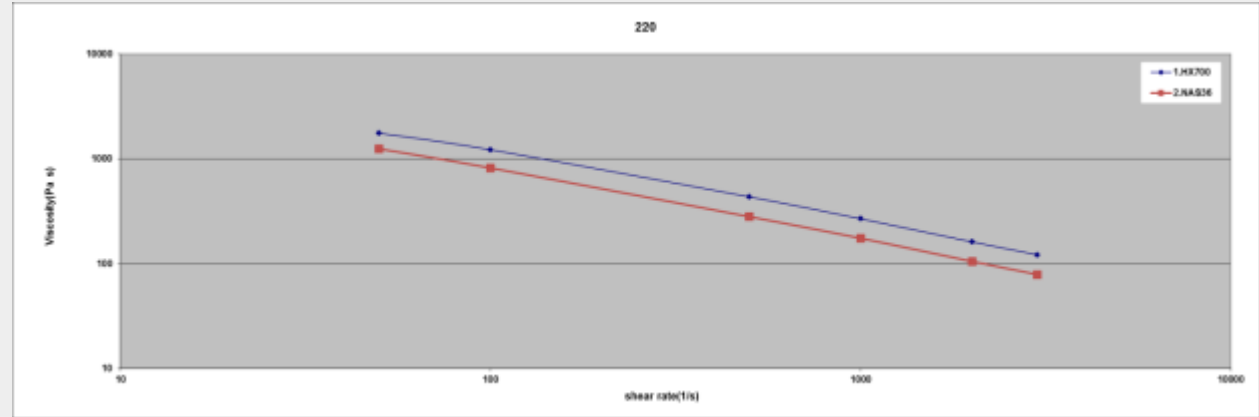
SMMA
Comparison
vs. competitor's

Items		Unit	Test Method	NAS36	HX700	CET116
Charpy Impact strength (notched)		kJ/m ²	ISO 179	1.1	1.3	
MFI		g/9min	ISO 1133	8.4	8.0	분석중
Rockwell hardness		M-scale	ISO 2039-2	68.9	87	update 예정
VICAT softening temp. (B50)		℃	ISO 306	96.4	102	
Light transmittance (3mm thick)		%	ISO 13468-1	87.1	91	
Tensile modulus (1 mm/min)		GPa	ISO 527	2.9	2.9	
Tensile strength (5mm/min, at break)		MPa	ISO 527	59	65	
Elongation (5mm/min, at break)		%	ISO 527	2.4	5.2	
Flexural strength (2mm/min)		MPa	ISO 178	95	105	
Flexural modulus (2mm/min)		GPa	ISO 178	3.2	3.2	
Tg		℃	DSC	99.8	105	
Mw		-	GPC	230K	125K	252K
Residual monomer	MMA	ppm	GC/MS	138	1,315	103
	SM (or MA)			313	1,821	665
TVOC		ug/g	P&T-GC/MS (240℃/10min)	1,200	1,500	

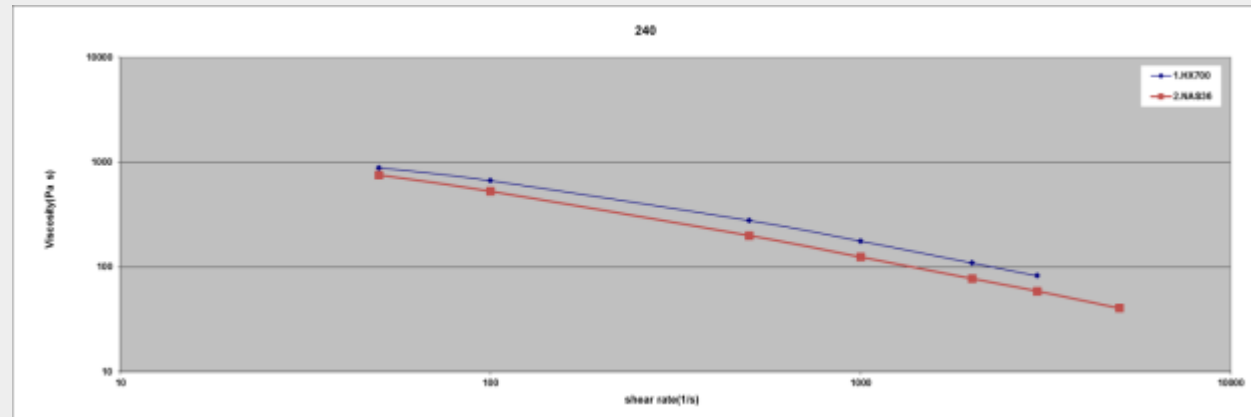
Capillary rheometer

SMMA
Comparison
vs. competitor's

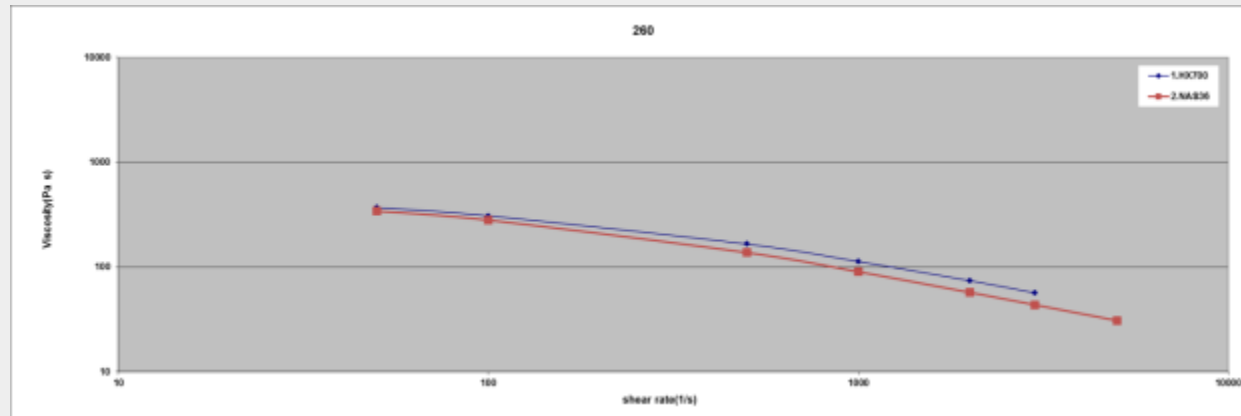
at 220°C



at 240°C



at 260°C



SMMA Application

- Cosmetic container



- Optical parts (Light guide plate, lighting cover, Lens)



- Food container (cups, ICE bucket, bowl and etc,.)



SMMA Comparison vs. PMMA

Physical properties

Items	Method	Unit	PMMA IF850	SMMA HX700	SMMA HX500
Water absorption	ASTM D570, 24hr	%	0.3	0.18	0.12
Specific Gravity	ISO 1183-1	g/cm ³	1.19	1.15	1.11
Refractive index	ISO 489	nd	1.49	1.53	1.55
Light transmittance	ISO 13468-1	%	92	91	91
HAZE	ISO 14782	%	<0.5	<0.5	<0.5
Rockwell Hardness	ISO 2039-2	M-scale	92	87	75
Melt Flow Index	ISO 1133 / at 230°C, 3.8kg	g/10min	13	7.9	8.0
VICAT Softening Temp.	ISO 306	°C	92	102	95
Tensile Modulus	ISO 527-2	GPa	2.8	2.9	3.1
Tensile Strength at Break		MPa	62	65	62
Tensile Strain at Break		%	4.0	5.2	3.0
Flexural Strength	ISO 178	MPa	101	105	100
Flexural modulus		GPa	2.9	3.2	3.1
CHARPY Impact	ISO 179 1eA	kJ/m ²	1.5	1.3	1.4
MW	-	-	95K	120K	200K
Tg	-	-	95	105	103



Thank you



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