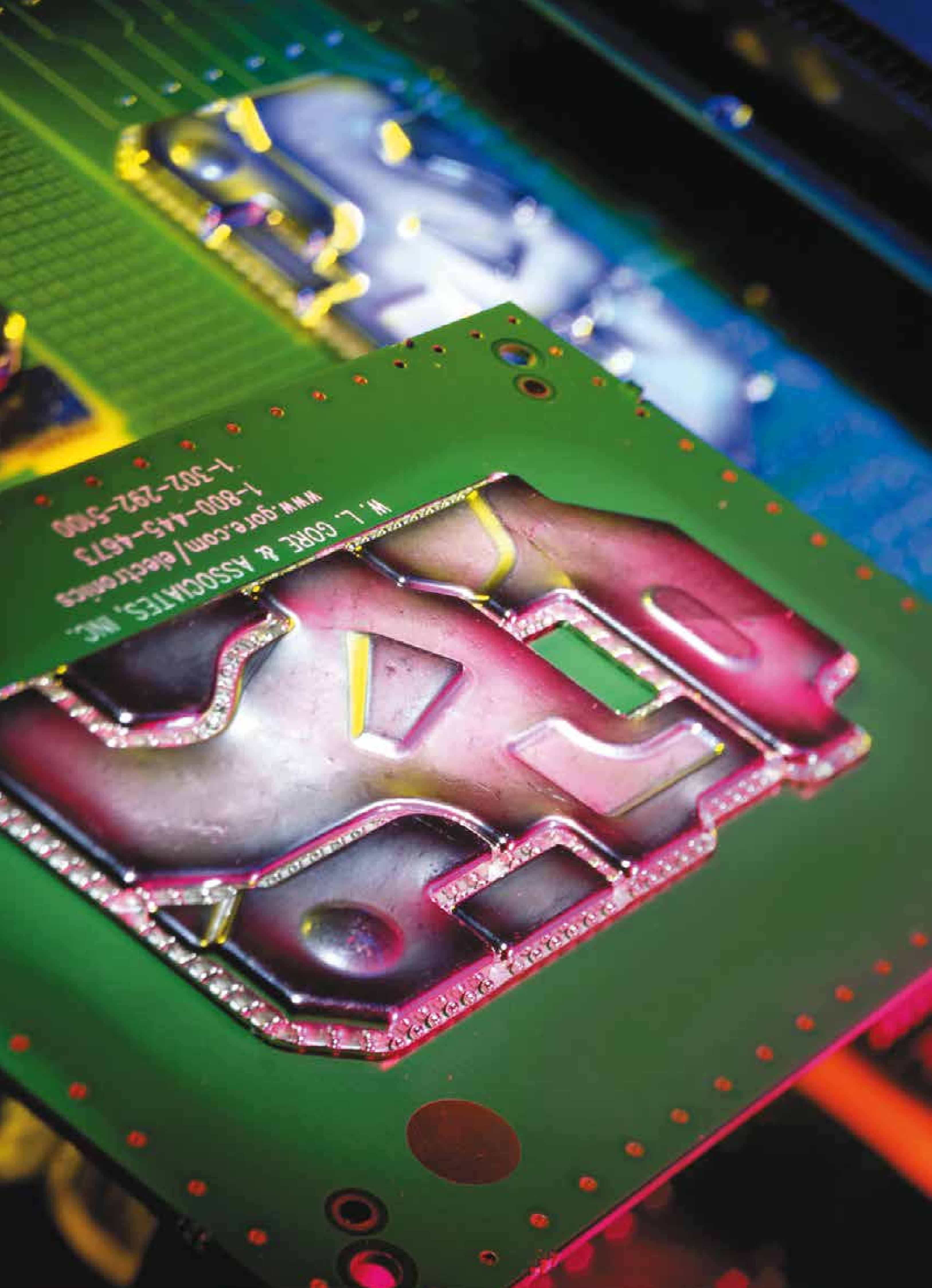
LEXAN™, VALOX™, ULTEM™, AND NORYL™ FILMS

TECHNICAL MANUAL

CHEMISTRY THAT MATTERS™

INDEX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LEXAN™, VALOX™, ULTEM™ AND NORYL™ FILMS

SABIC's Specialty Film & Sheet business, part of the Innovative Plastics business unit, offers high quality, engineered thermoplastic films across a wide variety of industries, ranging from graphics and consumer electronics to automotive. Our SABIC film portfolio is backed by advanced technical support and application development services around the world to meet our customers' global specification needs with local supply.

Speciality Film & Sheet business offers state of the art mono and multi-layer extrusion capabilities, in-line master sheeting, roll slitting and cut-to-size services. With our application development facilities, we provide lamination, folding, die-cutting; screen printing, laser-marking and 3D forming services to our Specialty Film & Sheet customers new application development needs.

SABIC operates a worldwide network of sales, distribution, research, manufacturing and technical service facilities. With all twelve ISO certified manufacturing sites across the USA, Canada, the Netherlands, Italy, Austria, China, Malaysia, India and Brazil, the Specialty Film & Sheet business serves customers around the world in a broad spectrum of industries and applications. As a business unit of SABIC, Specialty Film & Sheet benefits from global cross-business resources and expertise. From its network of technical centers in in the United States, the Netherlands, Saudi Arabia, China, Japan, Korea and India, the company provides a variety of services. These include hands-on engineering and technical support that extends from right material selection to characterization of mechanical, thermal, UV/heat aging data, advanced light measurements, optical modeling to part design and installation guidelines. The company also offers a local team, complete supply chain and distribution organization to provide a reliable source of materials to its customers wherever their manufacturing site is located.

LEXAN™ resin is a polycarbonate, amorphous engineering thermoplastic which has a high level of mechanical, optical, electrical, and thermal properties. The LEXAN resin portfolio provides a wide choice of products with potential benefits including high impact strength, inherent 'crystal-clear' transparency, and high heat resistance. Available in transparent, translucent, to opaque, the products can come in different colors.

VALOX™ resins are semi-crystalline materials based on polybutylene terephthalate (PBT) and/or polyethylene terephthalate (PET) polymers, offering a unique mix of value-added properties. Potential benefits include heat stability, electrical properties, environmental stability against chemicals and UV light, and flame resistance in certain grades.

ULTEM™ resin is an amorphous thermoplastic polyetherimide (PEI) resins that offers outstanding elevated thermal resistance, high strength and stiffness, and broad chemical resistance.

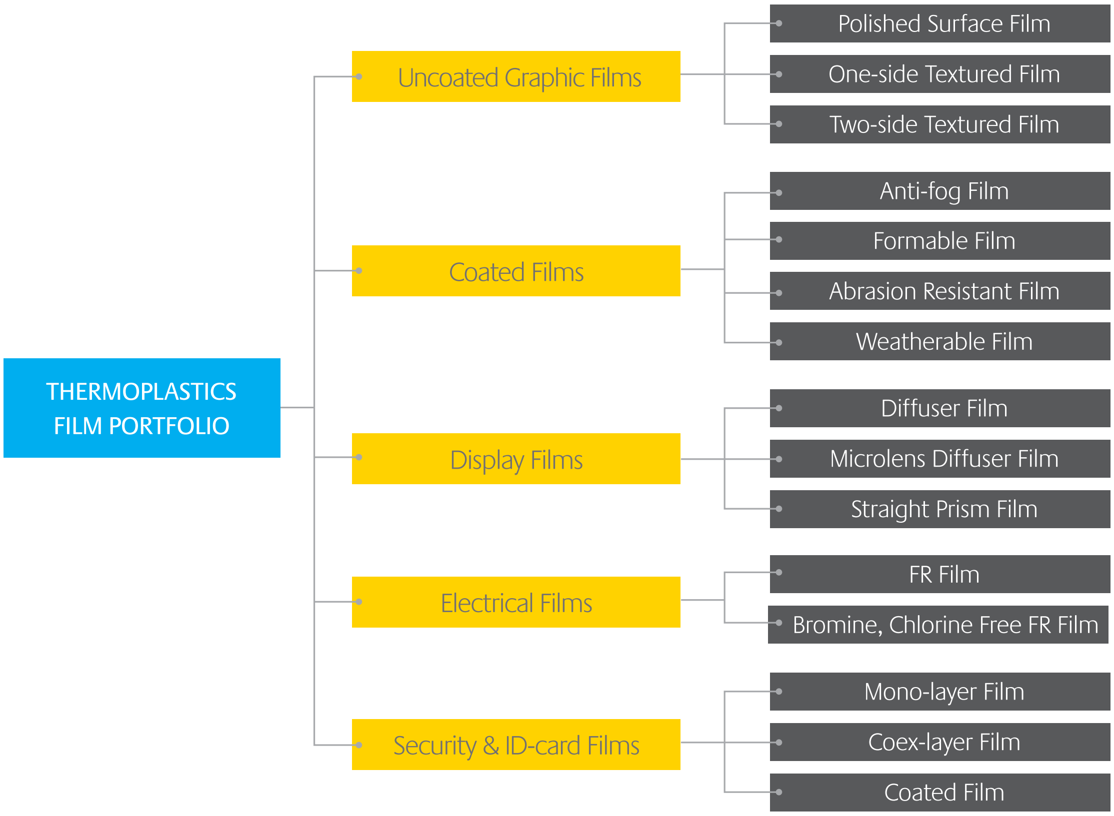
LEXAN™ SLX resin is a polycarbonate (PC) copolymer formulation that offers superior UV resistance compared to standard PC grades. The surface of the copolymer undergoes a chemical transformation to form protective UV-absorbing layer on the exposed surface. Potential benefits include gloss and color retention, chemical resistance, scratch, and weathering resistance.

NORYL™ resin is an amorphous blend of polyphenylene ether sometimes referred to as polyphenylene oxide (PPO™) resin. It is well known for good room temperature and low temperature impact strength, excellent hydrolytic stability, heat resistance, processability, and inherent flame retardance.

Note: Some of the other thermoplastic resin materials from SABIC include CYCOLOY™ resin (PC-ABS), CYCOLAC™ resin (ABS – Acrylonitrile:Styrene:Butadiene rubber), XYLEX™ resin (alloy of PC and polyester), GELOY™ resin (ASA – acrylonitrile:Styrene:Acrylic rubber) and XENOY™ resin (semi-crystalline blend of PC and PBT).

SABIC THERMOPLASTIC FILM PORTFOLIO

SABIC's Specialty Film and Sheet business offers high quality, engineering thermoplastic films across a wide variety of industries. Our thermoplastics film portfolio is backed by advanced technical support and application development services around the world.



Graphics Films

LEXAN™ Film Polished and Textured Grades

Polished LEXAN films offer 86-92% light transmission across all gauges. In addition, various masking types are available to meet customer requirements. Key benefits include true color reproduction, excellent depth effect with no loss of vividness in second-surface printing, chemical resistance and weathering (LEXAN SLX film), scratch and wear resistance (LEXAN 6060 film) and easy formability.

Textured LEXAN film grades offer broad design flexibility and aesthetic appeal. Either one-side or two-side textured products can be designed with square corners, straight sides, narrow-width lines and flat plateaus. Key features of the films include excellent printability without pre-treatment and clean edge die-cut ability. Clear windows can be wet out using screen printed inks for applications that require a combination of texture and polish. Textured films are suitable for a broad range of applications including automotive dials, consumer electronics, labels for industrial equipment, control panels for HVAC and office equipment.

Table 1: Surface Texture Guide:

Texture Guide	
Polished	Excellent printing surface with true ink color fidelity and optics. Potential applications include LED/LCD windows and a primary substrate finish for screener-applied selective textures.
Fine matt	Good printing surface and not as smooth as polished.
Matt Light diffuser	Hides filaments and eliminates 'hot spots' in back-lit applications. The preferred finish for 'dead front' graphics. Offers reduced surface reflection and gloss.
Velvet	Hides scratches, fingerprints and marring for heavy-use applications. Also acts as a diffuser for "windowed" or back-lit applications.
Suede	Often used in very heavy-wear applications. Benefits may include resisting abrasion while maintaining an attractive appearance.
Brushed	Unique brushed texture provides metallic appearance

Table 2: Partial list of Graphics Grade Films from SFS

LEXAN Film Grade	Resin Type	Texture	Gauges* (in/µm)
6060	PMMA-PC	Polish / Polish	0.005-0.015 (0.125-375 µm)
60610	PC	Polish / Polish	0.020-0.05" (500-1200µm)
8010 (Q)	PC	Polish / Polish	0.005-0.030" (125-750µm)
8010 (Q) SHT	PC	Polish / Polish	0.020-0.054" (500-1250 µm)
8040	PC (FDA approved)	Polish / Polish	0.007-0.030" (175-750µm)
11010	PC (SLX grade)	Polish / Polish	0.010-0.030" (250-750µm)
8A35	PC	Polish / Velvet	0.005-0.010" (125-250µm)
8A13F	PC	Polish / Fine Matte	0.007-0.010" (175-250µm)
8A13E	PC	Polish / Matte	0.003-0.020" (75 -500µm)
8A37	PC	Polish / Brushed	0.010-0.030" (250-750µm)
8B35E	PC	Matte / Velvet	0.003-0.020" (75 -500µm)
8B35F	PC	Fine Matte / Velvet	0.007-0.030" (175-750µm)
8B36	PC	Matte / Suede	0.010-0.020" (250-500µm)
8B38	PC	Velvet/Very Fine Matte	0.010-0.030" (250-750µm)
11A13	SLX	Polish / Matte	0.004-0.020" (100-500µm)
11B35	SLX	Velvet / Matte	0.004-0.020" (100-500µm)

*common gauges – other gauges available

Coated Films

LEXAN™ high performance (HP) coated films offer unique solutions for scratch resistance, weatherability, anti-glare and anti-fog applications. These films have excellent resistance to abrasive cleaners, chemicals and UV; providing excellent clarity of graphics and light diffusion as well as ease of printing and die cutting.

Table 3: Coated film surface finishes

92 gloss	Polished	High gloss, smooth, wet look finish
60 gloss	Very Fine Matte	Low glare. Not as smooth as polished.
40 gloss	Fine Matte	Lower surface reflection
12 gloss	Matte	Lowest surface reflection

Table 4: Partial list of coated film products (xx denotes gloss value)

Grades	Substrate	Key Benefits	Gauges*
HPxxS	PC	Abrasion resistance; printable both surfaces	0.007-0.030” (175-750µm)
HPxxW	PC	Weatherable and chemical resistance	0.007-0.030” (175-750µm)
HPxxX	PC	Weatherable and chemical resistance; printable	0.007-0.030” (175-750µm)
HPxxE	PC	Abrasion resistance and flexible	0.007-0.030” (175-750µm)
HPxxT	PC	Abrasion resistance and 2.5D formable	0.007-0.030” (175-750µm)
HPHAF	PC	Anti-fog	0.007-0.02” (175 - 500µm)
HPNGAF	PET	Anti-fog	0.004” (100µm)
HPNGFF	PET	Anti-fog with adhesive backing	0.004” (100µm)
OQ6DA	PC/PMMA	Dual coated, high pencil hardness and abrasion resistance	0.020-0.050” (500-1200 µm)^
OQ8DA	PC	Dual coated, chemical and abrasion resistance	0.020 - 0.050” (500-1200 µm)^

* common gauges – other gauges available
^ Sheeted films

LEXAN high performance films are potentially suitable for applications such as membrane switches, anti-reflective computer screens, display windows for consumer electronics, cell phone and hand-held device lenses, washing machine and microwave oven control panels, etc.

Electrical Films

Clear or opaque LEXAN™ FR films are flame retardant polycarbonate materials, which offer consistent properties for insulation and printability. These include puncture resistance, low moisture absorption, high thermal performance, formability and excellent dielectric strength. Potential applications include heat/dielectric insulation, die-cut insulators and spacers, labels and overlays, printed circuit boards and EMI shielding. These materials comply with UL94 V-0.VTM-0; HWI, HAI, CTI performance; meeting UL-1950, IEC950 for flame resistance requirements.

These materials support compliance with leading regulations such as the European Union (EU) Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) directives and the Registration, Evaluation and Authorization of Chemicals (REACH) standard.

Generally bromine is used as the primary flame retardant additive for thermoplastic materials. For polycarbonate, this is normally incorporated as a co-polymer using tetrabromobisphenol A as a reactant. Levels of bromine are then adjusted depending on the application and amount of flame retardance needed.

Polybutylene terephthalate based VALOX™ FR1 film offers benefits of good temperature resistance, dielectric strength, and ease of fabrication. This material has been used in a variety of applications in the graphics and electronics industries: barrier insulation in electronics and menu boards. Other key features of VALOX film are low moisture absorbance and chemical resistance that has led to use of this product in EMI/RFI shields.

Table 5: Electrical Film Products

Product Name	Key Features	Gauge Availability	UL Rating/Gauge
LEXAN FR60 Film	Clear Polish/Polish surfaces	0.005-0.030" - (125-750µm)	VTMO/125µm - V0/200µm
LEXAN FR63 Film	Translucent Matte/Polish surfaces	0.007-0.020" - (175-500µm)	VTMO/125µm - V0/200µm
LEXAN FR65 Film	Translucent Velvet/Matte surfaces	0.007-0.020"v(175-500µm)	VTMO/125µm - V0/200µm
LEXAN FR83 Film	Translucent Matte/Polish surfaces (Black and clear colors)	0.002-0.007" - (50-175µm)	VTM0/50µm
LEXANFR700 Film	Opaque Black Velvet/Fine Matte	0.010-0.030"v(250-750µm)	VTM0/175µm - V0/250µm
LEXAN FR25A Film	Opaque Black Velvet/Polish (Black and White colors)	0.010-0.030" - (250-750µm)	VTM0/175µm - V0/250µm
VALOX FR1 Film	Matte/Polish	0.003-0.030" - (75-750µm)	VTM0/125µm - V0/625µm

UL file numbers: EU-E45329, USA-E121562, China-E207780
All LEXAN FR films are certified with the Canadian Standards Association (CSA).

Bromine, Chlorine Free FR Films

These environmentally responsible, UL compliant, translucent or opaque films deliver non-brominated, non-chlorinated, flame retardant performance at various gauges, enabling electrical/electronic OEMs to go beyond current environmental directives by voluntarily eliminating halogenated additives in their products while meeting the requirements of the European Union's Restriction of Hazardous substances (RoHs) and Waste electrical and electronic equipment (WEEE) directives. Potential applications include heat/dielectric shielding and insulation barriers, EMI shielding, die-cut insulators and spacers, battery packs and adaptors for computers, laptops, mobile/cell phones.

First Bromine, Chlorine Free FR Film product from SABIC was PPO™ based NORYL™ EFR735 film which offers flame retardance down to 0.006" (150μm) thickness. It has been used in variety of applications for electrical, electronic, and transportation applications. More recent applications have been battery pack insulation film applications. PPO offers high dielectric strength and resistance to hydrolysis and provides ease of fabrication such as thermoforming, embossing, clean edges with die-cutting, score-and-bend.

Another classic Bromine, Chlorine Free FR Film that is inherently flame-retardant, PEI based ULTEM™ 1000B film which offers an excellent combination of high temperature performance with low moisture absorption and dielectric strength. It has been used in high voltage internal insulation, high-temperature PSA tapes, motor slot liners and wedges, transformer wraps, layer and phase insulation, and speaker cones. ULTEM 1000B film is a thermoformable material and can be heat-sealed to a wide variety of metals and thermoplastics.

Table 6: Bromine, Chlorine Free FR Film Products

Product Name	Key Features	Gauge Availability	UL Rating/Gauge
LEXAN EFR63 Film	Translucent Matte/Polish surfaces	0.005-0.020" - (125-500μm)	VTMO/100μm - V2/430μm
LEXAN EFR65 Film	Translucent Velvet/Matte surfaces	*0.002-0.020" - (50-500μm) **0.005-0.020" - (125-500μm)	VTMO/100μm - V2/430μm
LEXAN EFR85 Film	Black opaque Velvet/Polish	0.007-0.030"v(175-750μm)	VTMO/175μm - V0/375μm
LEXAN EFR95 Film	Velvet/Fine Matte surfaces Black and White colors	0.007-0.030" - (175-750μm)	VTMO/175μm - V0/375μm RTI 130ºC at 375μm and above
NORYL EFR735 Film	Black Matte/Fine Matte surfaces	0.006-0.030" - (150-750μm)	VTMO/50μm - V0/250μm
ULTEM 1000B Film	Matte/Matte; Polish/Matte	0.002-0.030" - (50-750μm)	VTMO/25μm - V2/200μm

UL file numbers: EU-E45329, USA-E121562, China-E207780

* 50-500μm available for black color
** 125-500um available for natural color

Both electrical and Bromine, Chlorine Free FR Films can be easily fabricated with conventional converting equipment including forming, embossing, and steel rule die creasing and/or cutting. Many electrical films offered by SABIC hold their shape when bent, which allows for ease of assembly. They are also well suited for lamination and use with adhesives that may provide flexibility to combine shielding and insulation in a single part.

Secure ID Films

SABIC's LEXAN™ SD film portfolio has been specially designed for easy manufacturing and lamination of complex secure ID cards. These products directly address accelerating industry trends calling for more and thus thinner card layers to accommodate additional safety features, provide easy processing and enchanced durability for ID cards and other security documents.

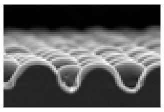
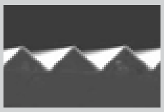
Table 7: LEXAN SD Film products

Grade Name	Key Features	Gauge Availability
LEXAN SD8B14 film	Clear 2 side textured monolithic PC clear overlays or intermediate layers.	30-400 μm
LEXAN SD8B24 film	Bright white, opaque 2 side textured monolithic PC film for core layers.	50-440 μm
LEXAN SD8B94 film	Clear laser mark able 2 side textured monolithic PC film for high contrast laser personalization	30-150 μm
LEXAN SDCX film	Clear or white co-extruded films for easy processing and laser marking	150 μm
LEXAN SC8A12E film	Flexible hard coated film with clear overlay	105 μm
LEXAN SC8A92E film	Flexible hard coated film with clear laser markable overlay	105 μm

Display Films

LEXAN™ Display films provide light diffusion and/or collimation while maximizing light transmission and LED hiding power for the LCD and LED back lighting industry. These products combine SABIC's expertise in optical quality resins and texture design with a clean room manufacturing environment.

Table 8: LEXAN Display Film products

Grade series	Texture	Key features	Gauge Availability
MB-grades Basic Lens Diffuser		- Excellent hiding power - Good luminance - Suitable for stackable format	200-350 μm
PA Grades Straight Prism		- Straight prism, rounded tip - Matte backside for anti-scratch - Two different pitches (200um) - Right balance collimation & moiré	300-500 μm

Masking

Masking is often used to protect surfaces of LEXAN films immediately after extrusion. This is especially true of polished and lightly textured grades. There are several types of masking that could be applied, and the most common are explained below:

Stick Masking: A masking with pressure sensitive adhesive, applied for use when rough handling is expected during shipping or processing. This can be used for applications requiring thermoforming, pressure forming, or other machining operations as required. Tack level (adhesion) of the masking is important and is generally measured in oz/in. Values between 0.5 and 2.5 oz/in are typical.

Cling Masking: A static-applied masking material designed for easy removal.

Polished LEXAN films are available with several masking materials to protect the surfaces during transportation and processing. Coated LEXAN films are available with masking on both sides. Typically cling masking is applied on the coated side while a variety of different maskings are applied depending on the gloss (texture) of the coated side. An example is the Y mask, a co-extruded masking available for 92 gloss HP films which prevents an increase in tack level due to age or processing even after up to 20 passes of solvent or UV ink printing.

Table 9: Masking information for uncoated films

Designation	Top Mask	Bottom Masking
C	CLING	STICK
E	CLING	CLING
Y	COEX	CLING

Table 10: Masking information for coated films

Designation	Top (Coated) Mask	Bottom (Uncoated) Masking
B (HP12, HP40, HP60)	STICK	CLING
D (HP12, HP40)	NO-MASK	CLING

Color of Films

Color of graphics films are generally natural (clear), black, or white. Custom colors are normally made with minimum order quantities required.

Core sizes of Film rolls

Typical core sizes available are either 6” or 10” in diameter for graphics and electrical films. Coated films are available only in 10” core sizes.

Properties and Test Methods for SABIC's Thermoplastic Films

The following section is intended as a brief introduction to general definitions and test methods for thermoplastic films with some values provided for SABIC films. For detailed test methods and procedures, it is recommended that the current ASTM, IEC, or other standard are consulted. For specific properties of SABIC film grades refer to the product data sheet for the most accurate information.

Table 11: Typical Properties of SABIC Graphics, Coated, EID and Display Films

			Graphics	Graphics	Coated Films	EID films	Display films
			LEXAN™ SLX Film	LEXAN™ Film	LEXAN™ Film	LEXAN™ SD8B 14-4 mil Film	LEXAN™ DS-10 mil Film
Property	**Test**	**Unit**		**Value+**	**Value+**		
Physical							
Specific Gravity	DIN 53479		1,26	1,20	1,20	1,20	1,20
Water Absorption, 24 hours	ASTM D570	% change	0,35	0,35	0,35	0,09	0,35
Surface Roughness (Ra)	ISO 4288	mm	-	-	-	0.9 (FM) / 2.3 (FV)	-
Surface Roughness (R3z)	ISO 4288	mm	-	-	-	4.2 (FM) / 12.3 (FV)	-
Surface tension	Dyne solutions	Dyne/cm	-	-	-	44 (FM) / 37 (FV)	-
Pencil Hardness	ASTM D3363	-	HB	B	HB-4H≠	-	-
Optical							
Haze	ASTM D1003	%	< 1	0.4 Polished	0.5 Polished	-	85-89
Light Transmission	ASTM D1003	%	88	91	92	87	90-92
Color : b-value	CIELab, Reflection, D65, 100		-	-		1,75	-
Refractive index, 25°C	ASTM D524A	-	1,6	1,6	1,5	1,6	1,6
Mechanical							
Tensile Strength	ASTM D882						
at yield		psi (MPa)	12,100 (75.4)	8,500 (60)	8,500 (60)	8122 (56)	(59.4) MD / (58.4) TD
at break		psi (MPa)	12,600 (85.7)	9,000 (65)	8,500 (60)	8122 (56)	(73.9) MD / (66.7) TD
Elongation at break	ASTM D882	%	74	100	100	85	101 (MD) / 115 (TD)
Tensile Modulus	ASTM D882	psi (Mpa)	367000 (2530)	300000 (2500)	305000 (2100)	311000 (2150)	-
Tear Strength							
Initiation	ASTM D1004	lb/mil (kN/m)	1.73 (245)	1.4 (245)	1.4 (245)	1.4 (245)	-
Propagation	ASTM D1922	g/mil (kN/m)	18 (10-20)	30-55 (10-20)	40 (14)	30-55 (10-20)	-
Coefficient of static friction	ASTM D1894	-		-	-	-	-
Coefficient of kinetic friction	ASTM D1894	-		-	-	-	-
Poisson's ratio	ASTM D132-61	-		0,38	0,38	-	-
Thermal							
Shrinkage at 302˚F (150˚C)	ASTM D1204	%		1,4	1,4	-	-
Shrinkage at 130˚C	Internal method	%	-	-	-	0,17	-
DTUL, @ 264 psi (1.8 N/mm2)	ASTM D648	°F (°C)	252 (122)	290 (145)	290 (145)		
Vicat Softening Temperature, B	ASTM D1525	°F (°C)	290 (144)	320 (160)	320 (160)	295 (146)	
Coefficient of Thermal Expansion	ASTM E831	x 10-5 /°F (x 10-5 /°C)	3.2 (5.8)	3.2 (5.8)	3.2 (5.8)	4.2 (7.5)	
Linear CTE, TD/MD	ASTM D696 / ISO 11359	ºC-1	-	-	-	-	6-7x10-5 *
Thermal Conductivity	ASTM D5470	Btu/hr/ft2/°F /in	1,35	1,35	1,35	-	-
		(W/m.°K)	(0.2)	(0,20)	(0,20)	-	-
Heat Shrinkage, TD	ASTM D2732 / ISO 11501	%	-	-	-	-	0,16
Heat Shrinkage, MD	ASTM D2732 / ISO 11501	%					0,06
Brittleness Temperature	ASTM D746	°F (°C)		-211 (-135)	-211 (-135)		

*Dual coated films

Table 11: Typical Properties of SABIC Graphics, Coated, EID and Display Films (continued)

			Graphics	Graphics	Coated Films	EID films	Display films
			LEXAN™ SLX Film	LEXAN™ Film	LEXAN™ Film	LEXAN™ SD8B 14-4 mil Film	LEXAN™ DS-10 mil Film
Property	Test	Unit		Value+	Value+		
Dielectric Strength, 23°C,							
10 mil (0.25mm)	ASTM D149	kV/mil		1.81 (71)	-	-	-
in oil, short time		(kV/mm)	-	-	-	-	-
Dielectric Constant	ASTM D150						
at 60 KHz			-	2,32	-	-	-
at 1 KHz			-	2,3	-	-	-
at 1 MHz			-	2,3	-	-	-
Dissipation factor	ASTM D150						
at 60 Hz			-	0,001	-	-	-
at 1 KHZ			-	-	-	-	-
at 1 MHz			-	0,006	-	-	-
Volume Resistivity	ASTM D257	Ohm-cm	-	8.65 E +16	-	-	-
Surface Resistivity	ASTM D257	Ohm/square	-	5.24 E+15	-	-	-
Arc Resistance, Tungsten	ASTM D495	s	-	70	-	-	-
Flammability •							
Oxygen index	ASTM D2683	%	-	25	25	-	-
UL Flammability	UL94		V-2, 0.250 mm	VTM-2, 0.075 mm VTM-0, 0.075 mm HB 0.25 mm	HB, 0.250 mm	-	-
			V-2, 0.250 mm V-0, 0.250 mm				

• These ratings are not intended to reflect hazards presented by this or any other material under actual fire conditions. n.a. not applicable

Table 12: Typical properties of electrical films

			Electrical films				
			FR LEXAN™ Film	LEXAN™ Bromine, Chlorine Free FR Film	NORYL™ Film	ULTEM™ Film	VALOX™ Film
Property	Test	Unit	Value+	Value+ EFR65	Value+	Value+	Value+
Physical							
Specific Gravity	DIN 53479		1,32	1,20	1,09	1,27	1,34
Water Absorption, 24 hours	ASTM D570	% change	0,28	0.14	0,07	0,48	0,48
Surface Roughness (Ra)	ISO 4288	mm	-	-	-	-	-
Surface Roughness (R3z)	ISO 4288	mm	-	-	-	-	-
Surface tension	Dyne solutions	Dyne/cm	-	-	-	-	-
Pencil Hardness	ASTM D3363	-	B	-	-	B	B
Optical							
Haze	ASTM D1003	%	0.6 Polished	97.2	-	-	103 white
Light Transmission	ASTM D1003	%	91	92.6	-	-	15
Color : b-value	CIELab, Reflection, D65, 100		-	-	-	-	-
Refractive index, 25°C	ASTM D524A	-	1,6	1,6	-	-	-
Mechanical							
Tensile Strength	ASTM D882						
at yield		psi (MPa)	10,000 (70)	7832	9000	14,500 (100)	7200 (50)
at break		psi (MPa)	8,500 (60)	8267	7900	13,800 (95)	6000 (41)
Elongation at break	ASTM D882	%	25	> 90	12	50	150
Tensile Modulus	ASTM D882	psi (Mpa)	319000 (2200)	295700 (2050)	294000 (2025)	421000 (2900)	277000 (1900)
Tear Strength							
Initiation	ASTM D1004	lb/mil (kN/m)	1.7 (298)	1.23 (216)	1.35 (236)	2.2 (365)	1.5 (250)
Propagation	ASTM D1922	g/mil (kN/m)	20 (6)	30.8	29	25 (8)	54 (20)
Coefficient of static friction	ASTM D1894	-	-	-	-	0,72	0,39
Coefficient of kinetic friction	ASTM D1894	-	-	-	-	0,65	0,35
Poisson's ratio	ASTM D132-61	-	0,38	-	-	0,42	0,38
Thermal							
Shrinkage at 302°F (150°C)	ASTM D1204	%	0,9	1.2 (MD) / 0.23 (TD)	0.15 (MD) / 0.08 (TD)	0.33 {170°C}	0,4
Shrinkage at 130°C	Internal method	%	-	-	-	-	-
DTUL, @ 264 psi (1.8 N/mm^2)	ASTM D648	°F (°C)	290 (145)			392 (200)	174 (79)
Vicat Softening Temperature, B	ASTM D1525	°F (°C)	347 (175)	303 (150)	282/309 (139/154)	419 (215)	346 (174)
Coefficient of Thermal Expansion	ASTM E831	x 10-5 /°F (x 10-5 /°C)	3.2 (5.8)	3,6 (6.5)	4.4 (7.9)	2.7 (5.0)	3.1 (5.7)
Linear CTE, TD/MD	ASTM D696/ ISO 11359	°C-1	-	-	-	-	-
Thermal Conductivity	ASTM D5470	Btu/hr/ft2/°F /in (W/m.°K)	1,35 (0,20)	1.66 -	- -	1,49 (0,22)	1,35 (0,20)
Brittleness Temperature	ASTM D746	°F (°C)	-211 (-135)	< -112 (-80)		-	-211 (-135)
Electrical							
Dielectric Strength, 23°C,							
10 mil (0.25mm)	ASTM D149	kV/mil	1.5 (59)	1,73	1.8	5 (197)	1.09 (43)
in oil, short time		(kV/mm)	-	-	-	-	-
Dielectric Constant	ASTM D150						
at 60 KHz			2,9	2.29		3,2	3,31
at 1 KHz			2,8	2.94	2.75	3,2	3,26
at 1 MHz			2,8			3,2	2,8
Dissipation factor	ASTM D150						
at 60 Hz			0,0026	0.01		-	0,0015
at 1 KHZ			0,0028	0.006	0.0028	0,004	0,004
at 1 MHz			0,0117			0,005	0,01
Volume Resistivity	ASTM D257	Ohm-cm	1 E+17	> 1.00E+17		2.5 E+15	1 E+17
Surface Resistivity	ASTM D257	Ohm/square	1 E+16	> 1.00E+16		1.9 E +16	1 E+16
Arc Resistance, Tungsten	ASTM D495	s	64			54	21
Flammability•							
Oxygen index	ASTM D2683	%	33	-	-	47	30
UL Flammability	UL94		VTM0 0.05mm V0 0.25-0.75mm	VTM2 0.05mm VTM0 0.1mm V2 0.42mm	VTM0 0.15mm V0 0.25 -0.75mm	VTM-0, 0.025 mm	VTM-2, 0.075 mm VTM-0, 0.127 mm

• These ratings are not intended to reflect hazards presented by this or any other material under actual fire conditions. n.a. not applicable


DANGER
Electrical Shock
Hazardous Voltage
Will cause
SEVERE INJURY OR DEATH.
Do not remove this cover.
Disconnect main power
before servicing.
See instruction manual.
40-00031-001-02

Physical Properties

Density/specific gravity (ASTM D792)

The difference between density and specific gravity is the following: density is mass per unit volume of a material at 73°F (23°C); specific gravity is the mass of a given volume of material at 73°F (23°C) divided by an equal volume of water at the same temperature. The conversion is: density (kg/m³) = specific gravity x 0.99756. The "relative density" is synonymous with "specific gravity".

Table 13: Specific gravity (g/cc)

LEXAN film	LEXAN FR film	VALOX film	ULTEM film	LEXAN SLX film	LEXAN Bromine, Chlorine Free FR Film	NORYL film
1.20	1.32	1.34	1.27	1.26	1.23	1.09

These values are used to determine the area factor, or the amount of coverage for a given thickness.

In a formula this reads:
Area factor in m²/kg = 1/(spec. gravity x thickness (mm))
Convert to ft²/lb by multiplying the Area factor in m²/kg by 4.8816.
Therefore, a 10 mil (0.254 mm) standard LEXAN film has approximate coverage of 3.28 m²/kg or 16.0 ft²/lb.

Water absorption/moisture (ASTM D570)

The determination of water absorption by a plastic specimen of defined dimensions is carried out by immersion in water for a specified time and at a specified temperature. The measured results are expressed in either milligrams absorbed water or as a percentage increase in weight.

The moisture content may result in changes in dimensions or in properties such as electrical insulation resistance, dielectric losses, mechanical strength and appearance.

Optical Properties

LEXAN films' optical properties are important for graphic and packaging applications. High light transmission and low haze values make LEXAN film one of the highest clarity films available. In applications where optical quality or low stress is important, Optical Quality (OQ) grades may be appropriate.

Haze

Haze is a measurement of the amount of perpendicular light transmission lost due to scattering within the film. Haze contributes to difficulty in seeing objects clearly through the film and muting of second-surface printed inks. LEXAN polished film's low haze levels provide clarity and excellent color of second-surface inks. LEXAN Display diffuser films' (MB, PA, PB and DS) high haze level provide good hiding power to the light sources behind the films which is desirable for display and lighting applications.

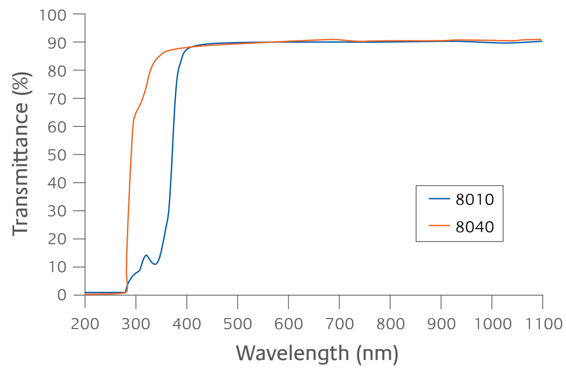
Yellowness Index

Yellowness Index is a number calculated from spectrophotometric data that describes the change in color of a test sample from clear or white color to yellow. It is commonly measured using a spectrophotometer according to ASTM E313 and the value is used to evaluate color changes in a material caused by real or simulated outdoor exposure Low YI values prevent color changes of white and pastel inks printed on the second surface of the film. Special LEXAN film products with controlled YI are available. Please contact your local film distributor for more information.

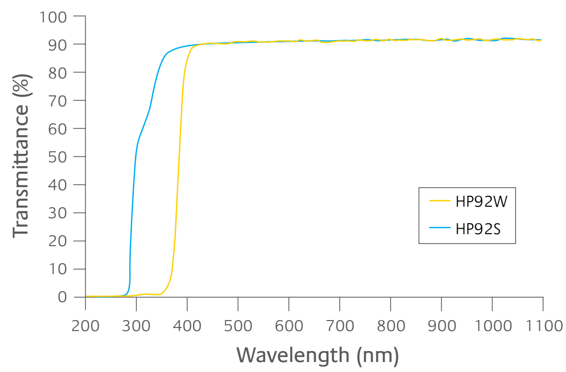
Light Transmission

As shown in Graph 1 and 2, most LEXAN films transmit approximately 90% of visible light and are somewhat opaque to ultraviolet light. This helps to protect second-surface graphics, package contents and the film itself from degradation caused by ultraviolet radiation from the sun and fluorescent lighting. Long-term, direct solar exposure, however, is not recommended without additional protection to reduce chalking of the film surface. Custom colors and grades are available to block or transmit more or less light at specified wavelengths.

Graph 1: Typical Light Transmission Values LEXAN Films Stabilized and Unstabilized



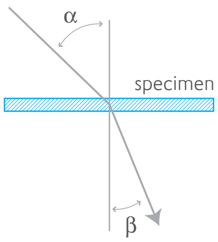
Graph 2: Typical Light Transmission Values Coated film stabilized and unstabilized



Refractive Index

A light beam is transmitted through a transparent specimen at a certain angle. The deviation of the beam caused when the light passes through the specimen is the index of refraction, which can calculated by dividing sin α by sin β. See figure 1.

Figure 1: Refractive Index



Gloss DIN 67350, ASTM D 523

Gloss is associated with the capacity of a surface to reflect more light in some directions than in others. Gloss can be measured with a glossmeter. A bright light is reflected off a specimen at an angle and the brightness of the reflected beam is measured by a photodetector. Most commonly, a 60° angle is used. Polished materials can be measured at 20° and matte surfaces at 85°. The angle used may also depend on the intended use of the material. The glossmeter is calibrated by using a black glass standard with a gloss value of 100. Gloss is commonly measured after printing operations as well. See Figure 2 and Tables 14/15.

Figure 2: Gloss meter

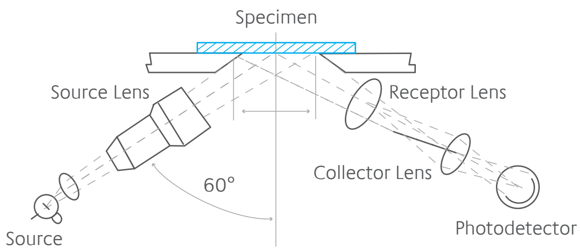


Table 14: Gardner Gloss Levels After Screenprinting Flat Black (min – max)

Film	Angle	Velvet	Matt	Suede
8B35	60˚	3.0 – 4.5	5.0 – 15.0	
8B36	60˚		3.0 – 12.0	0.0 – 2.0
8A13	85˚		4.0 – 10.0	
8A35	60˚	8.0 – 14.0		

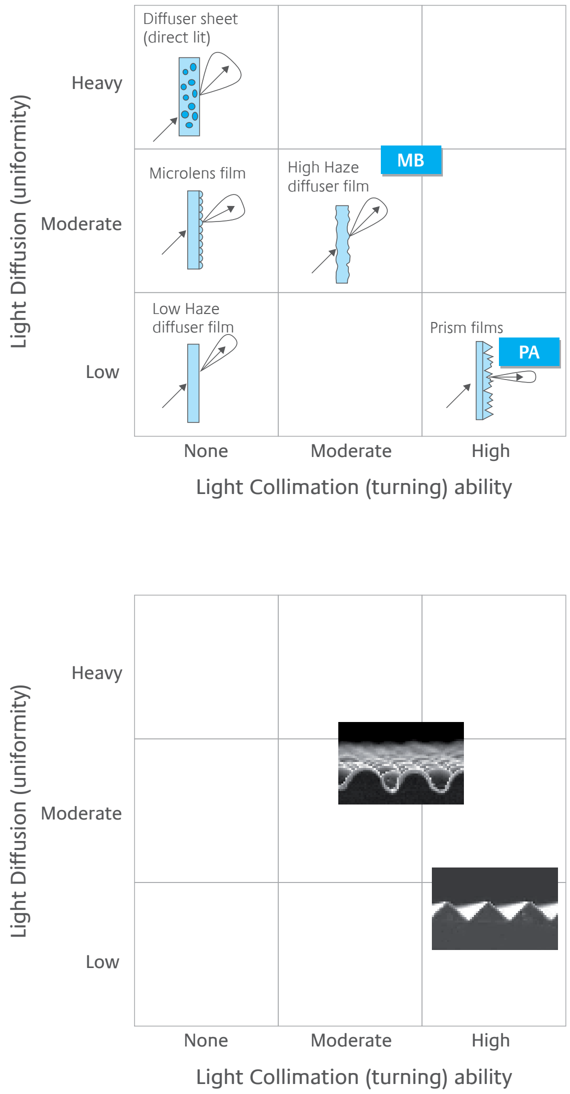
Table 15: Gardner Gloss Levels of Coated Films

	HP92S	HP60S	HP40S	HP12S	HP92W	HP92E	HP92T
Gloss-Backpainted ASTM D523 Gardner							
Flat Black							
60°	92	62	40	12	90	91	92
85°	99	57	46	45	99	97	99
20°	86	31	21		85	86	88
Gloss-Clear Over ASTM D523 Gardner							
White							
60°	177	103	64	27	175	174	174
85°	121	63	49	45	125	123	124
20°	173	80	44		182	178	182

Light Diffusion

Light diffusion in accordance with DIN 5036 is a measurement of the amount of perpendicular light transmission lost due to scattering of light. Light diffusion is measured when haze measurement becomes unreliable (>35%). Textures and special filter systems are used to improve light diffusion. Refer to Figure 3.

Figure 3: Display films



Light Collimation

The capability of a optical or diffuser film to redirect diffused input light toward the normal viewing direction of the display is defined as light collimation in this manual. LEXAN™ diffuser films, MB, PA and PB, are designed to have different light collimation capability for different end applications.

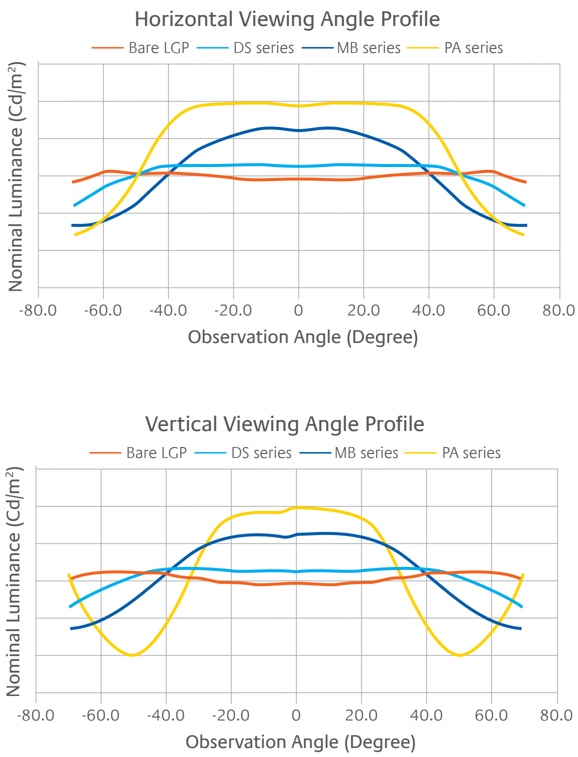
Luminance

Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. Luminance is often used to characterize light emission, reflection or transmission from flat surfaces. In display applications, luminance is thus an indicator of how bright the display devices will appear in a given direction.

Viewing angle

In display applications, viewing angle is the maximum angle at which a display can be viewed with acceptable visual performance. A full width at half-maximum (FWHM) from the angular plot of the luminance can be used to quantify the viewing angle capability of a display.

Figure 4: Viewing Angle profile



Mechanical Properties

Tensile strength, elongation and modulus are properties that describe the behaviors of film in tension. At room temperature, typical values for SABIC Specialty Film and Sheet's film are shown in Table 16:

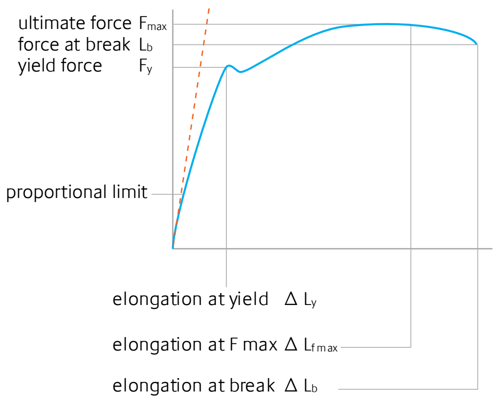
Table 16: Tensile properties of SABIC films

	Unit	LEXAN film	LEXAN Bromine, Chlorine Free FR Film	VALOX film	ULTEM film	LEXAN EFR film	LEXAN EFR735 film
Tensile strength at yield	psi (N/mm^2)	9000 (62)	10100 (70)	7200 (50)	16000 (110)	7832	9000
Tensile strength at break	psi (N/mm^2)	9400 (65)	8700 (60)	6000 (41)	1700 (115)	8267	7900
Elongation break	%	100	100	57	60	>90	12
Tensile modulus	kpsi (N/mm^2)	304 (2100)	319(2200)	275 (1900)	363 (2500)	296	294

Stress-strain

Stress-strain curves illustrate the ability to withstand short-term loading. A typical curve with general definitions is shown in Figure 5.

Figure 5: General Tensile properties and illustration



Stresses can be accurately predicted by using basic mechanical engineering equations. These equations, based on Hooke's Law, apply to the linear portion of the stress-strain diagram below the proportional (elastic) limit.

Hooke's Law states that stress is directly proportional to strain, and is expressed as:

$$E = \sigma / \varepsilon$$

Where: σ = Stress, psi (N/mm^2)
E = Modulus of elasticity, psi (N/mm^2)
ε = Elongation, mm/mm

Like most thermoplastics, LEXAN, VALOX™, and ULTEM™ film exhibit a spring-like behavior when loaded in tension below the proportional limit. This means that the film will stretch and return to its original dimension as tension is applied and removed. When printing or die cutting from a web in tension it could be important to consider this dimensional change.

The following formula can be used to compensate for this behaviour to ensure accurate registration:

$\varepsilon = F \,/\, A \times E$

Where: ε = Strain (stretch in inches (mm), per inch (mm) of web)
F = Web tension in pounds (N)
A = Cross-sectional area of web in square inches (mm^2) (width x thickness)
E = Tensile modulus in psi (N/mm^2)

The value of "E" will change with temperature.

A corresponding necking down or decrease in web width will occur. This can be quantified by using Poisson's ratio, which is the ratio of transverse contraction to elongation of a web under tension. For SABIC Specialty Film and Sheet's this number is 0.38. When multiplied by the strain in the previous formula, this will give the decrease in web width.

These properties are important in pressure-sensitive tape applications and whenever the film is processed in roll form.

Tear Strength

The tear resistance of a film is the force needed to initiate and propagate a tear. The stress is recorded and tear inititiation and propagation resistance is normally expressed in pound-force or Newtons. The tear resistance can also be expressed in force-per-unit of thickness, although comparisons between dissimilar materials and/ or thicknesses may not be valid. The tear resistance measured in accordance with ASTM D1004/ASTM D1925 is shown below in Table 17.

Table 17: Tear initiation and propagation of films

Material	Tear Intiation (D1004) lb/mil (kN/m)	Tear propagation (D1925) g/mil (kN/m)
LEXAN™ film	1.4 – 1.8 (245 – 298)	30 – 55 (10 – 20)
VALOX™ film	1.46 (250)	55 (20)
ULTEM™ film	2.1 (365)	24 (8)
LEXAN EFR95 film	0.88	37.9
LEXAN EFR65 film	1.23	30.8
NORYL™ film (10 mil)	1.35 (236)	29 (11.1)

Fold Endurance

When tested on a M.I.T. fold endurance machine LEXAN Film fold endurance varies widely with gauge. One-mil (25 μm) film will survive about 12,000 double folds; 5 mil (125 μm) 500 double folds; and 10 mil (250 μm) 200 folds. Additional data collected on electrical films is shown in table 18.

Table 18:

			LEXAN Film										NORYL Film
	testing method	unit	FR1	FR25A	FR700	FR60	FR65	FR83	EFR63-NC	EFR65-701	EFR65-NC	EFR95	EFR735
Fold endurance (MIT) @ 0.006"	ASTM D2176-69	double folds	-	-	-	-	-	-	-	-	-	-	> 1000
Fold endurance (MIT) @ 0.007"	ASTM D2176-69	double folds	2000	-	-	-	-	-	-	-	-	-	-
Fold endurance (MIT) @ 0.010"	ASTM D2176-69	double folds	-	45	27	45	60	-	57 (MD) /45 (TD)	74 (MD) /50 (TD)	74 (MD) /50 (TD)	-	> 80
Fold endurance (MIT) @ 0.017"	ASTM D2176-69	double folds	-	-	-	-	-	-	-	25 (MD) /21 (TD)	25 (MD) /21 (TD)	90.5	10
Fold endurance (MIT) @ 0.020"	ASTM D2176-69	double folds	-	20	12	30	20	-	-	18 (MD) /18 (TD)	18 (MD) /18 (TD)	91.1	-
Fold endurance (MIT) @ 0.025"	ASTM D2176-69	double folds	83	-	-	-	-	-	-	-	-	-	7

Frictional Characteristics

The smooth surface of VALOX film makes it an option for load bearing surface applications. VALOX film also has very low coefficients of static and dynamic friction against metal. The coefficient of static friction of VALOX film is 0.39 measured in accordance with ASTM D1894.

Thermal Properties

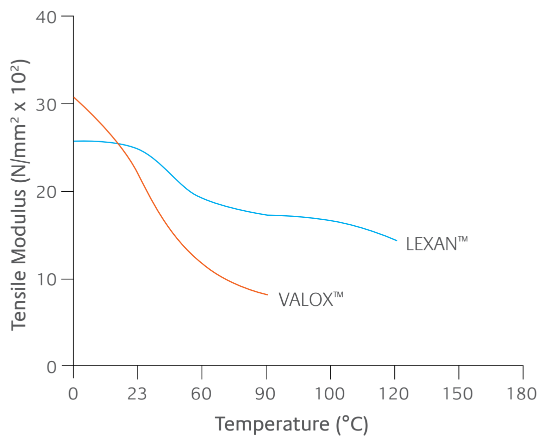
Tensile Heat Distortion, DTUL, Vicat

Tensile heat distortion, deflection temperature under load (DTUL) and Vicat softening temperature values provide an indication of the heat performance of plastic materials. They show the temperatures at which a test specimen will deflect a given distance under a given load in tension, flexure and compression under specified test conditions. The higher the reported value, the higher the material's practical end-use temperature is likely to be.

All thermoplastics undergo mechanical property changes with changing temperature. Amorphous materials such as LEXAN polycarbonate change slowly and in an almost linear fashion with increasing temperatures up to 300°F (150°C), where the material begins to soften. Softening continues until it melts at about 420°F (215 °C). Relative thermal stability of LEXAN film to 300°F (150°C) makes it a good candidate for high-temperature applications, and the wide softening range allows ease in thermoforming. Following the screen printing guidelines of LEXAN film, drying temperatures as high as 120°C can be used.

VALOX™ resin, being a crystalline thermoplastic polyester, shows a more pronounced dependence on temperature. Figure 6 illustrates tensile modulus as a function of temperature.

Figure 6: Tensile modulus vs. temperature



RTI and effects of Heat Aging

RTI, or Relative Thermal Index, is the continuous operating temperature of a plastic material used in electrical and/or mechanical applications, as tested by Underwriter's Laboratories (UL). RTI is often defined as "the maximum service temperature at which the critical properties of a material will remain within acceptable limits over a long period of time". The "end-of-service" life is defined as the time at which a material property has degraded to 50% of its original value after 100,000 hours' continuous exposure. RTI tests are important if the final product is to receive UL recognition. RTI values for various LEXAN films are listed in Table 19.

Table 19: Relative Thermal Indices of Select LEXAN films

			Relative Thermal Index (°C)		
				Mechanical	
Material	Color	Thickness	Electrical	With Elongation	Without Elongation (tensile)
VALOX™ FR1 Film	nc	0.075-0.100	-	-	-
	nc	0.125-0.225	125	120	120
	nc	0.250-0.350	125	120	120
	all	0.375-0.600	125	120	125
	all	³ 0.635	120	120	140
LEXAN™ FR6x Film	cl	0.250-0.350	130	125	130
	cl	0.375-0.740	130	125	130
	cl	³ 0.750	130	125	130
LEXAN™ FR700 Film	bk	0.250-0.350	130	125	130
	bk	0.375-0.740	130	125	130
	bk	³ 0.750	130	125	130
NORYL™ Film	bk	0.05 - 0.17	65	65	65
	bk	0,25	95	65	85
	bk	0,43	95	65	90
ULTEM™ Film	bk	0.75-0.83	95	65	90
		wt	0,25	105	105
	wt	0.5-0.55	105	105	105
LEXAN™ EFR95 Film	bk	0,38	130	80	130
	all	0,43	130	80	130
	all	0.5-0.55	130	80	130

LEXAN™ polycarbonate films exhibit resistance to oxidative embrittlement. After six months at 167°F (75°C) LEXAN films showed no measureable change in tensile yield and ultimate tensile strength. The tensile yield point and the ultimate tensile strength of the samples tested increased some 10% during six months at 257°F (125°C). However, the elongation of the same films dropped from an initial average of 97% to a final elongation of 9%. It should be noted that none of the film samples tested were brittle enough to crack by creasing even after the six month aging period.

Degradation of optical properties (decreased light transmission, increased haze and yellowness) may also occur after long-term exposure to high temperatures.

LEXAN film should not be exposed on a continuous basis to temperatures exceeding 185°F (85°C).

Low temperatures have little effect on LEXAN film, which remains ductile down to at least -150°F (-101°C).

Shrinkage

Since LEXAN and ULTEM™ films are isotropic and amorphous, they are dimensionally stable at elevated temperatures. Exposure to temperatures as high as 275°F (135°C) for LEXAN and 302°F (150°C) for ULTEM for short periods (30 min.) results in no detectable change in dimension.

LEXAN film from 3 - 5 mil (0.075-0.125 mm) will shrink about 0.5% at 302°F (150°C). Heavier gauge film may shrink 1-2% at 302°F (150°C) depending on gauge. At temperatures above the glass transition, 302°F (150°C), dimensional changes become more pronounced with LEXAN films.

Table 20: Typical shrinkage values of other films

Sample ID	Gauge (mil)	Shrinkage % (MD)	Shrinkage % (TD)
EFR95	10	1.5%	1.2%
EFR735-BK1005	6	0.3%	0.2%
FR1 film	10	1.1%	0.4%
ULTEM 1000B	2	0.2%	0.1%

The shrinkage off of the forming tools during thermoforming will vary somewhat depending on the temperatures and cooling times. For LEXAN film the shrinkage will range from 0.8% to 0.9%.

Electrical Properties

SABIC Specialty Film and Sheet's films are characterized by excellent dielectric properties. High dielectric strength and insulation resistance, together with consistent dielectric loss values and superior arc resistance, make them ideal materials for many applications in electronic and electrical components.

Dielectric strength

SABIC film provides excellent resistance to breakdown in the presence of high voltage AC stress. Table 21 shows the relation of dielectric strength to material thickness as tested according to ASTM D149. All films give similar results and are virtually unaffected by humidity and heat aging.

Table 21: Dielectric Strength, ASTM D149, kV/mm

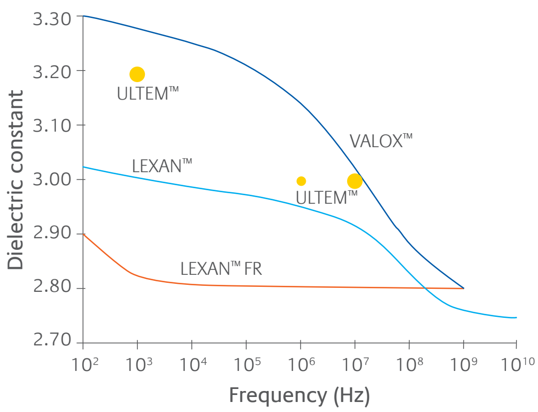
Gauge (mm)	LEXAN FR film	VALOX™ film	ULTEM film
0.050	-	-	6450
0.075	7550	9350	8100
0.100	9000	10800	9500
0.125	10300	12100	10800
0.175	12600	14300	13050
0.250	15650	17100	-
0.375	20050	21000	-
0.500	23850	24200	-
0.625	27300	27050	-
0.750	30500	29650	-

Dielectric constant

The dielectric constant (or permittivity) is a measure of the charge-storing qualities of a plastic specifically with respect to alternating current (ac). In general, low permittivity is preferred if the material is to be used as an insulator.

Dielectric constant at 60 Hz ranges from about 2.95 to 3.05 over the range of 32 - 257°F (0-125°C) for LEXAN™ and VALOX™ films. ULTEM™ film has a slightly higher dielectric constant of 3.2 over the same range. Higher frequencies do impact the dielectric constant and this is depicted in Figure 7.

Figure 7: Effect of frequency on the dielectric constant at 73°F (23°C)



Dissipation Factor

Values for dielectric loss, i.e., dissipation or power factor, are essentially the same across the LEXAN film range. From room temperature to 212°F (100°C), the factor is approximately 0.001 (0.1%). It increases gradually to 0.002 at 284°F (140°C) and increases sharply beyond 302°F (150°C). Figures 8 and 9 illustrate the effect of temperature and frequency on the dissipation factor, respectively

Figure 8: Variation of Dissipation Factor with Temperature (60Hz), LEXAN

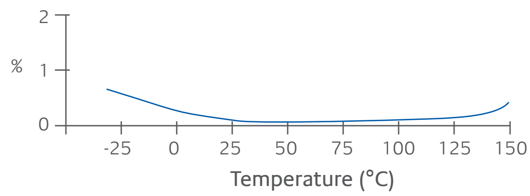
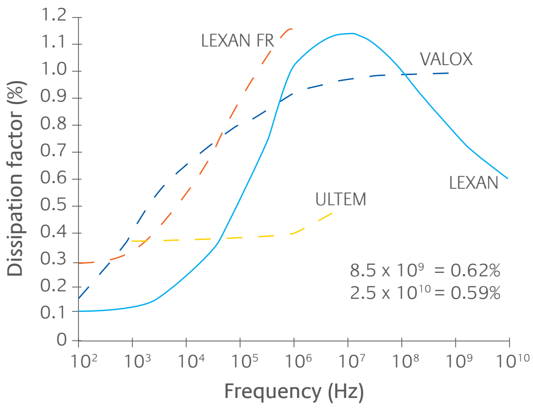


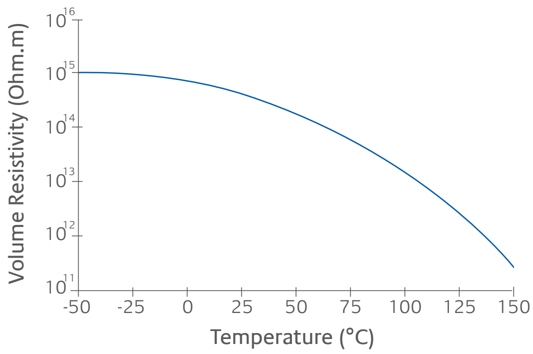
Figure 9: Effect of Frequency on the Dissipation Factor at 23°C



Volume / Surface Resistivity

LEXAN films exhibit high resistance to DC current both through and across the surface of the film. The volume resistivity is a ratio of the potential gradient parallel to the current in the material to current density. Surface resistivity is a ratio of the potential gradient parallel to current along the surface to the current of the surface. Figure 10 illustrates the effect of temperature upon the volume resistivity of LEXAN film.

Figure 10: Effect of temperature upon the volume resistivity of LEXAN film



Performance Level Categories, PLC

PLC, or Performance Level Categories, as defined by UL: "In order to avoid an excessive level of implied precision and bias, material performances for several tests are recorded as PLC, based on the mean test results (rather than recording the exact numerical results)". Material properties of hot wire ignition (HWI), high current arc ignition (HAI), high voltage arc tracking rate (HVTR), arc resistance (D495), and comparative tracking index (CTI) are given performance level categories. A brief definition of the test is provided below along with an explanation of the associated PCL values.

HWI: The hot wire ignition test consists of wrapping the test specimen with resistance wire and measuring the average seconds it takes to ignite or burn through.

Table 22: Hot Wire Ignition PCL Ratings

Average ignition time (sec)	PCL
120+	0
60 - 119	1
30 - 59	2
15 - 29	3
7 - 14	4
<7	5

HAI: The high current arc ignition test is a measure of the number of arc rupture exposures on the surface of a material necessary for ignition.

Table 23: High Current Arc PCL Ratings

Average number of arcs	PCL
120+	0
60 - 119	1
30 - 59	2
15 - 29	3
<15	4

HVTR: The high voltage tracking rate is the rate (mm/min) that a tracking path can be produced on the surface of a material under specified conditions.

Table 24: High Voltage Tracking Rate PCL Ratings

Tracking Rate (mm/min)	PCL
0 - 10	0
10.1 – 25.4	1
25.5 - 80	2
80.1 - 150	3
>150	4

D495: The arc resistance test is the resistance to high voltage, low current, arcing across the film surface; it may vary somewhat with the type of film. The time to form a conducting path between two electrodes is measured. Non-flame retarded grades such as LEXAN 8010 generally have better resistance to arc breakdown than the flame-retarded grades.

Table 25: Arc Resistance PCL Ratings

Arc Resistance (sec)	PCL
420+	0
360 - 419	1
300 - 359	2
240 - 299	3
180 - 239	4
120 - 179	5
60 - 119	6
< 60	7

CTI: The comparative tracking index is another surface electrical breakdown test. In this test, the voltage that causes tracking after 50 drops of 0.1% ammonium chloride solution have been applied is measured.

Table 26: Comparative Tracking Index PCL Ratings

Comparative Tracking Index (V)	PCL
600+	0
400 - 599	1
250 - 399	2
175 - 249	3
100 - 174	4
< 100	5

PLC levels are assigned to electric properties as tested according to UL746A. Please refer to the following Table 27 for a select PCL levels for several LEXAN film grades.

Table 27: PCL Ratings for Several LEXAN Films

Material	Color	Gauge (mm)	HWI	HAI	HVTR	D495	CTI
ULTEM™ 1000 Film	nc	0.050	-	-	-	5	-
VALOX™ FR1 Film	nc	0.075 - 0.100	-	-	4	6	2
	nc	0.125 - 0.225	-	4	6	2	2
	nc	0.250 - 0.350	4	0	4	6	2
	all	0.375 - 0.600	4	0	4	6	2
	all	^{3}0.635	3	0	3	6	2
LEXAN™ FR6X Film	cl	0.250 - 0.350	1	0	-	6	3
	cl	0.375 - 0.740	0	0	-	6	3
	cl	^{3}0.750	0	0	-	6	3
LEXAN™ FR700 Film	bk	0.250-0.350	1	0	-	-	3
	bk	0.375-0.740	0	0	-	-	3
	bk	^{3} 0.750	0	0	-	-	3
NORYL™ Film	bk	0.05 - 0.17	-	-	-	-	2
	bk	0.75-0.83	1	0	-	-	-
ULTEM™ Film	wt	0,25	-	-	-	-	-
	wt	0.5-0.55	-	-	-	-	-
LEXAN™ EFR95 Film	bk	0,38	-	-	-	-	3
	all	0,43	4	3	-	-	-
	all	0.5-0.55	3	3	-	-	-

Environmental Properties

Chemical Resistance

At moderate temperatures and low stress levels, SABIC Specialty Film and Sheet's film is generally compatible with most substances encountered in home or office environments. However, when stressed in some manner such as by cold-forming, flexing on embossing, some substances will cause the film to craze or stress-crack. Elevated temperatures can initiate or accelerate this type of degradation.

Some organic chemicals such as acetone, toluene and halogenated hydrocarbons will act as solvents to SABIC Specialty Film and Sheet's film. Methylene chloride, for example, is often used to solvent-bond SABIC films.

A coated film should be considered for applications where there is exposure to aggressive or incompatible substances. Tables 28 and 29 offer guidelines on SABIC Specialty Film and Sheet's film's compatibility with general classes of chemicals. Testing is strongly recommended when there may be a question of the film's resistance to substances encountered in either processing or end-use.

Table 28: General Chemical Resistance Overview

Chemical		Amorphous LEXAN	Semi-Crystalline VALOX
Hydrocarbons			
aliphatic		-/•	•
aromatic		-	+
halogenated	- fully	•/+	-
	- partly	-	-
Alcohols		+	+
Phenols		-	nt
Ketones		-	-
Amides		nt	nt
Amines		nt	nt
Esters		-/•	-
Ethers		-	nt
Acids			
Inorganic	- concentrated	-/•	•/+
	- diluted	•	+
Organic	- concentrated	•	•/+
	- diluted	•	+
Oxidising	- concentrated	-	•/+
	- diluted	+	+
Alkalis			
concentrated		-	-
diluted		-	•
Salts			
acids		+	+
neutral		++	+
alkali		•	+
Automotive fluids			
greases (non-reactive organic esters)		nt	+
oils (unsaturated aliphatic mixtures)		nt	++
waxes (heavy oils)		nt	+
gasoline		-	++
cooling liquid (glycol)		+	++
brake fluid (heavy alcohol)		-	++
detergents, cleaners		+	+
Water hot		-/•	•

Table 29: Chemical Resistance of LEXAN HP/OQ Films

LEXAN™ Coated Film Grades	HP92S		OQ92S		HP92W		HP92E	HP92T
	as made	postcured	as made	postcured	as made	postcured	as made	as made
Chemical Resistance - 1hour at 22°C								
Acetone	Failed	Passed	Failed	Passed	Failed	Failed	Failed	Failed
MEK	Failed	Passed	Failed	Passed	Failed	Passed	Failed	Failed
Toluene	Failed	Passed	Failed	Passed	Passed	Passed	Failed	Failed
Methylene Chloride	Failed	Passed	Failed	Passed	Failed	Failed	Failed	Failed
Ethyl Acetate	Failed	Passed	Failed	Passed	Passed	Passed	Failed	Failed
40% NaOH	Failed	Passed	Failed	Passed	Passed	Passed	Passed	Passed
Conc. HCl	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Gasoline	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Butyl Cellosolve	Failed	Passed	Failed	Passed	Failed	Passed	Passed	Passed
IPA	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Cyclohexanone	Failed	Passed	Failed	Passed	Passed	Passed	Passed	Passed
Xylene	Failed	Passed	Failed	Passed	Passed	Passed		
24 Hour Surface Exposure at 120°F								
Coffee	Passed	Passed	Failed	Passed	Passed	Passed	Passed	Passed
Formula 409#	Passed	Passed	Failed	Passed	Passed	Passed	Passed	Passed
Windex w/Ammonia D##	Passed	Passed	Failed	Passed	Passed	Passed	Passed	Passed
Mustard	Passed	Passed	Failed	Passed	Failed	Passed	Failed	Failed
Ketchup	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Tea	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Lemon Juice	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Spray N' Wash###	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Sunscreen (Banana Boat SPF 15)	Passed	Passed	Passed	Passed	Passed	Passed	Passed	Passed
Top Job####	Passed	Passed	Failed	Passed	Passed	Passed		
Fantastik***	Passed	Passed	Passed	Passed	Passed	Passed		
Wisk#####	Passed	Passed	Failed	Passed	Passed	Passed		
Downy####	Passed	Passed	Passed	Passed	Passed	Passed		
Clorox#	Passed	Passed	Failed	Passed	Passed	Passed		
Mr. Clean####	Passed	Passed	Passed	Passed	Passed	Passed		
Tomato Juice	Passed	Passed	Passed	Passed	Passed	Passed		
Grape Juice	Passed	Passed	Passed	Passed	Passed	Passed		
Vinegar	Passed	Passed	Passed	Passed	Passed	Passed		
Milk	Passed	Passed	Passed	Passed	Passed	Passed		

Formula 409 and Clorox are registered trademark of Clorox Company
Windex w/Ammonia D is a registered trademark of Drackett Products Company
Spray'N Wash and Fantastik are registered trademark of Texize, Division of North Norwich Products, Inc.
Top Job, Downy and Mr. Clean are registered trademark of Procter & Gamble Company
Wisk is a registered trademark of Lever Brothers Company

Effects of Water

No significant changes have been noted in tensile and elongation properties measured on films immersed in water for several weeks. However, boiling water immersion rapidly decreases the elongation of LEXAN films. Long-term immersion in sea water at normal temperatures has negligible effect on mechanical properties of LEXAN film. VALOX and ULTEM films show an improved performance over LEXAN films.

Effect of high temperature and humidity

Table 30: Results obtained for various films under the "pressure cooker test (PCT)" used for photovoltaic applications

Pressure cooker test condition: 121C, 18psi, 100%RH for 72 hrs; Only MD direction samples sample were tested

Film grade	Gauge (mil)	Initial breaking elongation (%)	Initial breaking strength (MPa)	breaking elongation post-PCT (%)	Breaking strength post-PCT (Mpa)	retention of breaking elongation (%)	retention of breaking strength (%)	Comment 1
LEXAN™ 8010 Film	10	105	67	4	62	4%	92%	fair to good retention
LEXAN™ FR65 Film	10	51	59	6	50	12%	86%	fair to good retention
NORYL™ EFR735 Film	6	5	60	4	66	83%	110%	very good retention
VALOX™ FR1 Film	10	54	41	1	20	2%	49%	Poor retention
ULTEM™ 1000B Film	1,5	12	103	4	116	33%	112%	fair to good retention

Permeability

Permeability is a function of the diffusion rate, the solubility of the gas in the barrier and the barrier thickness. (Permeability = Solubility * Diffusion Rate ; Typically this is normalized to unit thickness). Table 31 gives gas and moisture vapor permeability data for LEXAN film at room temperature for a gauge of 10mil (0.250mm).

Table 31: LEXAN Permeability to Gas and Moisture

	LEXAN film	Unit
Air	85 (1340)	ml/mil/100 in2/24 hr – atm (cc/m2 - 24 hrs – atm)
Nitrogen	50 (787)	ml/mil/100 in2/24 hr – atm (cc/m2 - 24 hrs – atm)
Oxygen	300 (3500)	ml/mil/100 in2/24 hr – atm (cc/m2 - 24 hrs – atm)
Carbon Dioxide	1075 (20000)	ml/mil/100 in2/24 hr – atm (cc/m2 - 24 hrs – atm)
Moisture Vapour	8 (85)	g/100 in2/24 hr – atm (cc/m2 - 24 hrs – atm)

Weatherability

Long-term exposure to direct sunlight will cause unprotected SABIC film to surface chalk (removable) and yellow. The length of time before a noticeable change occurs depends on the severity of the exposure and the thickness of film, and can be anywhere from several months to several years. Unprotected SABIC Specialty Film and Sheet's film is not recommended therefore, for outdoor applications where the retention of aesthetics and mechanical properties is required. For intermittent outdoor exposure or long-term exposure to fluorescent lighting, all SABIC Innovative Plastics Specialty Film and Sheet's films demonstrate good performance.

UV Resistance

LEXAN HP92W and HP92X films utilize a proprietary coating technology developed by SABIC, Innovative Plastics Division. This special coating protects the film from yellowing and hazing, maintaining the appearance of the graphics behind the film. With a yellowness index of less than 2.5 at 1000 hours of QUV testing, LEXAN HP92W film is a candidate for demanding outdoor applications.

LEXAN SLX 11010 film is a clear film of 7 to 10mil thickness that may be used alone or in a backmolded configuration to provide exceptional weathering, good chemical and scratch resistance and outstanding aesthetics for a wide variety of applications in automotive, telecommunications and outdoor vehicles. It can be printed either first or second surface and retains good aesthetics and performance, even after significant outdoor exposure.

QUV vs. Xenon Arc weathering

These accelerated weathering tests are not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and saltwater exposure. However, the exposure may simulate the weathering effects that occur when materials are exposed to sunlight and moisture as rain or dew in actual use.

QUV weathering test per ASTM G154 uses a combination of fluorescent light source and water condensation while Xenon arc weathering test per ASTM G155 uses a combination of filtered xenon arc light and controlled environmental conditions. A brief comparison of these two artificial weathering methods are given as below:

Table 32: QUV and Xenon-arc comparison

QUV	Xenon arc
UVA-340 - good simulation of shortwave UV (UVB-313 is too severe), but no visible light	Full spectrum - best simulation of UV and visible light
stable spectrum	spectrum changes when lamp ages
no RH control	Relative humidity control
water spray or condensation	water spray

Figure 11: Spectrum comparison of QUV-A, Xe-arc and natural sunlight

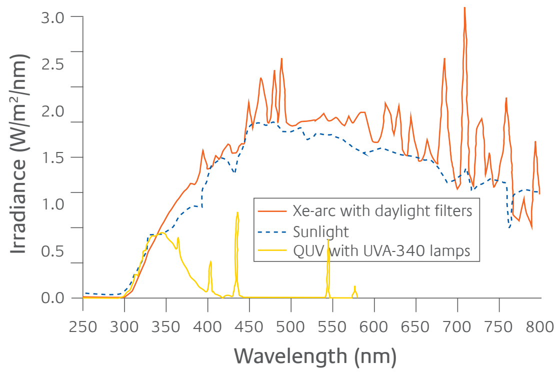


Figure 12: QUV Accelerated Weathering (ASTM G154 – UVA340 or UVB-313

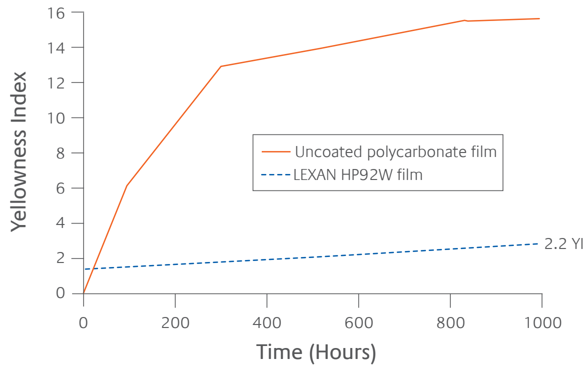
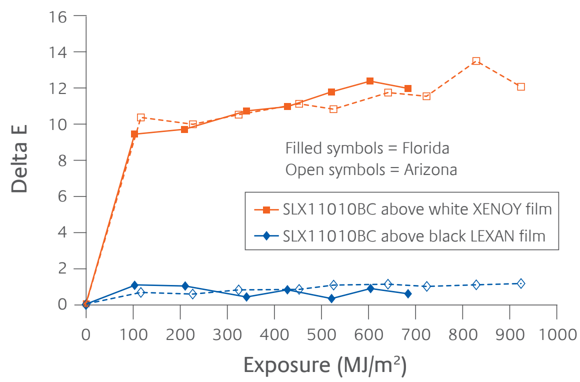


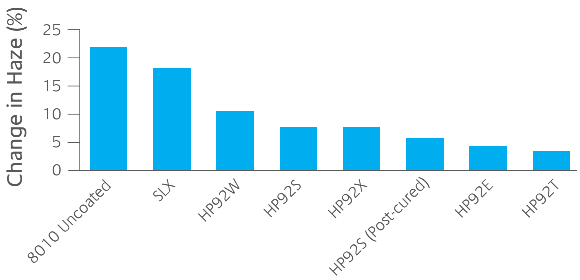
Figure 13: Delta E of SLX11010 laminated onto different opaque color background (measured with reflection mode – D65 10 deg Observer angle)



Abrasion Resistance

The coated surface of the SABIC's HP film products are substantially harder and more abrasion resistant than uncoated polycarbonate. A unique feature of HPXXS and HPXXW films is their receptivity to multiple-pass first-surface UV inks which, when cured, can further enhance abrasion resistance of the coating. Figure below shows a comparison between uncoated LEXAN 8010-112, HP92S, HP92W, HP92E and HP92T films and HP92S film exposed to top- surface UV curing conditions [one elliptical- focused, medium-pressure mercury vapor lamp (American Ultraviolet Model LC06-1-T3) at 300 watts/inch with a conveyor speed of 20 feet/minute].

Figure 14: Taber Abrasion Resistance of Coated LEXAN™ Film Products (# of cycles)



Flammability

Compared to most other polymers, several of SABIC's thermoplastic films are characterized by inherent flammability resistance. As a result, SABIC's thermoplastic films are widely used in electrical/electronic, automotive and construction applications. SABIC's flame retardant (FR) films are formulated to provide further protection against burning and ignition, as shown in Table 33.

Pencil Hardness

The Pencil Hardness test is an effective method to test film and sheet materials' coatings about their hardness and resistance to scratches and abrasion. The test method allows the use of pencils which have a known hardness grade to be moved over the surface to be tested at a fixed angle and pressure. These pencils, when passed for a specified number of times on the coating will also allow an abrasion factor to be determined which is related to the hardness of the pencil used. The lowest hardness value of the pencil which marks the coating determines the coating's hardness rating.

Table 33: Flammability Characteristics of Select SABIC thermoplastic films.

Property**	Test	LEXAN film	LEXAN FR film	VALOX film	ULTEM film	NORYL film
UL Flammability	Bulletin 94	HB	V, 0.250 mm	VTM-0, 0.127 mm	VTM-0, 0.025 mm	VTM-0 0.150mm
	-	VTM-2, 0.125 mm	VTM-0, 0.050 mm	VTM-2, 0.080 mm	-	V-0, 0.250mm
Oxygen Index	ASTM D2863	25	33	30	47	-
Flash Point	-	454°C	440°C	-	-	-
Self-Ignition Temperature	-	575°C	605°C	-	-	-
FMVSS 302	ISO 3792	pass >0.250 mm	pass >0.250 mm	pass >0.250 mm	pass >0.250 mm	-
NFPA 258-NBS Smoke	ASTM E662	D (4) = 17	D (4) = 6	-	0	-
Chamber						-
Test (.250 mm)	-	D (max) = 50	D (max) = 36	-	0	-
Horizontal Burn Rate	ASTM D635	-	-	-	-	-
Extent of Burn	-	75 mm	36 mm	-	-	-
Burn Time	-	65 sec.	5 sec.	-	-	-

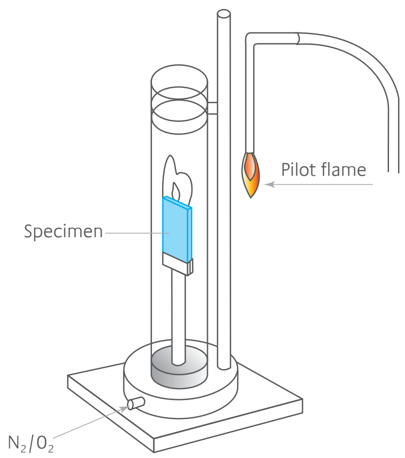
Limiting Oxygen Index ISO 4589 (ASTM D 2863)

The purpose of the oxygen index test is to measure the relative flammability of materials by burning them in a controlled environment. The oxygen index represents the minimum level of oxygen in the atmosphere that can sustain flame on a thermoplastic material. The test atmosphere is an externally controlled mixture of nitrogen and oxygen with a pilot flame, which is then removed. In successive test runs, the oxygen concentration is reduced to a point where the sample can no longer support combustion. Limiting Oxygen Index, or LOI, is defined as the minimum oxygen concentration in which the material will burn for three minutes, or can keep the sample burning over a distance of 50 mm. The higher the LOI value is the less the likelihood of combustion. Table 34 illustrates typical LOI values for film products and the apparatus for this LOI test is shown in Figure 15.

Table 34: LOI of different various materials

LEXAN Film	LEXAN FR Film	VALOX Film	ULTEM Film
25	33	30	47

Figure 15: Apparatus for Limiting Oxygen Index Test



UL94 flammability in general

The most widely accepted flammability performance standards for plastic materials are UL94 ratings. These are intended to identify a material's ability to extinguish a flame, once ignited. Several ratings can be applied based on the rate of burning, time to extinguish, ability to resist dripping, and on whether the drips are burning. Each material tested may receive several ratings based on color and/or thickness. When specifying a material for an application, the UL rating should be applicable for the thinnest wall section in the plastic part. The UL rating should always be reported with the thickness: just reporting the UL rating without mentioning thickness is insufficient.

Summary of the UL94 rating categories

HB- slow burning on a horizontal specimen
burning rate < 76 mm/min for thickness < 3 mm
burning rate < 38 mm/min for thickness > 3 mm

UL94V0 – burning stops within 10s on a vertical specimen; no drips allowed
UL94V1 – burning stops within 30s on a vertical specimen; no drips allowed
UL94V2 – burning stops with 30s on a vertical specimen; drips of flaming particles are allowed
5V – burning stops within 60s after five applications of a flame for 5s each – larger specimen than used in V-testing
5VA – Plaque specimens may not have a bern-through (no hole) – highest UL rating
5VB – Plaque specimens may have a burn-through (have a hole)
VTM0 – This rating applies to very thin gauge materials. A cylindrical test specimen is used instead of a test bar. The burning and dripping requirements are comparable to a V-test.

UL94HB

Where flammability is a safety requirement, HB rated materials are normally not permitted. In general, HB classified materials are not recommended for electrical applications except for mechanical and/or decorative purposes. For applications such as plug housings, requiring a high CTI value, HB classified materials may be suitable.

It should be stressed that non-FR materials, (or materials that are not meant to be FR materials, do not automatically meet HB requirements. Although the least severe, UL94HB is a flammability classification and has to be determined by testing.

UL94V0, V1 and V2

The vertical tests take the same specimens as are used for the HB test. Burning times, glowing times and, when dripping occurs, whether or not the cotton beneath ignites, are all noted. Flaming drips – widely recognized as a main source for the spread of fire or flames – distinguishes UL94V1 from UL94V2.

Table 35 depicts UL94 flame ratings for several SABIC film products and figures 16 and 17 represent UL94HB and UL94V-testing, respectively.

Table 35: UL94 Flame Rating

Material	Color	Thickness (mm)	UL94 Flame Rating*
ULTEM 1000 film	NC	0.025	VTM-0
VALOX FR 1 film	nc	0.08	VTM-2
	nc	0.127-0.51	VTM-0
LEXAN FR 6/7 film	cl	0.05	VTM-0
	cl/bk	0.13	VTM-0
	cl	0.25	V-0

* Not tested, generic value

Figure 16: Horizontal Burn Test

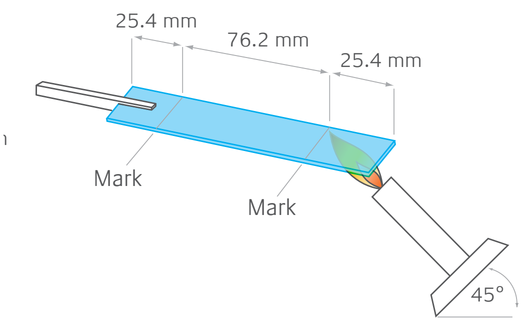
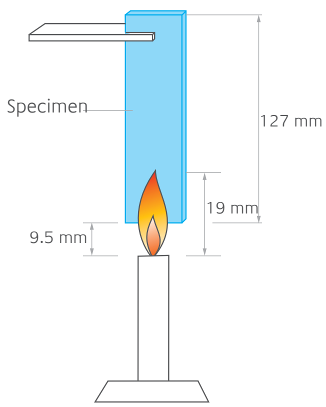


Figure 17: Vertical Burn Test



In-Mold Decoration (IMD)

One of the most efficient and cost-effective ways of decorating a part is to do it during the molding cycle. In-mold decoration (IMD) is also known as film insert molding (FIM), insert mold decoration (IMD), or in-mold labeling (IML), can provide several important advantages over other decoration methods. IMD offers many design flexibility and productivity advantages versus other decoration methods done after molding. These benefits include design flexibility; multiple colors, effects, and textures with a single operation; long-lasting graphics manufacturing productivity; and systems cost reductions.

Most IMD applications require the right materials in three categories: film, resin, and ink. Poor material selection can lead to poor mechanical properties, ink washout, or poor adhesion between film and resin substrate. SABIC offers many thermoplastics films specifically designed for use with IMD. These materials are usually decorated, shaped into the geometry of the injection molding tool by a forming and trimming process, placed in the tool, and then resin is injected onto it. The film stays with the part for the life of the part and, in most cases, is molded second surface where the graphic is sandwiched between film and resin. This second surface molding protects the graphic from damage for the life of the part. You can also explore available textures, finishes, and properties from LEXAN™ film portfolio.

Regarding IMD, SABIC has developed some guidelines to help you with three major aspects of the process that require concurrent design and consideration: material selection, part design, and processing. In- depth information about these guidelines can be found on-line at www.sabic-ip.com/imd website or you can contact your local SABIC representative for application assistance or an IMD seminar.

Printing

LEXAN™ polycarbonate film can be first (front) surface printed and, due to its excellent clarity at any gauge, it is also ideal for second-surface printing. Most inks adhere well to LEXAN film without pretreatment or print coat which many other plastic films require. Many printing techniques can be applied to LEXAN films including screen-printing, digital printing, sublimation printing, offset printing, and flexographic printing.

Many inks contain aggressive organic solvents that promote adhesion to the film but may contribute to film failure if not removed before further fabrication. Therefore it is suggested to thoroughly dry all inks after printing (preferably at elevated temperatures) to remove all solvents.

Tables 36 through 47 list manufacturers by ink system who carry products those manufacturers recommend for use on LEXAN polycarbonate film. This list is by no means all-inclusive and could be subjected to change resulting, for example, from changes in ink formulation by the ink manufacturers. Particular care should be taken in case the LEXAN film is to be stressed or bent after printing. In all cases it is recommended to perform end-use testing to determine compatibility with all materials in the system.

Tables xx through yy list manufacturers of ink systems that work with specific materials such as LEXAN SLX film, ULTEM™ film, and VALOX™ film. Again, these lists are not all inclusive and end use testing with these ink systems or with others should be conducted to ensure they will meet the needs of your application.

Many of the inks listed can be embossed or formed with vacuum thermoforming or pressure forming. Consult the ink manufacturer for the appropriate ink for your particular application needs and contact your local SABIC representative for prototyping assistance.

Printing Tips

a. Use static eliminators to facilitate sheet handling and reduce dust attraction. Air ionization, liquid treatments and special cleaners may be used for static control with SABIC Specialty Film and Sheet films. A partial listing of suppliers can be found below.

Table 36: Static Control and Web Cleaners for LEXAN Film

Suppliers	
Alpha Innovation, Inc	www.stopstatic.com
ElectroStatics, Inc	www.electrostatics.com
NRD	www.nrdstaticcontrol.com
Polymag	www.polymagtek.com
Simco	www.simco-static.com
Teknek	www.teknek.com
R.G. Egan	www.rgegan.com

Anti-static Treatments for LEXAN™ Film

Canberra Corporation (419) 841-6616
Anti-Stat #1 and #2

Novus Company (612) 944-8000
Brillianize Anti-Static Polish

Chemical Product Company (402) 345-5432
210 Plastic Cleaner & Anti-Static

Summer Lab (617) 542-8656
8A Anti-Fog/Stat Lens Cleaner

EMA Company (414) 276-1741

b. Keep the printing press and area free of dust and smoke.
c. Web processing - refer to Section, Mechanical Properties, for web stretch information.
d. Drive off solvents as soon as possible. LEXAN™ film can be safely dried at temperatures up to 250°F (120°C)
e. Make sure UV inks are formulated to cure completely according to your requirement.
f. Follow guide-lines for offset printing on synthetic materials; i.e. with low-solvent inks or thin ink film, increase alcohol content of dampening solution, use short lifts to prevent set-off, etc.
g. Work with SABIC Specialty Film and Sheet, your film converter, and ink supplier for best results.

If a particular ink or process does not provide adequate adhesion during printing then a number of options exist to improve the surface tension of LEXAN film. These include:

1) Wiping with iso-propyl alcohol prior to printing
2) Corona discharge treatment
3) Plasma treatment
4) Flame treatment
5) Electronic beam

Any of the above treatments may work to improve printability with LEXAN™ film for a limited period of time although corona discharge is the preferred method due to its ability to treat in-line and inexpensively. It is advisable to print on the product immediately after treatment or as soon as possible after treatment because the effectiveness of the treatment can be reduced over time. Other factors that can reduce the effectiveness of the treatment include:
Handling - Use clean white, lint free gloves since oils from the skin can reduce treatment effectiveness.
Grease, Machine Oils, and Mold Releases - Avoid contact with dirty equipment before and after treatment. Contamination with grease, mold release, or oil will prevent effective treatment.
Wiping the Parts - Wiping treated material with cloth or paper towels will destroy the treatment. If dust or dirt must be removed then blow it off with deionized air.

Since treatment is not visible, it is advised to print a few samples with the desired process and inks and then test with a cross-hatch adhesion test once the inks have been fully cured per the manufacturers recommendations.

Printing Inks Compatible with LEXAN Film (as of 2009)

Table 37: Physical Solvent Drying Systems

Manufacturers	
Akzo Nobel Coatings Inc.	www.akzonobel.com
SunChemical	www.sunchemical.com
JUJO Chemical Co., Ltd.	www.jujo-chemical.co.jp
Seiko Advance Ltd.	www.seikoadvance.co.jp
Teikoku Printing Inks Mfg. Co., Ltd.	www.teikokuink.com www.teikokuink.com/en
Naz-Dar Corporation	www.nazdar.com
Visprox B.V.	www.visprox.com
RUCO Druckfarben	www.ruco.de
ECKART	www.eckart.net.html
Pröll KG	www.proell.de
Sericol Limited	www.sericol.com
Marabuwerke GmbH & Co.	www.marabuwerke.de www.marabu.com

Table 38: Conductive Inks

Manufacturers	
Creative Materials	www.creativematerials.com Product: 114-31 (formable conductive ink)
Conductive Compounds	www.conductivecompounds.com
Acheson	www.achesonindustries.com www.achesonelectronicmaterials.com

Table 39: UV Curing Systems

Manufacturers	
SunChemical	www.sunchemical.com/products.aspx
ECKART	www.eckart.net.html
Visprox B.V.	www.visprox.com
Sericol Limited	www.sericol.com
Polymeric Imaging Inc.	www.polymericimaging.com/2/
Marabuwerke GmbH & Co.	www.marabuwerke.de www.marabu.com/
RUCO Druckfarben	www.ruco.de/
Nor-Cote UK Limited	www.norcote.com/

Table 40: Membrane switch inks formulated for LEXAN film

Nor-Cote UK Limited www.norcote.com IGX

Manufacturer		Product
Nor-Cote UK Limited	www.norcote.com	IGX

Table 41: Screen Print / Spray Protective Masking

Use a 1.5 to 2 mil (37 to 50 µm) thickness for ease of removal.
Apply over textures prior to forming to limit the increase in gloss.

Manufacturers	
Kiwo	www.kiwo.com
Spraylat	www.spraylat.com/home.aspx

Table 42: Coatings and Clear Varnish for Abrasion/Chem Resistance

Manufacturers	
Ernst Diegel GmbH	www.diegel.de/
ECKART	www.eckart.net.html
Pröll KG	www.proel.de Proell Noricure UV-L3 scratch proof lacquer

Table 43: Offset Printing Inks

Manufacturer	
Eastern Marking Machine	www.easternmarking.com/consumables.html#inks

Table 44: Flexographic/Letterpress/Gravure Inks

Manufacturers	
ECKART	www.eckart.net.html
Sicpa Sinclair	www.sicpa.com
Del-Val Ink & Color	www.dvink.com
Custom Printing Inks	www.customprintinginks.com

Table 45: Sublimation Inks

Manufacturers	
Gans Inks	www.gansink.com
Apollo Colors	www.apollocolors.com
Naz-Dar Corporation	www.nazdar.com

Table 46: Flexographic/Letterpress/Gravure Inks

Manufacturer		Product
Naz-Dar Corporation	www.nazdar.com	2400 Series

Table 47: Ultraviolet Cured Texturing Inks for use with HP92

Manufacturer		Product
Nor-Cote	www.norcote.com	09 Matte
Sun Chemical	www.sunchemical.com	MTG-FORM

Inks for 2nd Surface In Mold Decoration (IMD)

LEXAN polycarbonate film can be used in the In Mold Decoration (IMD) process. If the inks will be 1st surface printed then the ink systems found in tables 48 through 51 may be suitable if they meet the durability requirements for the application. If the part will be a second surface IMD application then the ink will become sandwiched between the injection molded resin and the film that the ink is printed on. In this instance the inks must be able to withstand the high thermal and mechanical shear of the injected resin. Table 48 lists ink systems that have been found to be compatible with2nd Surface IMD.
Learn more about IMD at www.sabic-ip.com/imd.

Table 48 : Inks compatible with 2nd surface in Mold Decoration

Manufacturers	Products	Type: UV	LED	Waterbased	Solvent	2 Part	TY-layer/ binder needed
JUJO Chemical Co., Ltd. www.jujo-chemical.co.jp	3300 Series				●		
	3200 Series				●		Yes, JUJO
Marabuwerke GmbH & Co. www.marabuwerke.de www.marabu.com	Maramold MPC				●		No
Naz-Dar Corporation www.nazdar.com	2400		●				Yes, Seiko or Pröll binders
	3400	●					
	8400 CVIM				●		No
Nor-Cote UK Limited www.norcote.com	IM	●					Yes, Seiko or Pröll binders
Pröll KG www.proell.de	Noriphan HTR				●		No
	Noriphan HTR HF				●		No
	Noriphan N2K				●	●	No
	Noriphan XWR				●	●	No
Seiko Advance Ltd. www.seikoadvance.co.jp/	MP-4 Slow Dry				●	●	Yes, JT20
	KKS Super Slow Dry				●	●	No
	AKE (N)				●	●	Yes, JT25
SunChemical www.sunchemical.com	DMU Ultrabond	●					No
	C-37				●		No
Teikoku Printing Inks Mfg. Co., Ltd. www.teikokuink.com www.teikokuink.com/en	IPX				●	●	IMB HF-009 IMB HF-006 IMB 003
	IPX-HF				●	●	IMB HF-009 IMB HF-006
	ISX				●		
	ISX-HF				●		
	INQ				●	●	

Table 49 : Inks compatible with 2nd surface in Mold Decoration

Ty-layer Adhesive and Binder inks Manufacturer		Type		
Manufacturers	Products	Waterbased	Solvent	2 Part
Pröll KG www.proell.de	Nori-Press SMK		●	●
	Aqua-Press	●		
Seiko Advance Ltd. www.seikoadvance.co.jp/	JT-20		●	
	JT-25		●	
Teikoku Printing Inks Mfg. Co., Ltd. www.teikokuink.com www.teikokuink.com/en	IMB 003		●	
	IMB-HF 006		●	
	IMB-HF 009		●	

Table 50 : Inks for LEXAN SLX film with and without IMD

Suggested Inks for LEXAN™ SLX film

Manufacturer	Ink Series	IMD	TY-layer needed
Solvent Inks			
SunChemical	C-37	YES	
SunChemical	HG	NO	
Marabu	Maramold MPC	YES	
Nazdar	9600	YES	
Nazdar	8400	YES	
Proell	Noriphan HTR	YES	
Proell	N2K	YES	
Proell	PUR-ZK	NO	
Proell	ThermoJet	NO	
Ultraviolet Cured Inks			
SunChemical	DMU	YES	NO
Marabu	UVPK	YES	YES
Norcote	MSK	YES	YES
Norcote	IGI	NO	N/A

Table 51: Inks Compatible with VALOX Film

Manufacturer	Type	Product/Series
EMMCORP	Offset	ER
EMMCORP	UV Offset	UV
Sun Chemical	Screen	HG
Nor-Cote International	UV Screen	80 w/ 1% 800 initiator
Nazdar	UV Screen	1600 Powerprint UV w/ or w/out catalyst NB80
Spraylat Corp.	Spray	599-Y1249 two component epoxy copper conductive coating
Spraylat Corp.	Screen	Lacral 800
Henkel (Acheson Colloids) Company	Screen	Electrodag 478SS conductive silver
International Microelectronics Research Corp	Screen	PSC-4411 conductive silver

Table 52: Inks Compatible with ULTEM Film

Manufacturer	Type	Product/Series
EMMCORP	UV Offset	UV
Spraylat Corp.	Screen	Lacral 800
Henkel (Acheson Colloids) Company	Screen	Electrodag 478SS conductive silver
International Microelectronics Research Corp	Screen	PSC-4411 conductive silver

Digital Printing

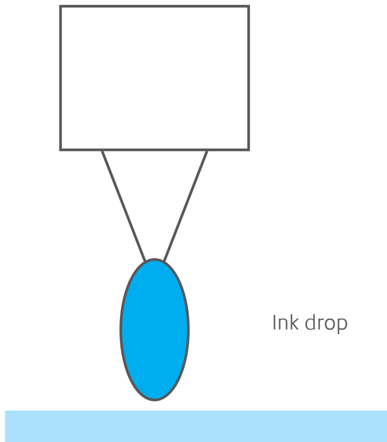
Polycarbonate LEXAN™ film is compatible with digital printing and in many instances can be printed on directly with the digital printing machine without a print receptive pre-treatment. Piezo-head technology is the most popular technology and has been found to be the most compatible with LEXAN film. It enables hot-melt inks to be used which solidify immediately upon contact with the LEXAN film substrate. The figure below shows a schematic of this technology. Table 53 lists several companies that manufacture UV ink jet or solvent ink jet printing equipment capable of direct printing on LEXAN film. These suppliers offer flat bed and/or roll fed options. Conditions for direct printing on LEXAN film will vary from one printer to the next so inquire with the equipment manufacturer about conditions and work with you r SABIC representative to trial some LEXAN film with the equipment manufacturer. In general, using higher pass counts of 8, 16, or more on digital ink jet printers will improve adhesion to SABIC's film substrates. It is possible to digitally print on the coated side of HPxxS, HPxxX and the anti-fog films.

Table 53: Digital Ink Jet Printing Equipment Suppliers

Supplier	
Vutek Inc.	www.vutek.com
Oce	www.oce.com
Inca	www.incadigital.com
Roland	www.rolanddga.com
Mimaki	www.mimakiusa.com
Mutoh	www.mutoh.com
Lotte	www.lotte.co.jp/english/index.html
Gandinnovations	www.gandinnovations.com
HP Scitex Industrial Printers	www.hp.com
Mimaki	www.mimakiusa.com
Durst	www.durstus.com
Inca	www.incadigital.com
Epson	www.epson.com
AGFA	www.agfa.com
Dupont Cromaprint	www.dupont.com
Anhui Liyu	www.ahliyu.com
Digirex	www.digirexdigital.com
Flora	www.floradigital.com
Gerber Scientific Products	www.gspinc.com
Infiniti	www.infinitidigitech.com
Luscher	www.luescher.com
Neolt	www.neolt.it
SkyJet	www.skyair-ship.com
Teckwin	www.teckwin.com

Schematic of digital ink jet technology

An image is created by super heating ink until it forms a bubble which pops out through a nozzle or port in the print head and makes a dot on the media.



Drop on Demand (DOD)
Super heating ink until it forms a bubble

Piezo print-head
Electrically charges the ink

Continuous Ink Jet (CIJ)
Continuous stream and broken into drops

Advantages of using SABIC films with digital printing

There are several advantages to using LEXAN and VALOX™ film for digital printing. Digital printing offers design freedom for custom and specialized OEM parts. It also dramatically shortens lead times for producing prototypes and short run production parts. Using LEXAN and VALOX films as the substrates for digitally printed parts provides higher heat resistance compared with substrates like PETG, vinyl, and PET. LEXAN films offer higher clarity at thicker gauges, easier fabrication through die cutting, and no need for ink receptive coatings as compared with PET. VALOX films provide for a bright white background for eye popping color and contrast. When flame resistance is needed, LEXAN and VALOX film materials provide UL V0 ratings without harmful chloride gas as is found with vinyl. Digital printing and SABIC films are a winning combination when you want high quality, astonishing images that last.

Bonding

Many different adhesive systems, as well as heat sealing, can be used with SABIC's thermoplastic films. The choice of adhesives will be dictated by the specific application. Amorphous materials like LEXAN™ and ULTEM™ films are easier to bond because of their limited chemical resistance. The solvents in the adhesives make the surface swell and dissolve, resulting in good adhesion. A drawback is the sensitivity of amorphous materials to environmental stress cracking. It takes time for evaporation of solvents or water, in the case of water-based adhesives. This curing process increases the cycle time and limits the handling of components after bonding. The adhesive type primarily determines the characteristics of an assembly. (Table 54)

LEXAN, ULTEM, and VALOX films can be bonded to itself or to other materials by a wide variety of commercially available adhesives. Since adhesive bonding involves the application of adhesive media between two molded parts, end-use environment is of major importance in selecting an adhesive system. Good adhesion can be affected by surface activation such as corona discharge or flame treatment.

Table 55 lists a number of adhesive suppliers with adhesives that are generally compatible with LEXAN film. The list is not all-inclusive, and testing is recommended prior to use. Note that some adhesives may have an adverse effect on some inks used on the film.

Table 54: Adhesive Types and Characteristics

Type-Function	Adhesive	Curing	Characteristics
Structural (gap filling)	Epoxies	A+B comp.	chem./moist./heat/creep resist.,
		chemical reaction	stiffness, brittle, low impact
	Polyurethanes	A+B comp.	ductile, flexible, impact, creep, high peel strength
		chemical reaction	
Sealants (gap filling)	Polyurethanes	chemical reaction	ductile, flexible, impact, creep, high peel strength
		moisture	
	Silicones	chemical reaction	impact, flexible, heat resistance, low shear
		moisture	
Contact (not filling)	Polyurethanes	chemical reaction	see above to Polyurethanes
	Cyano acrylates	chemical reaction	fast curing, high peel strength,
		humidity	chem. aggressive, moisture sensitive
Hot melts	EVA	temperature	fast adhesion, low temp. resistance
		chemical reaction	
Solvents (not filling)	MeC12. M.E.K.	physical	easy application, high strength,
	Toluene	evaporation	stress cracking, polluting, toxic

Table 55 lists a number of adhesive suppliers with adhesives that are generally compatible with LEXAN film. The list is not all-inclusive, and testing is recommended prior to use. Note that some adhesives may have an adverse effect on some inks used on the film.

Table 55: Manufacturers with Adhesives that are generally Compatible with LEXAN Film

Manufacturer	Product			
Pressure Sensitive Transfer Adhesives				
3M		www.3m.com		
Avery Dennison		www.averydennison.com		
Dielectric Polymers		www.dipoly.com		
Flexcon		www.flexcon.com/index-flash.htm		
Scapa		www.scapaeurope.com www.scapaasia.com www.scapana.com		
Mac Tac		www.mactac.com		
Henkel		www.henkel.com www.nationaladh.com/Adhesives/		
Sun Process		http://sunprocess.com		
H.B. Fuller Company		www.hbfuller.com/		
One and Two-Part Epoxies/Urethanes				
Henkel		www.henkel.com www.nationaladh.com/Adhesives/		
Huntsman		www.huntsman.com/		
Rohm & Haas		www.rohmhaas.com		
H.B. Fuller Company		www.hbfuller.com/		
Argotech Inc.		www.argotec.com		
Sierracin/Sylmar Corp.		www.ppg.com		
3M		www.3M.com		
Hartel Enterprises		(818) 952-7652		
Lord Corporation		www.lord.com		
Cytec Industries Inc.		www.cytec.com		
Synthetic Surfaces Inc.		www.nordot.com/		
Henkel Corporation		www.loctite.com		
Royal Adhesives & Sealants		www.royaladhesives.com		
Hotmelt Adhesives				
3M		www.3m.com		
Henkel		www.henkel.com www.nationaladh.com/Adhesives/		
H.B. Fuller Company		www.hbfuller.com/		
Contact Cements				
3M		www.3m.com		
Solvent Adhesives				
Local chemical and warehouses distributors	Dichloromethane methylene chloride Caution: lowers impact			
RTV Silicon Adhesives				
Momentive Performance Materials Inc	Dichloromethane methylene chloride Caution: lowers impact	www.momentive.com		
IMD Adhesion Promoters				
Ty-layer Adhesive and Binder inks Manufacturer		Type		
Manufacturers	Products	Waterbased	Solvent	2 Part
Pröll KG www.proell.de	Nori-Press SMK		●	●
	Aqua-Press	●		
Seiko Advance Ltd. www.seikoadvance.co.jp/	JT-20		●	
	JT-25		●	
Teikoku Printing Inks Mfg. Co., Ltd. www.teikokuink.com www.teikokuink.com/en	IMB 003		●	
	IMB-HF 006		●	
	IMB-HF 009		●	

Table 56: Adhesives for ULTEM™ Film

Adhesive	Surface Treatment#	Cure		Tensile Shear Strength (psi) ULTEM grade##			Tensile Shear Strength (N/mm^2) ULTEM grade##		
		temp (°C)	Time	1000	2100	2200	1000	2100	2200
Polyurethanes									
Hughson 7501	SW	23	72 hrs	960	1500	1900	7	10	13
	SW/S	23	72 hrs	1000			7		
H.B. Fuller Accuthane, UR-150	SW/CD	150	30 min	1500	1400	1400	10	10	10
Cyamid	SW	105	20 min	1400	1200	1200	10	8	8
Cybond HG 1311-176-1	SW/CD	105	20 min	1400	1200	1200	10	8	8
Epoxies (Non-Amine)									
3M EX 1838 (Polyamide Type)	SW/CD	23	72 hrs	780			5		
3M 3501 (Mercapitan Type)	SW/CD	23	72 hrs	1250			9		
3M 2216 B/A	SW	23	72 hrs	1600			11		
	SW/CD	23	72 hrs	1500			10		
Epi-Bond	SW	23	72 hrs	900			7		
156 A/B	SW/CD	23	72 hrs	800			6		
Silicones									
GE RTV 157 (also 102,108,158 and 106)	SW/CD	23	7 days	450	640	640	3	4	4
	SW/F	23	7 days	490			3		
	CA	23	7 days	530			4		
Hot Melt									
3M 3779 (Polyamide Type)	SW	205		480			3		
	SW/CD	205		830			6		
	SW/F	205		800			6		
Cyanoacrylates									
Eastman 910	SW	23	5 min	300	1500	1900	7	10	13
	SW/CD	23	5 min	250			7		
Loctite 414	SW	23	5 min	720					
	SW/CD	23	5 min	350					
Peel Strengths									
ULTEM 1000 to copper foil laminate (Goodyear Pliobond 30)				lb/in width###					
	None	180	4 min	9.1					
	SW	180	4 min	9.4					
	SW/CD	180	4 min	12.4					
	SW/F	180	4 min	12.1					
ULTEM 2000 to transfer adhesive				oz/in width####					
3M 468	SW	23	16 hrs	79					
3M Y9463	SW	23	16 hrs	61					

\# SW = Solvent Wipe (heptane)
S = Sanding
CD = Corona discharge
F = Flame treatment
CA = Chromic acid etch

\## ULTEM 1000: Unmodified resin
ULTEM 2000: 10% glass reinforced resin
ULTEM 2200: 20% glass reinforced resin

\### Press cured at 200psi (1.5 N/MM^2), pulled in 1 inch wide strips at 2 IPM, 90° peel. Many circuit board specifications call for a minimum of 9.0 lb/in.

\#### Transfer adhesive tape bonded to ULTEM, pulled 1 inch wide strips, at 10 IPM, 180° peel. Typical minimum acceptable peel adhesion is 32 oz/in.

Table 57: Adhesives for VALOX™ film

Material	For Bonds to VALOX	For Bonds to Metal	For Bonds to Other	Catalyst	(PPH) Catalyst	Cure Temp.	Time	Tensile strength Lap-Shear	Maximum Service Range	Chemical Resistance
One Part Systems										
Loctite #430	●	●	●	–	–	73°F	12 hrs	300-900	-110°F to -175°F	Soluble in MEK, Acetone and Toluene
Loctite #496	●	●	●	–	–	73°F	12 hrs	300-900	-110°F to -175°F	Nitrometh-ane
Scotch Weld #2214 Regular	●	●	●	–	–	250°F	40 min	400-1000	200°F	–
Scotch Weld #2214 Hi Density	●	●	●	–	–	250°F	40 min	400-1000	200°F	–
Scotch Weld #2216	●	●	●	–	–	300°F	–	650-950	<300°	Good
Two Part Systems										
Uralane 5738A	●	●	●	5738/B	100-55	200°F 73°F	1-2 days 7 days	1100-1500	300°F	–
Uralane 5742A	●	●	●	5742/B	100-55	200°F 73°F	1-2 days 7 days	1100-1500	300°F	–
Uralane 8615A	●	●	●	8615/B	100-55	200°F 73°F	1-2 days 7 days	650-750	300°F	–
Scotch Weld 3520A	●	●	●	3520/B	100-100	200°F 73°F	15 min 24 hrs	1100-1500	<180°F	–
Epon 828	●	●	●	Versamid 40	100-100	260°F	1-3 hrs	1000-1700	200°F	–
Eopon 828	●	●	●	Versamid 25	100-100	260°F	1-3 hrs	1000-1700	200°F	–
Cadco A 400	●	●	●	B-400	100-100	150°F	1-3 hrs	500-1000	200°F	–
DuPont 46971	●	●		RC805	50-1			400-600		Excellent
Hartel HE 17017	●	●		A/B	100-85	150°F	4 hrs	450-800	<300°F	Good
Armstrong A12	●	●		A/B	2-3	165°F	2 hrs	750-650	<300°F	
Amicon X71242	●	●		A/B	1-1	73°F	27 hrs	800-1250	–	
Thermoset DC-80	●	●		A/B	1-2	200°F	5 hrs	450-1150	250°F	

Material	Catalyst	Cure Temp.	Time	Tensile strength Lap-Shear	Chemical Resistance
Potting Compounds					
Thermoset DC-795		173°F	12 hrs		Excellent
Thermoset DC-23A/B		240°F	60 min		Excellent
Thermoset #314A/B					Excellent
GE-RTV-511	Follow manufacturers' recommendations	73°F	24 hrs		Excellent
GE-RTV #7A/B foam		73°F	24 hrs		Excellent
Silastic S-5370 foam		73°F	24 hrs		Excellent
Scotch Cast-4407					
Scotch Cast-4401					
Sealants					
GE-RTV-102	Follow manufacturers' recommendations for catalyst addition	73°F	24 hrs	100-200	Excellent
GE-RTV-124#		73°F	24 hrs	100-200	Excellent
GE-RTV-154		73°F	24 hrs	100-200	Excellent
GE-RTV-108	No Catalyst	73°F	24 hrs	50-100	Excellent
Dow Coming RTV-732	No Catalyst	73°F	24 hrs	40-70	Excellent
Dow Coming RTV-734	No Catalyst	73°F	24 hrs	40-110	Excellent
Dow Coming RTV-3145	No Catalyst	73°F	24 hrs	100-200	Excellent

Table 58 provides a snapshot of the various bonding techniques that can be used with LEXAN, ULTEM, and VALOX film. Specific welding conditions depend on film thickness and weld technique. Many welding equipment suppliers are available for each technique and most are willing to assist with testing prior to purchasing a piece of equipment. It is important to test the assembled product in the end use environment or through accelerated life testing to ensure that the assembly will meet the needs of the application.

Table 58: Overview of assembly techniques for SABIC's Specialty Film and Sheet films

Material	Welding	Adhesives	Mechanical Assembly
LEXAN film	Vibration, Ultrasonic, Induction possible	Generally easy, critical are Cyanoacrylate and Acrylic because of stress cracking	Avoid high stresses at point loadings
ULTEM Film	Vibration, Ultrasonic, Induction possible	Epoxy, PUR(2K), Silicones possible, Acrylic, Cyanoacry-late critical because of stress cracking	All techniques possible
VALOX Film	Vibration, Ultrasonic, Induction possible	Epoxy, PUR, Silicones, Cyano-acrylate possible	All techniques possible Prevent creep

Heat Sealing

Three methods are satisfactory for heat sealing LEXAN films: impulse, jaw, and ultrasonic sealing. Preliminary testing indicates that the ultrasonic technique is the most reliable, producing peel strengths of 8.6 lbf per inch (38 N per 25 mm) of width. Speeds for this method range from 6 in/s (150 mm/s) with 0.003 inch (0.075 mm) film to 1.2 in/s (30 mm/s) for 0.020 inch (0.500 mm) film.

Impulse and jaw methods produce bonds ranging from 3-14 lbf per inch (13-62 N per 25mm) of width. As shown in Table 59, the impulse method is more rapid, particularly with the thinner gauges. It should be noted that these times were obtained on laboratory equipment with only single jaw heating. Times on actual production equipment running at normal operating temperatures would be much faster.

Table 59: Sealing Time (Seconds)

Method	Thickness (inch (mm))		
	0.001 (0.025)	0.003 (0.075)	0.005 (0.125)
Impulse	2.5	3.5	4.5
Jaw	7	8	9

Jaw sealing requires temperatures of 400°F (205°C) for 0.001 inch (0.025 mm) film and 430°F (220°C) for the two thicker films. Dielectric sealing is not practical with common commercial equipment because of LEXAN films' low dissipation factor.

Cleaning

Periodic cleaning using correct procedures can help to prolong service life. For cleaning, it is recommended that the following instructions be adhered to:

Cleaning Procedure for Small Areas - Manual

1. Gently wash film with a solution of mild soap and lukewarm water, using a soft, grit-free cloth or sponge to loosen any dirt or grime.
2. Fresh paint/ink splashes, grease and smeared glazing compounds can be removed easily before drying by rubbing lightly with a soft cloth using petroleum ether (BP65°), hexane or heptane. Afterwards, wash the sheet using mild soap and lukewarm water.
3. Scratches and minor abrasions can be minimized by using a mild automobile polish. We suggest that a test be made on a small area of LEXAN film with the polish selected and that the polish manufacturer's instructions be followed, prior to using the polish on the entire sheet of film.
4. Finally, thoroughly rinse with clean water to remove any cleaner residue and dry the surface with a soft cloth to prevent water spotting.

Cleaning Procedure for Large Areas - Automated

1. Clean the surface using a high-pressure water cleaner (max. 100bar or 1,450psi) and/or a steam cleaner. We suggest that a test be made on a small area, prior to cleaning the entire sheet of film.
2. Use of additives to the water and/or steam should be avoided.

Other Important Instructions for All Specialty Film and Sheet Films:

- Never use abrasive or highly alkaline cleaner on Specialty Film and Sheet film materials.
- Never use aromatic or halogenated solvents like toluene, benzene, gasoline, acetone or carbon tetrachloride on Specialty Film and Sheet film materials.
- Use of incompatible cleaning materials with Specialty Film and Sheet film materials can cause structural and/or surface damage.
- Contact with harsh solvents such as methyl ethyl ketone (MEK) or hydrochloric acid can result in surface degradation and possible crazing of Specialty Film and Sheet film materials.
- Never scrub with brushes, steel wool or other abrasive materials.
- Never use squeegees, razorblades or other sharp instruments to remove deposits or spots.
- Do not clean Specialty Film and Sheet film materials in direct sunlight or at high temperatures as this can lead to staining.
- For all mentioned chemicals consult the manufacturer's material safety datasheet (MSDS) for proper safety precautions.

Die Cutting

SABIC's thermoplastic films can be die cut with either steel rule, matched metal and, to a lesser extent, rotary dies. LEXAN's shear strength of 10,000 psi (70 N/mm2), relatively low in comparison to metals, simplifies and eases tool design and processing. In addition, parts may be cut from single or multiple sheets depending on press tonnage, working area and material thickness.

The press tonnage required to die cut LEXAN film can be determined by the simple formula:

$$F = \frac{(P)\ (A)}{9807\ \text{N/metric ton}} \qquad F = \frac{\{P\}\ \{A\}}{2000\ \text{lb/ton}}$$

F = press tonnage
P = shear strength of LEXAN film
A = cross-sectional area

The cross-sectional or shear area can be found by multiplying the total length of the cut by the film thickness. For example: (Note: SI and metric examples are not equal)

Figure 18 shows a 4" x 10" rectangle with a 2" diameter circular cutout in the center.

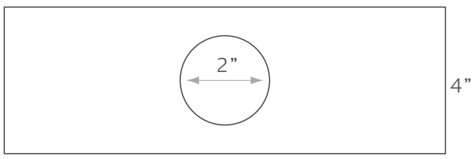
Figure 19 shows a 100 x 300 mm rectangle with a 50 mm diameter circular cutout in the center.

Of the three die cutting methods described earlier, steel rule die cutting is the most popular and least expensive method used. Generally, a 2-point rule (0.0275 inch or 0.7 mm thick) is used to cut SABIC's Specialty Film and Sheet films up to 0.015 inch or 0.375 mm thick, whereas a 3-point rule (0.04 inch or 1.0 mm thick) is used for films greater than 0.015 inch or 0.375 mm in thickness. When careful make-ready is applied, over 25,000 cuts can be obtained from a steel rule die.

Steel rule dies are manufactured by two different methods: laser and jig. The laser cut die will maintain the most accurate dimensional tolerances (to ± 0.004 in or 0.1 mm), while the jig cut die will provide the least (± 0.016 in or 0.4 mm). In manufacturing a die, a steel rule is fitted into a pre-cut pattern in a wooden die board. Stripping rubber on each side of the rule eases part ejection. Generally, stripping rubber should be no more than 0.12 in (3 mm) above the height of the rule. Figure 20 illustrates a typical steel rule die.

Several different steel rule bevel designs are available, as illustrated in Figure 21.

Figure 18



Total length of cut = 2L + 2W + πD
= 2 (4") + 2(10") + π(2")
= 8" + 20" + 6.28"
= 34.28"

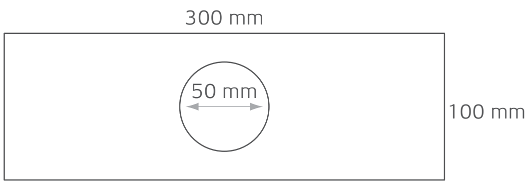
Shear Area = total length x thickness of film
= 34.28" x 0.010"
= 0.343 in^2

Press tonnage

$$F = \frac{(P)\ (A)}{2000} = \frac{(10{,}000\ \text{lb/in}^2)\ (0.343\ \text{in"})}{2000\ \text{lb/ton}}$$

F = 1.72 ton

Figure 19



Total length of cut = 2L + 2W + π D
= (2) (300 mm)
+ (2) (100 mm) + π (50 mm)
= 600 mm + 200 mm + 157 mm
= 957 mm

Shear area = (total length) x (thickness of film)
= 957 mm x 0.250 mm
= 239.25 mm^2

Press tonnage

$$F = \frac{(P)(A)}{9807} = \frac{70\ \text{N/mm}^2 \times 239.25\ \text{mm}^2}{9807\ \text{N/metric ton}} = 1.7\ \text{metric ton}$$

Figure 20

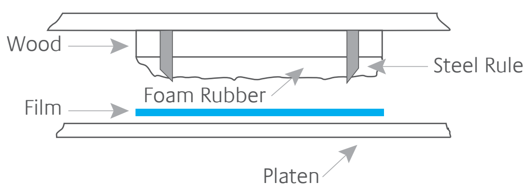
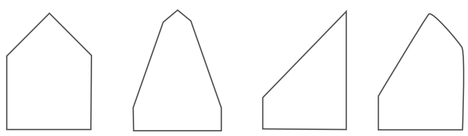


Figure 21



Although the center bevel rule is the most common and provides the longest life in terms of wear, cleaner cuts can be attained by using a facet bevel rule. The longer bevel reduces material displacement, especially with thick material, while the broad tip remains sharp. The flush bevel rule also provides clean cuts, but has a weak tip that is susceptible to roll-over. To maximize both cut quality and rule longevity, the side bevel rule is recommended. In this case the long bevel side should face the scrap or trim of the piece.

Depending on rule design, size and shape of part, and thickness of film, the cut parts will be slightly different in size than the rule: holes will be smaller and cut outs will be larger. Therefore, dies are usually manufactured on either end of the tolerance range. For example, dies to cut holes are made slightly larger than the part size indicated on the print.

SABIC's thermoplastics films can be successfully "kiss cut" with platen presses having close tolerance impression adjustment controls. In kiss cutting, a side bevel is recommended in the die design. The problem of cutting through both the printed SABIC's thermoplastic films and transfer tape or liner can be solved by using a heavier or thicker liner. For instance, using a 0.006 in. (0.15 mm) liner (3M, 9668) versus a 0.004 in. (0.10 mm) liner (3M 468) will provide a flatter piece and cushion the impact of the steel rule. Obviously the thicker liner will be more difficult to cut through completely, and so the kiss-cutting problem will be reduced.

Finally, two other methods are used to die cut SABIC's thermoplastic films; matched metal and rotary. Matched metal dies consist of hardened male and female die halves. Match metal die cutting operates by shearing the film and is used to cut intricate patterns, to maintain tight dimensional tolerances (± 0.001 in. or 0.025 mm), and to cut thicker films on larger volume production runs (100,000+). Clearance between dies should be less than 0.001 inch or 0.025 mm.

In roll-to-roll film processing (i.e. flexographic printing), rotary dies can be used for cutting SABIC's thermoplastic films. This process offers a high-speed production capability versus steel rule and matched metal die cutting.

Table 60 is a partial list of diemakers for SABIC Specialty Film and Sheet films.

Table 60: Diemakers for SABIC Specialty Film and Sheet Films

Manufacturer	
Marbach Werkzeugbau GmbH	www.marbach.com
A&H Formes Ltd.	www.ah-formes.co.uk
Millennium Die Group	www.millenniumdie.com
Atlas Die, LLC	www.atlasdie.com
Independent Die Service	www.wsids.com

Web Stretch

One common technical hurdle for roll-to-roll web processes is overcoming the issue of web stretch. When LEXAN film is handled in web form (roll to roll), a predictable dimensional change can occur when tension is applied to the unsupported web. This change is an important consideration when printing, stamping or die cutting operations are performed on the material when the web is under tension.

The following information can be useful in compensating for dimensional change
to insure accurate registration.

All thermoplastic materials will exhibit a spring-like behavior when loaded in tension below the proportional limit where permanent deformation occurs. This means that tension can be applied and removed and the material will stretch and return to its original dimension, respectively. The property that describes this condition is the Tensile Modulus of Elasticity which for LEXAN film is 300,000 psi at 73°F and 270,000 psi at 167°F. The formula is simply:

$$E = \frac{\sigma}{\varepsilon}$$

where: E = tensile modus in psi
σ = tensile strength in psi
ε = strain (stretch) in inches per inch of material

and

$$\sigma = \frac{F}{A}$$

where: F = tensile force in lbs. (web tension)
A = scross-sectional area in sq.in. (web width x thickness)

This formula can also be used to predict web stretch by rearranging to:

$$\varepsilon = \frac{\sigma}{E} \quad \text{or} \quad \varepsilon = \frac{F}{A \times E}$$

For example, a typical problem would be to determine how to design a die to cut a 4" square out of a 5" web of 5 mil LEXAN film with 20 lbs. of web tension at room temperature.

$$\varepsilon = \frac{F}{A \times E} \qquad \varepsilon = \frac{20 \text{ lbs.}}{.025 \text{ sq.in.} \times 300{,}00 \text{ psi}} = .0027 \text{ in/in}$$

F = 20 lbs.
A = 5" x .005"=.025 sq.in.
E = 300,000 psi A 4 inch part cut from the web under tension will be 4 in x .0027 in/in = 0.0108 in shorter in the web direction when relaxed.

A corresponding necking down or decrease in web width will occur. This can be quantified by using Poisson's ratio which is the ratio of the transverse contraction to the elongation of a web under tension. For LEXAN film this number is 0.38. In the above example, the decrease in width will be 0.38 x .0027 in/in= 0 .0010 in/in.

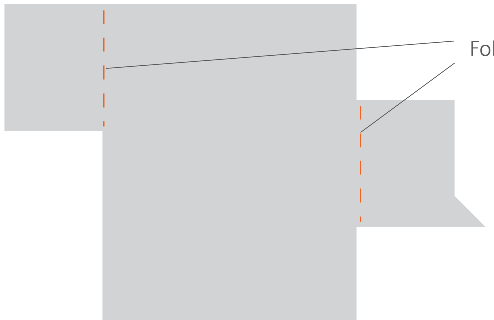
A die that is designed to cut a 4 inch square from the web in the above example should be about 0.011 inch larger in the web direction and 0.004 inch smaller in the transverse direction.

Screen and printing plates can be modified likewise to compensate for web stretch. The amount of displacement between work stations can also be determined and controlled by web tension. If the distance between two printing stations is 5 ft., in the above example the displacement of one imprint to the next is 0.162 inch. Decreasing the web tension to 10 lbs. will reduce the displacement to 0.081 inch. Heating a portion of the web in a dryer can increase the displacement because of the lower tensile modulus at elevated temperatures and thermal expansion. However, the amount of web stretch at each work station will be the same if the film is at a similar temperature at each station.

Creasing and Folding

Rule Design

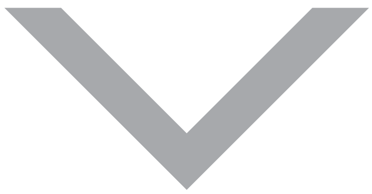
SABIC Specialty Film and Sheet films are notch sensitive which makes them very easy to die cut. When it is necessary to fold these films it is important not to notch or score the folding lines unless it is desired to break the film along the score line. If a folding line is needed, LEXAN™, ULTEM™, and VALOX™ films should be creased with a crease rule to maximize fold life.



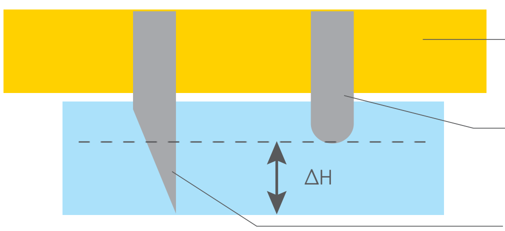
Crease rule

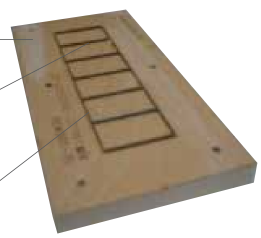
Crease knife width of 0.7mm (0.028 in) is commonly used by Fabricators. Radius = ½ width

Crease Line Depth – example of 17mil gauge
- ΔH greater than 0.1mm may allow for 6 or more 180˚ bends along the crease line
- ΔH of at least 0.2mm is suggested to avoid film cracking due to tolerances in crease depth
- Crease lines can be put on both the polish and textured sides of the film
- Bend so that the crease creates an inside corner of the part. It is not suggested to bend so that the crease is the outside corner of the part.



A crease knife width of 0.7mm is commonly used at fabricators with a radius of 0.35 mm





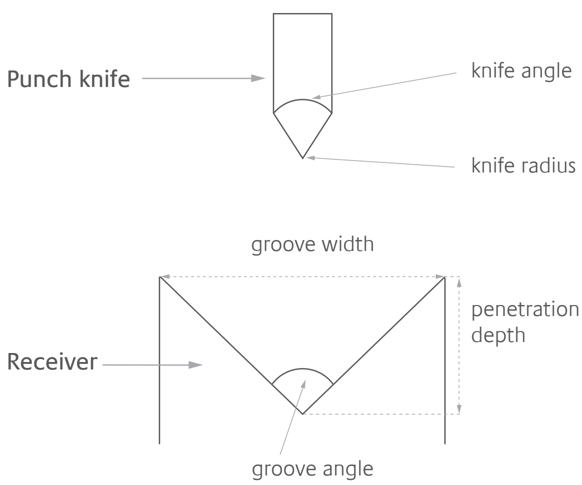
Cold Line Bending/Folding

Tool Design

The tool is built with a punch and receiver similar to press breaks used for metal fabrication. These tools are used primarily to fold the film into 90 degree angles but other angles are possible. Suggested dimensions of the punch and receiver for film thicknesses of 0.007 inch to 0.030 inch are as follows: (See figure below)

Groove Width – 4 times film thickness
Groove Angle – 15 to 20 degrees
Punch knife radius – film thickness to 1 mm
Punch Angle – Grove angle or Grove angle minus 2 degrees
Penetration depth – 4 times film thickness
Bending Speed – 500 to 1000 mm/min
Hold time – 4 seconds

After bending the finished angle of the part should be 84 to 85 degrees and should open to approximately 90 degrees after 24 hours. Tools should be made of hardened steel for durability. The punch should never have a sharp tip as this will score the material and cause it to crack.



Cleanliness

Any chad/residue stuck on the receiver may cause yield loss because it can create a dent along the fold line. Monitor the receiver during processing. Avoid oils and grease during processing and fully clean the tool prior to each run. Any oils or grease that are used should be checked for chemical compatibility with the SABIC film being used.

Machine Speed

Excessive line speeds of 20 to 50 m/min can cause yield loss due to pin holes. Speeds of 0.5 m to 1 m per minute are suggested.

Folding Orientation

IIt is suggested to fold in the direction perpendicular to the extrusion direction of the film to minimize yield loss due to pin holes.

Inspection

“Hi-pot” (dielectric strength) testing along the bend line is suggested as the preferred method for quality control.

Special Conversion Considerations for Display Films

Environment

LEXAN Display film is manufactured in clean rooms to meet the requirements of the display industry. All secondary processing must be conducted in a clean room.

Slitting

Use of a polished, chrome free/idle roller on the slitting machine is suggested to prevent the risk of scratching the film. If a polished chrome roll is not possible then wrapping the roller with a clean film product (e.g. thin foam or high quality masking) is also helpful to control scratches. If any idle roller does not work or rotate smoothly, scratches may result. All rollers need to be cleaned before processing.

Always remove the first one or two winds from the roll to prevent contamination or particles from entering the slitting machine. Static control and elimination techniques such as those mentioned on page 36 are suggested to reduce and remove static build-up when winding and slitting the roll. It is advisable not to have personnel present during winding and slitting to reduce the potential for contamination.

Caution The voltage from static electricity may exceed 20 kV if there is no or poor static control.

Die-cutting

In most cases, the conveyor belt is made from a thick polyester film. It is important not to allow the cutting die to penetrate more than 15 μms into the conveyor belt. Excessive penetration can result in wear and particles from the conveyor belt which can cause dents or white marks on the LEXAN Display Film. All rollers, the die, and the conveyor belt must be cleaned before manufacturing. Conveyor belts with excessive wear should be replaced.

It is important to monitor the edge quality of the die cut part to ensure the tool quality is being maintained. Poor edge quality is an indication that the die should be repaired or replaced.

It is suggested to install a tacky-roller cleaning machine directly after the die-cut process.

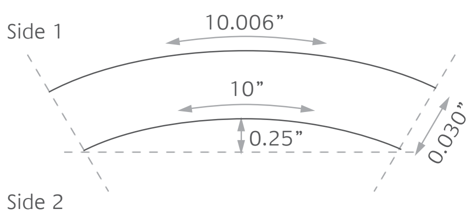
Film collection into a stack after the die cut process is also a critical operation. Scratches can occur during the shuttling of the film from the cleaning machine to the collection tray. Deionizing fans should be used to help float the film onto the stack and minimize scratching.

Inspection
100% manual inspection is applied in the display film conversion industry. Inspecting to a specification that is beyond the actual product specification is a typical cause for low yields. Conducting a fitness for use test by assembling the films onto the backlight or liquid crystal module (LCM) is a good technique to align the inspection method with the end customer's needs. For example, some minor scratches that triggered a rejection during inspection may not be visible when the film is assembled onto a LCM and should not be cause for rejection.

Conducting multiple inspections further reduces yield do to having to handle the film multiple times. A single inspection is recommended when inspecting products for the display industry.

Reverse Winding to Ameliorate "Roll Set"

Introduction
Roll-set is an inescapable partner to roll wound, thermoplastic film and sheet products. Like all thermoplastics, LEXAN Display film, LEXAN film, ULTEM film, and VALOX film will flow (or creep) over time, under conditions of elevated stress. Roll-set arises from stress induced "creep". The degree of creep is a function of the material, the temperature, the time at stress and stress level. The stress level, in turn, will be affected by winding tension, radius of curvature and material thickness.



As shown above, the creep behavior which leads to roll-set is created by Side 1 being slightly longer than Side 2 and results in the characteristic observation that a cut sheet of the material curls towards Side 2. The creep does not need to be profound to induce a significant curvature. For example, on a 10" long sheet of 30 mil film, a dimensional change (Side 1 – Side 2) of only ≈0.006" (about 600 ppm) would result in a 1/4" center-line deflection as pictured in Figure 1.

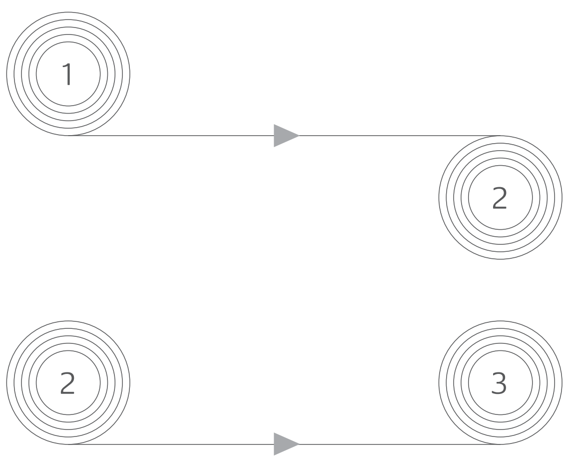
The importance of time in creep behavior cannot be overstated. Creep is a viscoelastic behavior that requires long times to reach its full effect. Similarly, efforts to ameliorate roll-set (as described below) by inducing a "counter-creep", will also take long times to reach their full effect. Indeed, over a sufficient amount of time, reverse winding techniques would be expected to induce a counter-curl (Side 2 now longer than Side 1).

Reverse Winding
Reverse winding is a technique that can be used to reduce roll-set to an accept¬able level. While reverse winding is not an exact science, it has been used effectively on LEXAN™ films for many years. As its name implies, the process induces a counter-creep, roughly equal in magnitude but opposite in direction to the creep that induced the initial roll-set or curl. As indicated above, the results of employing this procedure will vary with the time between manufacture and reverse winding as well as with the time between reverse winding and sheeting. An optimum effect is expected between 2 and 4 days after reverse winding. It is therefore recommended that provision for reverse winding be included in quoted lead times and that orders are promptly shipped, sheeted or other¬wise processed following this 2 to 4 day waiting period. Since roll-set and reverse winding are related to "wound-in-tension" as well, it is further recommended that persons intending to employ reverse winding conduct studies (on each material type and gauge) to determine the best "waiting period" associated with their particular equipment.

Since the bending forces that induce creep are more pronounced near the roll core (because of the tighter radius) and taper off near the outer convolutions of the roll, the stress, the creep and the resultant roll-set are more pronounced near the core. An effective reverse winding technique must therefore have the following two results:

- The direction of the film curvature must be reversed.
- The end of the film originally near the core must also end-up near the core.

These goals are accomplished through the two-step process pictured below.



Packing

For LEXAN™ display without masking, two dummy sheets (one on top and one on bottom) are applied for protection of the sheeted film. It is suggested that the film stack be packed into an anti-static bag and wrapped so that no part of the packaging is folded onto the surface of the stack. (Image 1 below). All excess packaging must be wrapped and secured so that it is only along the vertical edges of the stack. (Image 2 below)

Image 1a (Folding wrapping onto stack surface)

Image 1b (Folding wrapping along height of stack)

Backlight Assembly

Personnel & Environment

Personnel who handle LEXAN™ display films should be aware that LEXAN™ display film is more sensitive to foreign particles compared to coated bottom diffuser films. It is recommended that all personnel on the assembly line wear lint free clean room suits and powder free gloves. A class 1,000 or better clean room is recommended during backlight assembly. It is suggested that customers reduce and control particles in the clean room by periodically cleaning tools, tables, staging areas, and the floor.

Handling Guidelines

Image 2a

Do not bend the film excessively or fold it to avoid crease marks

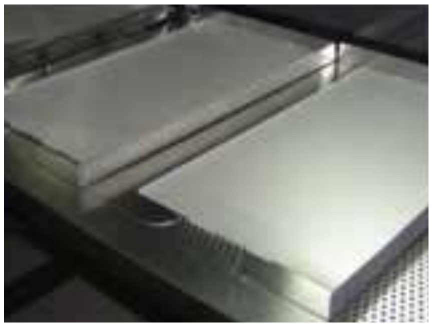


Image 2b

Use a tray during transportation to avoid applying excess pressure on the film

Image 2c

Only handle the film by the tabs along the edge and always handle with 2 hands.

Masking Removal (for PA & PB films)

A de-ionizing fan is needed to reduce and control the static electric charge generated during masking removal. Tape is suggested to initiate masking removal. Avoid creating dents from fingernail or finger marks.

Image 3a

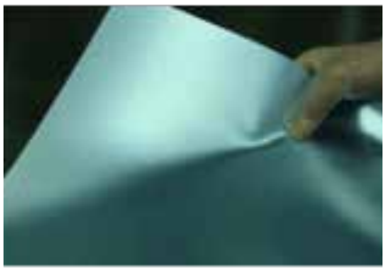


Image 3b

Assembly onto Backlight

Remove particles or coating beads on the film (normally on the bottom diffuser) with a tacky roller prior to putting the prism film on top.

Image 3a

Hold tabs along the edge to assemble the film into the backlight module and avoid scratching or denting the prism film.

Image 3b

Inspect the BLU and remove dust if needed according to the suggestions below.

Dust Removal & Cleaning

Removing dust by using tape is not recommended because the adhesive could leave a residue on the surface. It is recommended to use a “sticky rod” as shown in C above. Some customers use a tacky roller for dust removal and it is suggested that they verify whether this operation is effective for their assembly operation.

If cleaning of the film is needed, it is suggested to only use ethanol for this task. Many organic solvents like ether, gasoline, acetone & naphtha are harmful to LEXAN™ film.

Waving Resolution

Root Cause

A wave in the film leads to non-uniform brightness in the display which is referred to as "mura" in the display industry. (image 4) Mura is created when the film does not lay flat in the backlight unit (image 5). This phenomenon is called waving.

Waving is primarily driven by a temperature gradient seen between the over lamp and LED rail (image 6). This temperature gradient results in thermal expansion of the film inside the backlight unit which can result in loss of film flatness if not accounted for. The film may return to a flat state when the temperature gradient is gone. Temperature gradients increase waving risk!

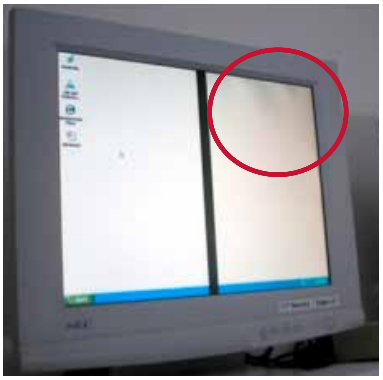


Image 4

Image 5

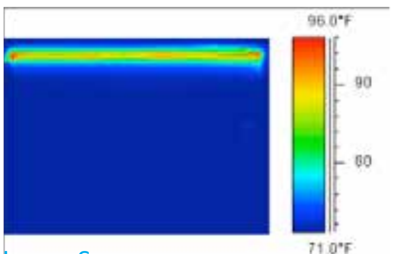


Image 6

Inherent Property of LEXAN™ Display Film

The Coefficient of Thermal Expansion (CTE) of LEXAN Display Film is about 70 ppm/ oC; which is greater than that of coated PET film (about 20 ppm/ oC). When a temperature gradient is applied to LEXAN Display film and PET coated film, the CTE difference contributes to a larger dimension change of LEXAN Display film. If not accounted for and enough space is not left inside the backlight or LCM for the film to expand, the film will be constrained and waving will occur.

LEXAN Display film is not as stiff as coated PET at the same film thickness. Using a thicker LEXAN Display film will provide improved stiffness.

LEXAN Display film does not have a coating on it and is therefore not as sensitive as coated PET film once it has been placed into a high humidity environment like it might see during shipping. The photographs shown below were taken after 65oC, 95% RH, 12 hours of exposure with 3 edges constrained.

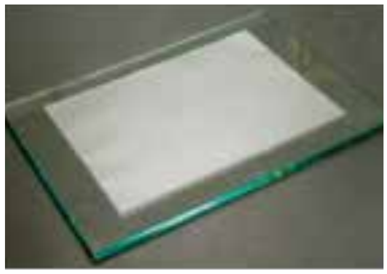


Image 7: LEXAN Display film

Image 8: Coated PET film

Resolution of Waving

Waving can be reduced by,

a) Considering the temperature gradient in the design. Cut the film to allow for thermal expansion of the LEXAN Display Film (about 70 ppm/ °C) inside the backlight or LCM. Cutting the film too small may result in LCM light leakage or scratches during shipping due to vibration.

b) Reducing the temperature gradient in the design. Sidelight type backlights with a larger distance between the film edge and the lamp rail is also helpful to reduce waving.

c) Using a thick film as the top film in the stack can flatten waves in the thin middle and bottom film layers.

d) Using a thick film increases the stiffness which helps maintain the flatness of the film. Ensure that the film is not so thick that it reduces the gap between the film stack and the LCM frame. This may result in constrained film expansion. In some cases, a small gap can help improve waving performance. The gap typically varies between 0 mm to 0.8 mm for different LCM designs.


Li-ion

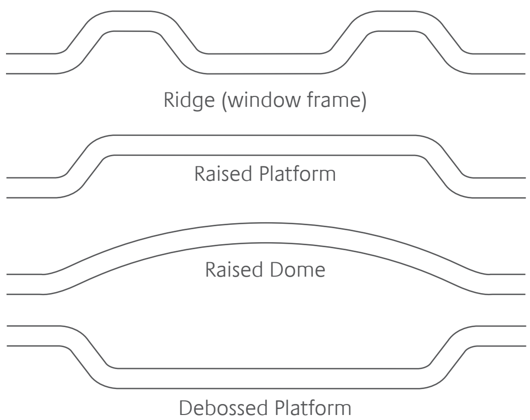
Embossing

SABIC's thermoplastic films can be embossed to form raised areas for membrane switch keys, or raised letters and design. Thicknesses up to 0.01 in. (0.250 mm) can be readily embossed, and films up to 0.02 in (0.500 mm) can be embossed in certain configurations. For films over 0.02 in (0.500 mm) thick, thermoforming should be used to create three-dimensional effects.

Embossing raised areas for membrane switch keys may significantly decrease switch life. Since switch size and travel, film thickness, embossed height and working environment can all be factors, product life cycle testing is strongly recommended. For longer actuation life, minimize gauge, travel, and height of the emboss while maximizing the emboss area. Printing on the material can dramatically reduce switch life as well. Inks must be tested and the life expectancy adjusted accordingly.

A wide variety of embossed configurations are possible with SABIC Specialty Film and Sheet films, as shown in Figure 22.

Figure 22: A wide variety of embossed configurations

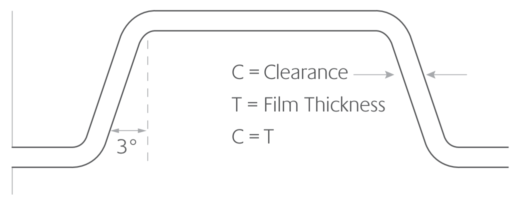


Die Design

Dies for embossing can be matched male/female or either male or female with a rubber counter die. Materials for dies include metals such as zinc, magnesium, brass, aluminum, and steel, as well as polyester/fiberglass and silicone rubber. Sharp detail usually requires the use of metal dies.

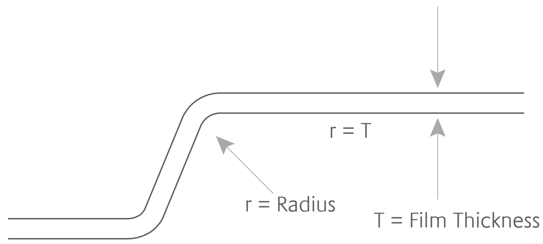
Dies should be designed so the clearance between the male and female sides is approximately equal to the film thickness. Minimum draft angles of 3° should be designed into both male and female walls, as shown in Figure 23. If using LEXAN HP92TTY film, the minimum draft angle should be 20°.

Figure 23: Minimum draft angles of 3° should be designed into both male and female walls of the die.



To keep localized stresses in the embossed overlay to a minimum, embossing dies should contain no sharp corners at points in contact with LEXAN film. Radii at all internal corners will reduce stress concentration and help prevent failure from fatigue or impact. As a rule of thumb, radii should be equal to, or greater than, the thickness of the film. In other words, a 0.01 in. (0.250 mm) thick LEXAN film should contain a 0.01 in. (0.250 mm) minimum radius at any corner (Figure 24).

Figure 24: Radii



Heated platens with temperatures as high as 290 F (143 C) may also be used to reduce stresses from embossing and to obtain more emboss detail.

Embossing Press

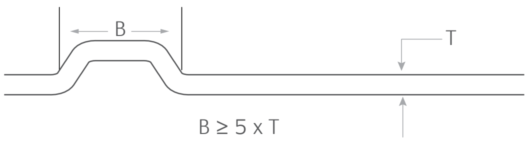
Several types of press can be used to emboss SABIC's thermoplastic film. The most popular of these is the platen press, which also can be used in steel rule die cutting.

Part Design

The following design recommendations for embossed parts will help to minimize stress and maximize key life in membrane switch applications.

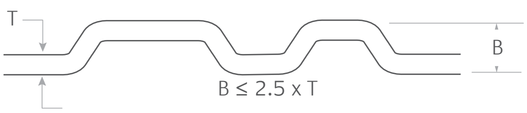
a. Embossed Width
The width of ridge-type embossing should be equal to, or greater than, five times the film thickness.
If adhesive and liner are not zoned away from the embossed area, their thickness must be added to the film thickness when determining width (Figure 25).

Figure 25: The width of ridge-type embossing should be equal to, or greater than, five times the film thickness.



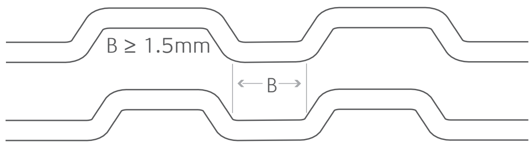
b. Embossed Height
The height of an embossed area should be no greater than 2.5 times the material thickness (excluding adhesive and liner), with material thickness included in the measurement (Figure 26). Greater embossed heights can be attained, but are not recommended for membrane switch keys.

Figure 26: The height of an embossed area should be no greater than 2.5 times the material thickness.



c. Embossed Spacing
Spacing between embossed areas should not be less than 0.06 in. (1.5 mm) to minimize distortion of the sheet after embossing (Figure 27)

Figure 27: Spacing between embossed areas should not be less than 0.06 inch.



d. Inks/Adhesives
Inks used on SABIC's thermoplastic film that is to be embossed should be compatible with the material and also somewhat flexible. The ink coating will be stretched and bent, and may fracture slightly. This is an important consideration in back-lit applications, and may require special handling by the printer.

Adhesives should be zoned away from the embossed area wherever possible to facilitate embossing. If adhesive is required in the embossed area, it should be carried on a polyethylene liner instead of on paper.

Thermoforming

LEXAN film's high melt strength makes it ideal for thermoforming. Recommended forming techniques are pressure forming and vacuum forming, with or without plug-assist over female molds, along with drape-forming over male molds. The following guide-lines should be followed for successful forming.

Mold Design

Male molds as shown in Figure 28 are preferred for deep draws and interior detail appearance parts. Good material uniformity can be maintained in depth of draw ratios between 1:1 and 2:1. A draft of 3-5 degrees per side and a micro roughened surface finish provides for easy removal from the male mold and will avoid air entrapment.

Female molds like the example shown in Figure 29 are recommended when exterior detail is important. Unless plug-assisted or mechanically formed, parts made on female molds will generally be limited to a maximum draw ratio of 1:4 with a draft of between 2-3 degrees per side.

Because of the high tensile strength of SABIC Film and Sheet film, undercuts may be troublesome when forming film 0.02 in. (0.500 mm) and 0.03 in. (0.750 mm) thick. If they cannot be avoided, split molds with sliding sections solve the problem of removing the part after forming. Figure 30 and 31 shows an example of a tool with a cam as well as a removable insert that allows for an undercut.

Recommended tooling materials are steel and cast aluminum for attractive, durable surface finishes, maintenance of close tolerances, and rapid heating and cooling. Materials such as silicone, hardwood, fiberglass, melamine, and phenolic are only for prototypes or limited-production work.

Figure 28: Vacuum Forming (Male Mold)

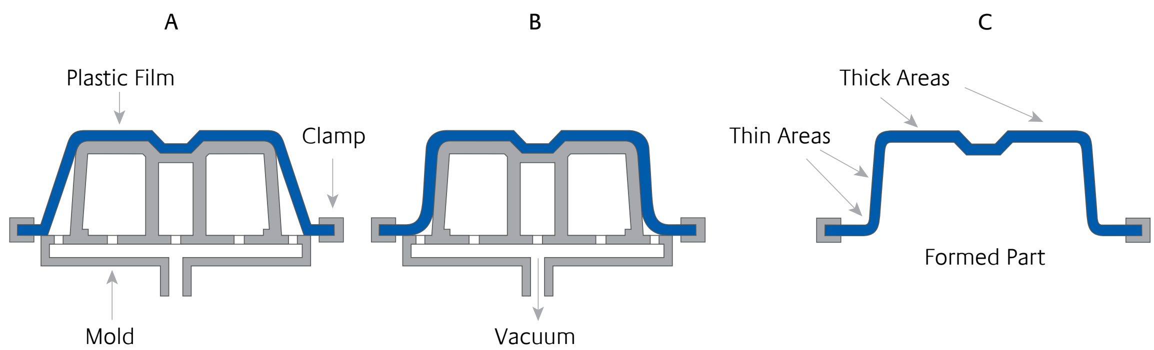


Figure 29: Vacuum Forming (Female Mold)

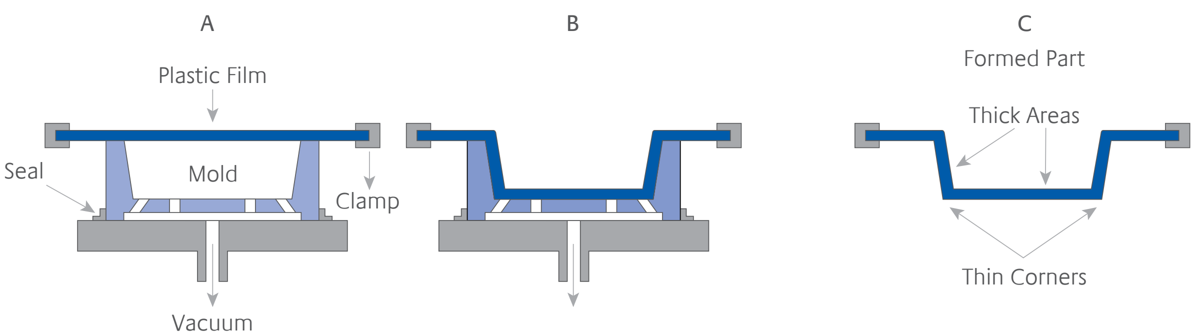


Figure 30: Mold with Cam and Removable Inserts

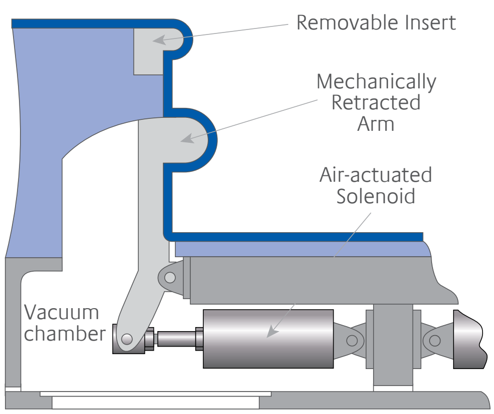


Figure 31: Release for Mold with Cam and Removable

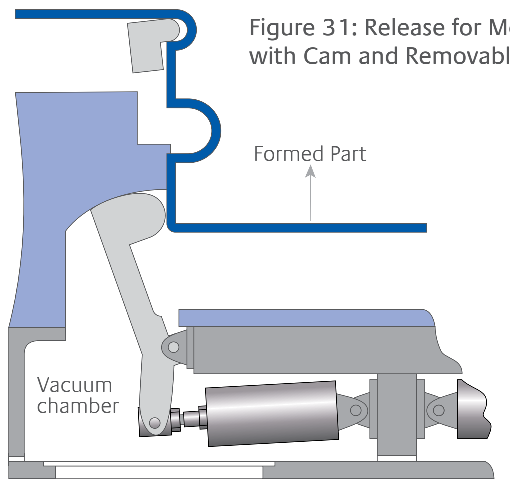
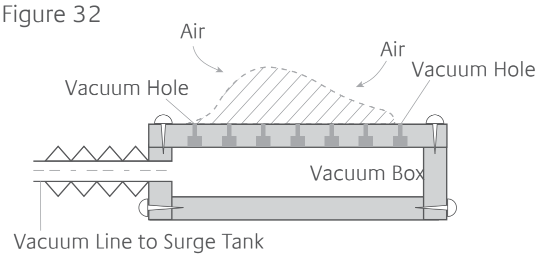


Table 61

Mold Materials	Advantages	Drawbacks	Estimated Production Life
Plaster	Quick turnaround time.	Poor surface, brittle.	1-5 parts
Hardwoods	Ease of construction and mold modifications.	Poor surface quality, limited life	5-25 parts
Silicones (RTV 662, 668)	Castable, good mold surface, excellent cast reproduction, quick turnaround.	Need pattern, poor dimensional stability, large expansion rate with elevated temperatures. Too costly for larg molds.	25-1000 parts
High Temperature Epoxy	Cost effective, excellent cast reproduction, good dimensional stability. Temperature control possible. Good surface finish.	Mold modifications are difficult, small detailed areas, ribs, bosses, etc., susceptible to damage.	Up to 1500 pieces
Cast Aluminium	Medium cost production molds, durable, good thermal conductivity, lightweight, virtually unlimited life, capable of handling additional pressures developed in pressure forming.	Require internal heating, higher cost, difficult to modify design, slight surface porosity.	Large production runs virtually unlimited parts.
Syntactic Foams (Epoxy Matrix)	Lightweight, durable, dimensionally stable, low thermal conductivity, excellent surface finish, requires no internal heating or thermostatic monitoring.	Only available in rods and blocks, not a casting resin, must be machined.	Suspect long life, no long term data.

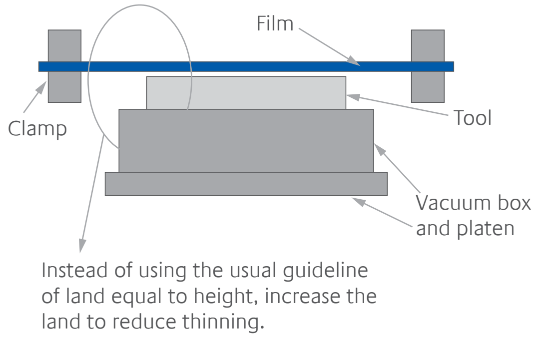
Vacuum holes of 0.02 in. (0.50 mm) diameter and/or shims that supply adequate vacuum flow are recommended for male and female molds. Where fine detail is required, vacuum holes should be spaced as close as 0.25 in. (6.4 mm). On large flat surfaces, 1 to 3 inches (25 to 75 mm) spacing is adequate. Back drilling with larger drills (i.e. > 0.25 in. or 6 mm) is suggested to speed up air evacuation. See Figure 32 below.

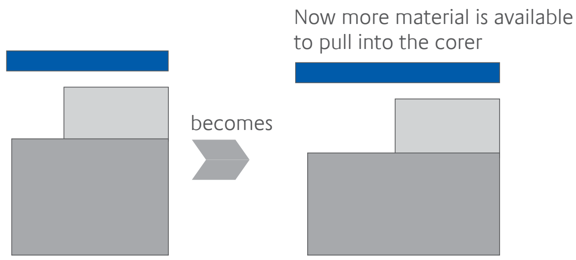
Figure 32



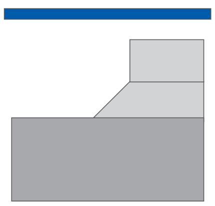
Special Tooling Considerations for LEXAN HP92TTY Film
LEXAN HP92TTY film has a formable hardcoat that can be thinned by 10 to 15%. In order to minimize the thinning of the material, the following techniques are suggested.

1)





2) Mount the tool onto a tapered block so that the area of maximum thinning falls below the trim line.



Shrinkage
All thermoplastics will shrink after they have gone through a forming process. Tools must be oversized by the percentage that the film shrinks in order to obtain the desired dimensions for the finished part. It is important to note that most tooling materials will also expand proportionally according to their coefficient of thermal expansion (CTE). In sizing the tool, the final dimension must be expanded by the film shrinkage and also contracted by the thermal expansion of the forming tool material. The shrinkage factor for all SABIC Specialty Film and Sheet films is 0.6 to 0.7%. Generally use 0.6% on male tools an 0.7% on female tools. For In-Mold Decoration (IMD) it is suggested to use a value of 0.85% for film shrinkage on male tools so that a steel safe design is reached that can be modified if needed.

Mold Temperature
Optimal forming of SABIC Specialty Film and Sheet films requires heated molds. Mold heating can facilitate making deep-drawn parts with plug-assist, producing superior surface quality and minimized formed-in stresses. Mold temperature affects the appearance of the formed part, length of the forming cycle, thinning of the walls, and size of the finished part. For LEXAN film, minimum mold temperatures of 194°F (90°C) are recommended, 248-257°F (120-125°C) is suggested when appearance is critical. For VALOX film, minimum mold temperatures of 150°F (66°C) are recommended, 230°F (110°C) is suggested when appearance is critical. For ULTEM film, molds should be internally heated between 300 °F (150 °C) and 325 °F (163 °C). If a plug assist is used for any of these films, the plug assist should also be heated to the same temperature as the mold. Oil and electrical systems are recommended for mold heating when forming SABIC Specialty Film and Sheet films.

Drying
Despite the low moisture absorption (0.35%), which contributes to the excellent dimensional stability of SABIC Specialty Film and Sheet film parts, drying of film stock is essential. A circulating oven set at 257°F (125°C) is recommended for drying sheeted LEXAN and VALOX film stock. ULTEM film stock should be dried at 320°F + 5°F (160°C + 3°C). Residence times are indicated in Table 62.

Table 62: Drying Time for Sheeted LEXAN, VALOX, and ULTEM Films

Gauge in. (mm)	Time (min.)
0.01 (0.250)	15
0.015 – 0.02 (0.375-0.500)	20
0.02 – 0.03 (0.500-0.750)	30

Web-fed forming of SABIC Specialty Film and Sheet film roll stock up to 0.03 in. (0.750 mm) may be accomplished without pre-drying. Care must be taken to allow the film to reach forming temperature gradually to avoid bubbling in the web. Sandwich style heating units are recommended to be four times the length of the forming station dimension (i.e. 12 in. tool = 48 in tunnel or a 300 mm tool = 1200 mm tunnel).

Forming Temperatures

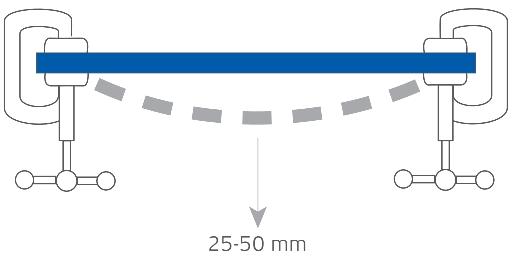
Normal processing temperatures for SABIC Specialty Film and Sheet film range between 350 - 440°F (177 - 227°C) for LEXAN film, 420 - 460°F (216 - 238°C) for VALOX film, and 500 - 550 °F (260 - 288 °C) for ULTEM film. For optimal gauge versus temperature parameters for LEXAN film see Table 63.

Table 63: Gauge Versus Forming Temperature

Gauge in. (mm)	Temperature °F (°C)
0.01 (0.250)	374 - 383 (190 - 195)
0.02 (0.500)	383 - 392 (195 - 200)
0.03 (0.750)	392 - 410 (200 - 210)

Sandwich heaters (top and bottom) are preferable so that both sides of the film can be heated simultaneously. See Figure 33 for optimum sag appearance. This recommendation avoids overheating one side and under-heating the other which might create strains and stresses, excessive sag and degradation of material on the heater side.

Figure 33



Pressure Forming

In the pressure forming process, heated film is forced into the die using compressed air. The sheet makes contact with the edge of the mold, forming a seal. Air pressure is then introduced on the side of the sheet away from the mold. This pushes the sheet against the mold to form the part. Often, a vacuum is also applied to help bring the sheet into contact with the mold. Pressure forming allows faster cycles than vacuum forming because the sheet can be formed at lower temperatures. This processing method usually has a couple of distinct advantages over vacuum forming:

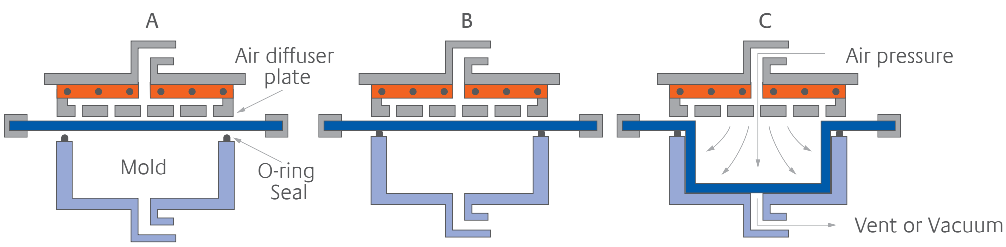
- Greater reproduction of details from the mold surfaces. Sharp, crisp corners; sharp, well-defined edges; various surface textures; letter and logo reproduction, both raised and etched; and accurate location of apertures reproduce well.
- Closer contact of the sheet with the mold surface. This allows greater control over cooling, which can lead to less residual stress and faster cooling cycles.
- Greater dimensional control.

Processing Tips for SABIC's LEXAN film portfolio materials:

1. Film processing temperatures are generally 40~60°F (20~30°C) cooler compared with standard thermoforming. Typical pressure forming temperatures range from 290~340°F (145~170°C) depending on thickness for film, while vacuum forming temperatures range from 330~390°F (165~200°C).
2. Mold temperatures are equal to those used for standard thermoforming. A higher mold temperature will produce flatter, stiffer formed parts.
3. Rapid mold clamping and closing speeds help to keep the film at the elevated temperatures needed for forming. Slow speeds can result in poor definition, stress whitening, or tearing of the film.
4. Maximum pressure should be reached as quickly as possible to provide the best forming definition.

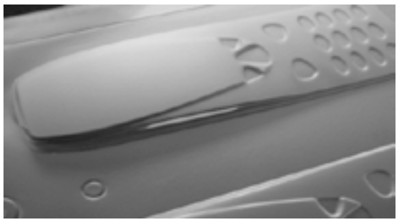
Tooling Tips for Pressure Forming:

1. An O-ring should be used to ensure an air tight seal around the perimeter of the tool.
2. Provide for plenty of venting at the base of the tool to avoid air entrapment; vents should be machined so that they are 0.002 ~0.003 inch (0.05~0.075mm) for cosmetic surfaces. If vents are too large the slot will leave a witness mark from the high pressure.
3. Radii in the tool should be smaller than the desired radii for the finished part due to the stress relaxation that occurs after the forming process.
4. Pressurized air should not be forced directly against the cosmetic surface of the film and tool. A diffuser plate should be used to uniformly distribute the air flow over the surface of the film.
5. Place complicated part structures closest to the heating elements used to heat up the film. Left/right symmetry structures should be perpendicular to the clamp and heating element shuttle path.

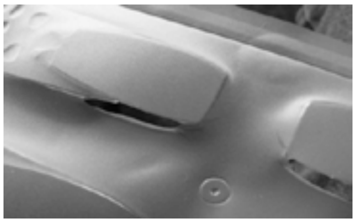


Pressure Forming Trouble Shooting

1) Material too cold



Side Wall Whitening



Tearing

Wrinkle or Chill Mark

2) Tool too cold

Whitening at the Base of Draw

General Forming Guidelines for Thermoforming and Pressure Forming

- All Temperatures should be ACTUAL temperatures as measured with thermal couples (TCs) or surface probes.
- Plumb tools with Oil or use Cal Rod Heaters
- Control tool heat with TCs placed 5mm below tool surface
- Cycle Machine based on Sheet Temperature and NOT Time whenever possible

Special Forming Considerations for IMD

SABIC's thermoplastic films can be readily formed by any number of different methods: embossing, hydroforming, vacuum forming, pressure forming, etc. The method of forming is not as important as is the final shape when using the film for an in mold decorated (IMD) insert. The formed film should conform nearly perfectly to the surface of the injection mold. If this is not done, the pressure of the injected resin will cold form or stretch the film as the mold cavity is packed. When films like LEXAN film are stretched over 1%, they become susceptible to environmental stress cracking. The worst case is when the film is stretched into a female cavity and this surface is then exposed to the environment. The outer surface of the film is in tension and can crack when exposed to aggressive chemicals. The higher the stress, the greater the chance the film will show signs of environmental stress cracking from exposure to chemicals or changes in temperature and humidity.

Stress in the IMD part can be alleviated by annealing the molded part at 260°F for 1 hour. Care must be taken to keep the part very clean before and during annealing since the high temperature will increase the sensitivity to aggressive chemicals and accelerate chemical stress cracking.

Sizing Male Form for Insertion into a Cavity OR Female Form for Insertion into a Core

FD = (CD + TEIM + FS – TEFM) – FT

FD: forming tool dimension
CD: injection cavity/core dimension
TEIM: thermal expansion of injection mold at processing temperature (60 to 80°C)
FS: film shrinkage (0.85% for LEXAN™ film)
TEFM: thermal expansion of forming tool at processing temp
FT: film thickness (as a shell of the part).

(TEFM and TEIM cancel out if tools are run at similar temperatures and if the tools are made from the same material). Don't forget to account for the film thickness at the radii.

Sizing Female Form for Insertion into a Cavity OR Male Form for Insertion into a Core

FD = CD + TEIM + FS – TEFM

FD: forming tool dimension
CD: injection core/cavity dimension
TEIM: thermal expansion of injection mold at processing temperature (60 to 80°C)
FS: film shrinkage (0.85% for LEXAN™ film)
TEFM: thermal expansion of forming tool material at processing temp.

(TEFM and TEIM cancel out if tools are run at similar temperatures and if the tools are made from the same material)

Do not account for the film thickness for these setups.

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