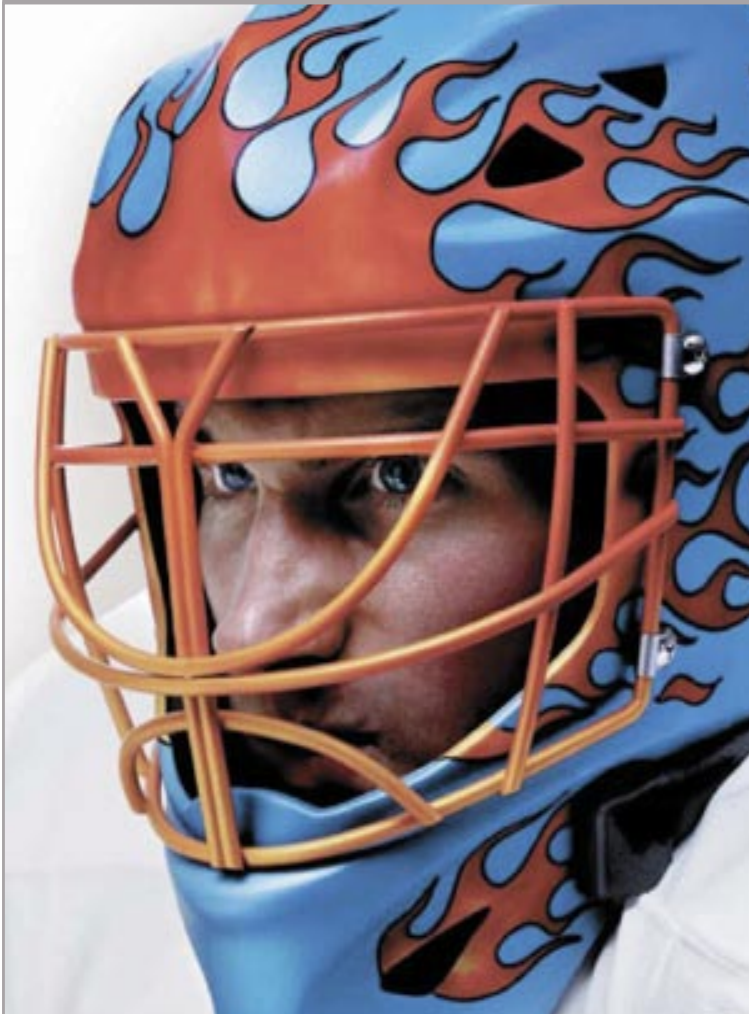


Lexan* resin



PC resin product brochure

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1. Introduction

Lexan* polycarbonate resin is an amorphous engineering thermoplastic which is characterized by high levels of mechanical, optical, electrical and thermal properties. The Lexan portfolio provides broad design versatility through its wide range of viscosities and product options.

These options include

- ECO label* conforming flame retardancy
- Impact modification
- Glass-reinforcement
- Optical quality
- Compliance with stringent FDA and USP requirements

Lexan resin offers

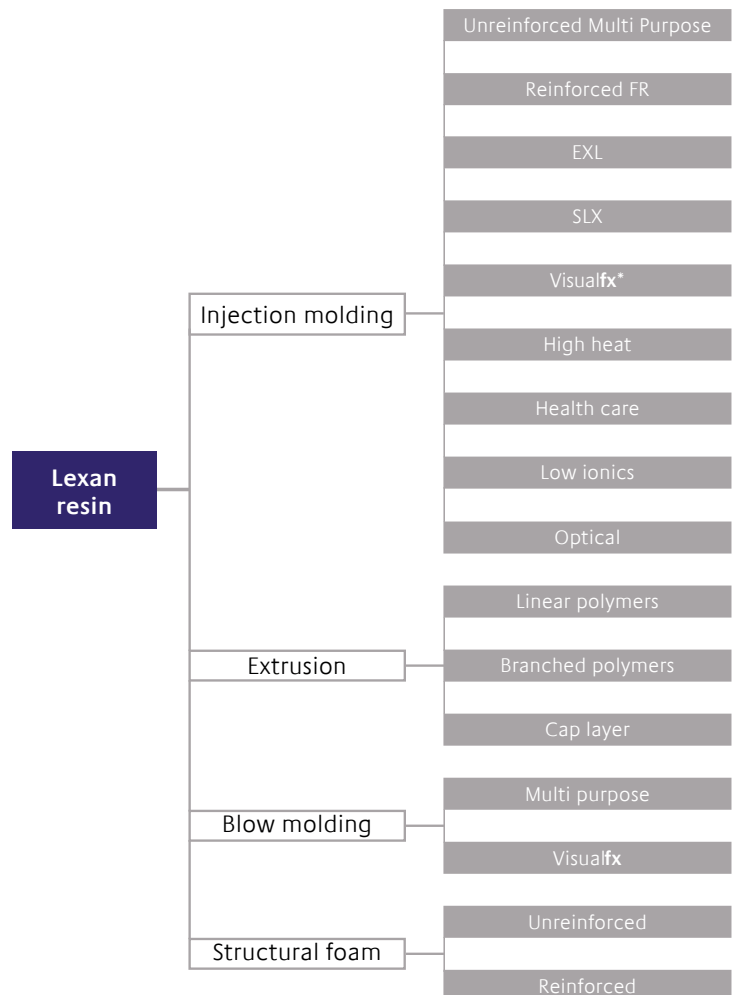
- High impact strength
- Inherent "water-clear" transparency
- Product purity, consistency, and durability
- High heat resistance — RTI up to 125°C/257°F
- Dimensional stability at elevated temperatures
- Unlimited colors — transparent, translucent and opaque
- Flame resistance
- UV stability
- FDA compliance
- Very good processability

Lexan resin is tailor-made for a range of conversion processes including injection molding, extrusion, blow molding, foam processing. High-flow grades have been developed which can be ideally suited to thin wall, long flow length applications.

After its first application life, Lexan resin can be reground and reused. As is characteristic of an engineering thermoplastic, Lexan resin retains a high residual value and, in many cases, can be recycled into similar applications within the same industry. Alternatively, Lexan resin can be cascaded down for reuse in less demanding applications.

Typical applications for Lexan resin include

- Building and construction — glazing
- Optical lenses, corrective eyewear, sunwear lenses
- Compact discs (CDs), digital video discs (DVDs)
- Health care components
- Water bottles
- Cellular phone housing
- Electronic equipment housing
- Electrical appliances
- Lighting
- Automotive lighting



*TCO 99, Blue Angel, WEEE 'draft', DIN, VDE 0472 part 815

2. Applications

Electrical Lighting Telecommunications

Eyewear Automotive lighting Appliances

2.1 Electrical

With its broad portfolio of flame-retardant and non-flame retardant grades, both unreinforced and glass reinforced, Lexan* resin is found in a wide range of electrical products. These include meter and fuse box housings; domestic switches, plugs and sockets; and switchgear, relays and connectors.

Lexan resin's key properties for the electrotechnical industry include its

- ECO label* conforming flame retardant system, with most grades passing the Glow Wire Test at 850°C
- Excellent thermal properties with all grades passing the Ball Pressure Test at 125°C
- Quality surface finish, high gloss or textured, in a wide range of colors and aesthetic finishes in the Lexan Visualfx* portfolio
- High impact resistance
- Good resistance to tracking and arcing (CTI >175 volts)
- Consistent electrical properties in aggressive environments
- Excellent processability
- Compatibility with lasermarking process

2.2 Lighting

Lexan resin is well-established in the lighting industry, providing manufacturers with lightweight, quality parts, fast cycle times through consistent processability and unlimited opportunities for design integration and intricate, snap-fit assembly.

Typical applications include linear fluorescent luminaires, street lamps, traffic lights, spotlights, reflectors, lamp holders, emergency lights, explosion-proof lights, conduits, electrical supply track systems and diffusers where Lexan resin features

- Outstanding impact resistance over a wide range of temperatures, from sub-zero to +125°C
- Excellent optical properties
- High heat resistance, with an HDT under load of 133°C
- Excellent dimensional stability and low uniform shrinkage
- Good resistance to tracking and arcing (CTI >175 volts)
- Good UV stability
- Inherent corrosion resistance and long-term weatherability; scratch and chemical resistance can be further increased through the application of a Silicone hardcoat
- Wide range of transparent and opaque colors; differentiation also possible with the Lexan Visualfx portfolio



*TCO 99, Blue Angel, WEEE 'draft', DIN, VDE 0472 part 815

Packaging

Table- and kitchen-ware

Health care

Media

Extrusion

2.3 Telecommunications

Lexan® resin is the material of choice for a range of indoor and outdoor telecommunications enclosures, including power supply connection boxes and base-stations, where it features

- High temperature resistance
- Good impact strength
- Good dimensional stability
- Good UV stability
- ECO label* conforming flame retardant system
- Quality aesthetics and differentiation possibilities with the Lexan Visualfx® Portfolio

Lexan structural foam grades can be an ideal choice for structural components where load-bearing capability at elevated temperatures is a key requirement. They can be an excellent alternative to metal or other plastics for the efficient production of large parts such as outdoor distribution cabinets. Here they can provide important weight savings through an inherently high stiffness to weight ratio. Furthermore, for optimum UV protection, parts can be easily painted.

2.4 Eyewear

A family of Lexan optical quality (OQ) resins has been specifically developed for the optical industry. The portfolio of products includes high-impact grades for safety eyewear, optical quality clean-room grades for corrective lenses and grades offering maximum UV screening up to 400nm for sunglasses and ski visors. The increasing use of Lexan polycarbonate resin in both prescription and non-prescription eyewear is due to its unique performance characteristics, including

- Clarity as measured by light transmission, yellowness index and haze
- Impact resistance that meets many internationally recognized industry standards for projectile impact tests
- High refractive index which allows for the production of lenses that are up to 20% thinner than traditional materials
- Low specific gravity compared to traditional materials, producing lighter weight lenses
- The ability to be tinted to a wide variety of colors
- UV screening capabilities



Motorola, Mobile Phone
*TCO 99, Blue Angel, WEEE
'draft', DIN, VDE 0472 part
815

2. Applications

2.5 Automotive lighting

Tough lightweight Lexan® LS resin is specifically developed for headlamp and rear lenses. Its unlimited design flexibility and moldability allow it to be formed into complex shapes. Excellent clarity provides exceptional lighting performance, while integrating functionality reduces components and simplifies assembly.

Lexan LS resin is compatible with several hard-coating systems including silicones, which provide optimum abrasion resistance through the life of the vehicle.

Lexan resin can also be ideally suited for the production of bezels, which can be metallized without the use of primer or lacquer. Auto lighting companies can produce lightweight, state-of-the-art parts with optimum cost-efficiency, thanks to Lexan resin's inherent design freedom and opportunities for thin-wall molding and part integration.

Lexan Visualfx® resin can bring aesthetic finishes. Lexan High Heat resin can provide higher heat options.

2.6 Appliances

Lexan resin is widely used in the appliances industry for products such as food mixers and processors, steam iron water tanks and oven control panels where its key features include

- Exceptional practical impact resistance
- High heat resistance
- Consistent processability
- High quality glass-like transparency and gloss
- Wide range of colors, with many colors having transparent, translucent, opaque and many Visualfx resins in different versions of these grades
- Inherent design freedom

For products like vacuum cleaner motor end-caps, diffusers and brush holders, which require superior rigidity and stiffness, glass-filled Lexan polycarbonate offers high modulus and high-impact performance. Its ease of assembly offers unlimited opportunities for design integration and intricate, snap-fit assembly.



Dyson, Vacuum Cleaner



2.7 Packaging

The use of Lexan* polycarbonate returnable bottles is well-established as a cost-effective, user- and environmental-friendly alternative to glass, one-way disposable cartons and plastic bottles. Popular with dairy, distributors and consumers alike, the Lexan resin bottle can be washed and refilled up to 50 times, while maintaining excellent taste neutrality and its characteristic high quality, glass-like transparency.

The key advantages of Lexan resin in packaging are its

- Glass-like transparency and gloss
- Excellent taste and aroma protection in the compliance with FDA and European food contact regulations
- High impact properties and practical toughness for safe handling
- High temperature resistance to withstand repeated wash cycles
- Light-weight for ease of handling and cost-effective transportation
- Compatibility with existing material handling systems
- Wide design flexibility for a diversity of bottle shapes, sizes and features
- Wide range of colors, and differentiation possible with Lexan Visualfx* resin
- Recyclability for use in other non-food applications

Lexan resin is also used in the production of water bottles where, as with milk packaging, its key properties are its taste neutrality, high temperature resistance for cleanability and long life expectancy compared with glass products. This tailor-made, branched resin offers molders the ability to produce a high-quality water bottle with a more uniform wall thickness.

In food packaging applications, Lexan resin can also be used as a top layer in the coextrusion of multi-layer film where it provides

- High mechanical strength
- High heat resistance
- High gloss
- Good slip, anti-blocking and film winding properties



2. Applications

2.8 Table and kitchen-ware

Lexan* polycarbonate table and kitchen-ware is well-established in the domestic, commercial and institutional catering markets. In addition to full compliance with FDA and European food legislation, Lexan resin offers these markets the following key benefits

- Inherent high impact strength and practical toughness for products which are virtually unbreakable
- Excellent thermal and dimensional stability allowing repeated washing at high temperatures and reheating of foodstuffs using hot air, water bath or microwave oven
- Aesthetic differentiation, possible via the Lexan Visualfx* portfolio

2.9 Health care

Lexan resin for health care offers clarity, impact, biocompatibility, heat resistance, design flexibility! In the ever-changing healthcare industry, plastics are replacing traditional materials in many medical products and devices. Plastics can offer significant manufacturing systems-cost, savings and meet performance characteristics critical to a variety of applications. For instance, Lexan resin's inherent clarity, processability, high heat and high impact resistant properties allow Lexan resin to be a strong candidate for many healthcare applications. Lexan products are available which are suitable for sterilization by gamma radiation, EtO gas and steam autoclave.

Lexan resin is also available to meet the specialized needs of healthcare applications which require biocompatibility according to USP VI and/or ISO 10993 standards. Among typical medical applications are stopcocks, syringes, trocar tubes, dialysis apparatus, blood filters and blood oxygenators. Lexan resin made from blends with high heat polycarbonates can be suitable for medical applications which have higher temperature requirements.

The key properties of Lexan resin in medical applications are its

- Clarity
- Impact resistance
- High heat resistance
- Processability and design versatility
- Multiple sterilization options



Dideco, Medical Device

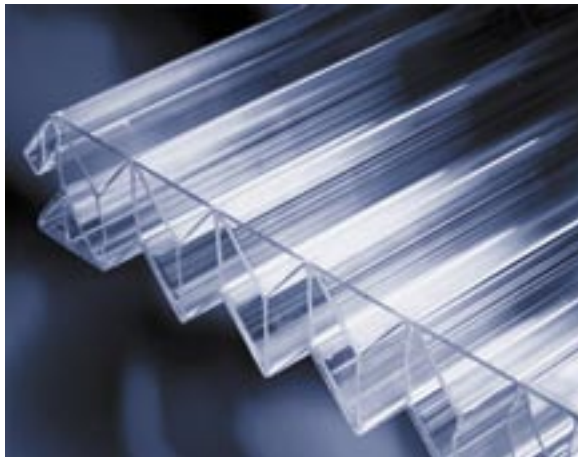


Tupperware

2.10 Media

With dedicated manufacturing facilities in the USA, Europe and the Pacific, SABIC Innovative Plastics is a global supplier of polycarbonate resin to the optical disc market. Tailor-made Lexan® Optical Quality (OQ) resin is renowned for its excellent product consistency, both in terms of purity and processability. Due to its low molecular weight, the material has an ultra-high melt flow rate which allows the molding of discs with very low birefringence and excellent pit and track replication.

Working closely with its industry partners, SABIC Innovative Plastics continues to push forward with state-of-the-art materials and process technologies, which will revolutionize the production of new optical media. Included in recent developments is a further improved flow Lexan OQ resin, featuring lower birefringence, enhanced surface replication and superior flatness for the DVD format.



2.11 Extrusion

Specially developed UV-stable Lexan resin extrusion can be readily extruded on conventional equipment. The range includes both linear and branched polymers for solid, multi- and twin-wall sheet extrusion.

In general, Lexan resin extrusion grades offer

- Consistent ease of processing
- Excellent surface finish and transparency
- Outstanding impact performance

In addition, glass clear UV cap-layer materials have been specifically developed to improve the UV performance of extruded solid, multi- and twin-wall polycarbonate sheet. For typical applications such as roofing sheets, these unique materials meet many critical industry standards for outdoor weatherability, while providing enhanced productivity.



Lexan SLX resin

Lexan EXL resin

3.1 Lexan SLX resin

Lexan SLX resin is a new offering of injection-molding products from SABIC Innovative Plastics. The polyester carbonate technology is based on resorcinol arylates. This unique copolymer results in extreme weatherability. Two families of products will soon hit the market. SLX1000 / 2000 Series are UL94 listed weatherable products – available in both transparent and colors. SLX has the high heat and impact attributes of Lexan resin, with the added benefit of gloss/color retention upon UV exposure. The product is initially targeted towards the outdoor lighting industry. SLX can have a nice fit in lens and refractor applications, offering four times improved weathering performance over UV-stabilized polycarbonates. According to GE Lighting, warranty claims are a huge issue with brittleness of PMMA and glass components and the yellowing of polycarbonate. Lighting manufacturers have an option to eliminate expensive secondary UV coating operations.

The SLX6000 Series are opaque compounded blends that offer high initial gloss and excellent retention of gloss after weathering. This product line also offers high heat and impact characteristics, as well as improved scratch and chemical resistance. SLX blends can be ideally suited for outdoor paint replacement applications. Validation partners include tractor hoods and outdoor telecom enclosures.

3.2 Lexan EXL resin

It is a new generation of super-tough polycarbonate, when the job calls for a material that can withstand the toughest conditions, consider Lexan EXL resin. It delivers the benefits you've come to expect from our standard Lexan polycarbonate resin - but with added impact performance, low temperature ductility and resistance to heat and humidity aging.

Properties include

- **Weatherability**
Maintains impact ductility after outdoor exposure
- **Impact**
Low temperature ductility to -60°C
- **Flame retardant**
Conforms to Blue Angel and TCO99 standards
- **Chemical resistance**
Resists a variety of industrial and consumer chemicals
- **Processability**
Possible 20 - 40% cycle time reduction and can eliminate sticking
- **Heat and humidity aging**
Can withstand exposure to high heat and humidity environments with less loss of properties than standard polycarbonate

These attributes, plus its light weight, can make Lexan EXL resin a great material for a variety of applications, including telecommunications, portable electronics and outdoor equipment. It is also available in a variety of opaque colors. So for design engineers looking for the next level of durability and flexibility, Lexan EXL resin can be the material of choice.



Mirror housing made of Lexan SLX resin

Lexan* Visualfx* resin Lexan Low Ionics

The current portfolio is designed to meet a variety of market needs by combining different benefits of Lexan EXL to tailor a material solution for a specific application. In the future we will be introducing new resins, as well as expanding the current portfolio to include transparent products.

3.3 Lexan Visualfx resin

The Lexan Visualfx portfolio consists of six major families of colors and special effects, backed by a range of dedicated services.

Using standard processing equipment, Lexan Visualfx materials provide parts with a consistently high quality surface finish straight from the mold. Furthermore, in many cases the range of special effects eliminates the need for secondary operations, such as painting, metallizing or sublimation printing, providing cost-effective product differentiation.

As some of the aesthetic effects of Lexan resin will influence the properties of the final material and molding behavior may be affected, it is recommended therefore that application testing is carried out.

SABIC Innovative Plastics offers customers a full range of processing and design support.

3.4 Lexan Low Ionics resin

In clean room applications, even moderate levels of ionic species can cause contamination of the environment and reduction of the service life in electronic applications. Lexan low ionics resin is manufactured using a proprietary process that not only reduces outgassing in Lexan resin to extremely low levels, but also minimizes the level of extractable ionic species. These special low ionic, ultra-clean grades of Lexan polycarbonate meet some of the most stringent clean room specifications in the industry. Typical industry applications include those that are highly sensitive to contaminants, including clean-room assembly, silicon wafer carriers, chip carriers and internal components of hard disk drives.

Lexan resin is often selected for these applications for the following features

- Extractable ionic species at the parts-per-billion level
- Extremely low levels of outgassing
- Color capability for product differentiation during assembly processes
- Stabilized grades for applications which require protection from UV light



Braun shaver made of Lexan Visualfx resin

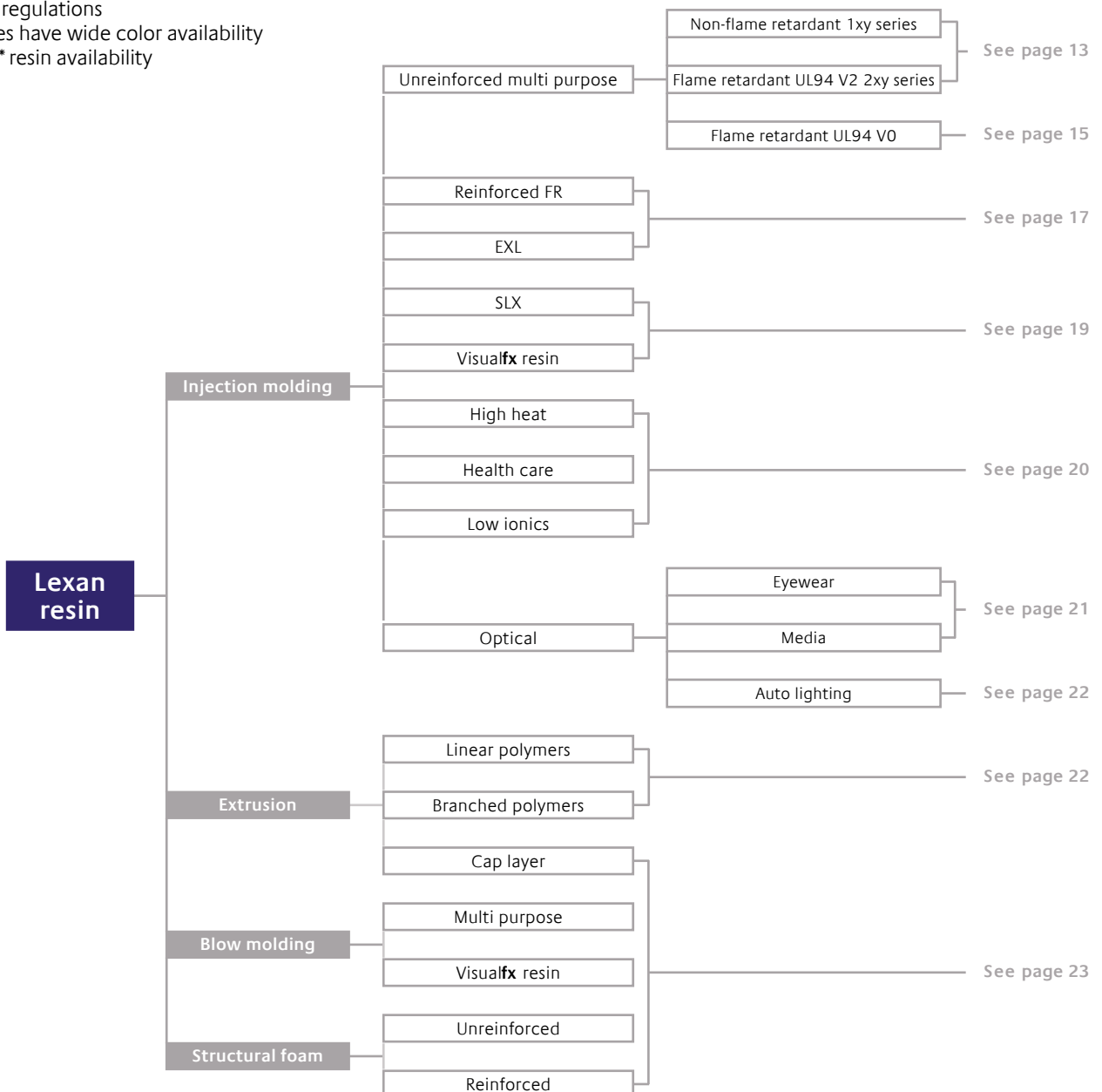
4. Product selection overview

4.1 Product description

4.1.a Lexan* 100 series

(unreinforced, non-flame retardant)

- Wide viscosity range
 - 120 series low viscosity
 - 140 series low to medium viscosity
 - 160 series medium viscosity
 - 100 series high viscosity
 - 130 series very high viscosity
- R grades have easy release characteristics
- H grades have hydrolytical stability
- 1x3R grades are UV stabilized
- 1x4R grades comply with various food contact regulations
- All grades have wide color availability
- Visualfx* resin availability

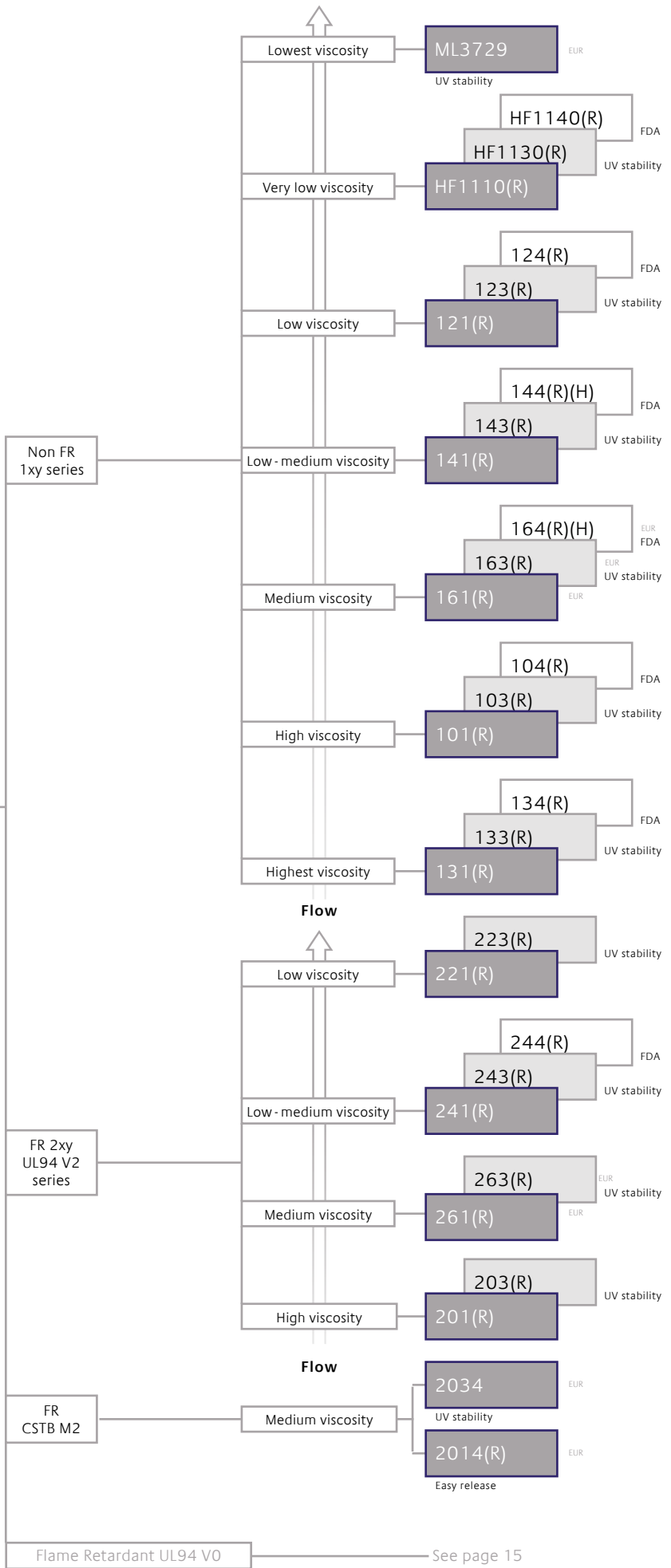


Lexan* resin

Injection molding

- Page 17 SLX
- Page 17 Visualfx*
- Page 19 EXL
- Page 19 Impact Modified
- Page 19 Reinforced FR
- Page 20 High Heat
- Page 20 Health Care
- Page 20 Low Ionics
- Page 21 Optical

See page 22



4. Product selection overview

4.1.b Lexan* resin HF series (high flow)

- Formulated using a unique chemical modification of the base polycarbonate polymer
- Very low viscosity levels with minimal reduction in inherent properties
- Can be ideally suited to thin wall, high flow length applications
- All grades have easy release characteristics
- HF1 130R is UV stabilized
- HF1 140R can be suitable for food applications

4.1.c Lexan resin 200 series

(unreinforced, flame retardant)

- Differing levels of viscosity
 - 220 series low viscosity
 - 240 series low to medium viscosity
 - 260 series medium viscosity
 - 200 series high viscosity
- R grades have easy release characteristics
- 2x3R grades are UV stabilized
- All grades have wide color availability
- All grades are rated UL94 V2 at measured thickness

4.1.d Lexan resin 900 series

(unreinforced, flame retardant)

- Transparent and opaque UL94 flame class rated grades
- Available in different melt viscosities
- All products have easy release characteristics
- 9x3 and 9x3A grades are UV stabilized
- 9xy series are available only in opaque colors
- 9xyA series are available in opaque and transparent colors
- 9x5 series, ECO conforming label grades (check page 13)
- Visualfx* availability

4.1.e Lexan resin LS series (lens system)

- Specifically developed for automotive lenses
- AMECA listed
- Range of viscosity levels
- Global production
- Lexan LS2 resin meets all global automotive OMS specifications including SAE 576
- Colorability
- Compatible with different hard coating systems
- Excellent balance on impact and flow properties
- Visualfx resin availability

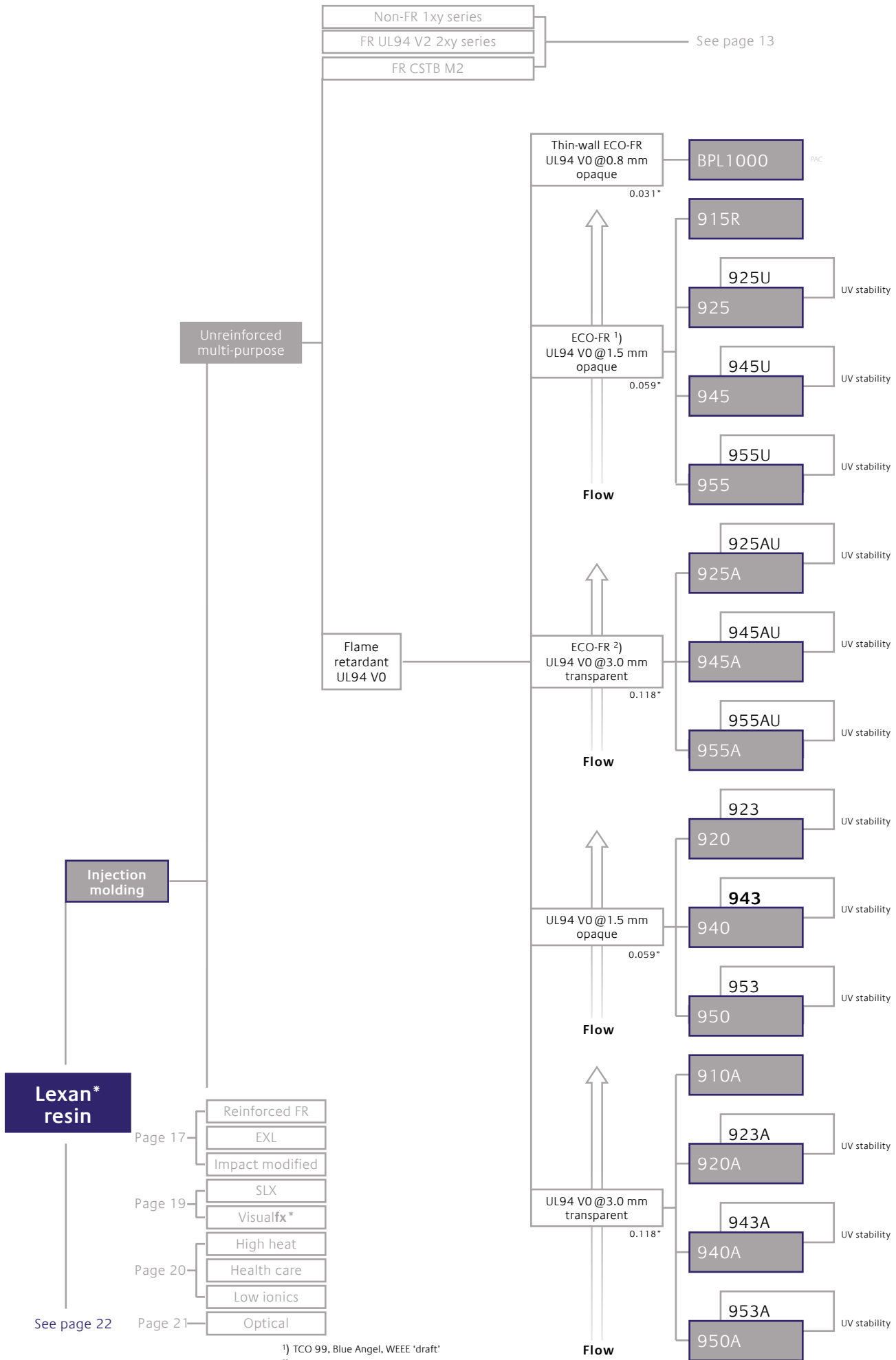
4.1.f Lexan resin media

- Tailor-made Lexan OQ (Optical Quality) resin satisfies stringent purity requirements of optical data storage discs
- Grade with ultra-high melt flow rate and lower birefringence for high density DVD market
- Grades for LCD's available with different melt viscosities
- Range of transparent colors complemented by opaque white for a very high degree of reflectivity

4.1.g Lexan resin

glass reinforced, flame retardant series

- UL94 flame class rated grades
- 10% to 40% glass reinforced grades
- Excellent rigidity, high heat resistance and superior impact strength compared with other filled resins
- Highly stable mechanical and electrical properties
- Lower coefficient of thermal expansion and reduced mold shrinkage
- Availability in different viscosity levels
- R grades have easy release characteristics



4. Product selection overview

4.1.h Lexan* resin

Extrusion and blow molding series

- Extrusion, injection blow molding and extrusion blow molding grades
- Linear and branched polymers
- CSTB M2 rated material available
- Tailor-made grades meet specific requirements for UV stability, hydrolytic stability and compliance with most food contact regulations

4.1.i Lexan resin structural foam molding series

- Stress-free moldings particularly suitable for large parts
- High heat distortion, combined with good flame retardancy and high electrical resistivity
- 5% glass filled foam grades
- Tailor-made low pressure chemical blowing agent for standard and increased process temperatures

4.1.j High heat series

- Blends of high heat polycarbonate provide a range of heat resistance up to 150°C (302°F)
- FDA compliant grades available for food contact applications
- Improved processing release grades available for demanding applications

4.1.k Health care

- Complete portfolio of products targeting the health care market
- HP grades for applications requiring EtO sterilization
- HPS grades for applications requiring Gamma sterilization
- Some grades capable of withstanding multiple autoclave cycles while maintaining impact strength and ductility
- Chemically resistant grade compatible with extended exposure to lipids

4.1.l Eyewear

- OQ2 grades provide clarity and impact required for safety glasses and goggles
- Melt filtered OQ3 products provide ultra-clean resin to replace glass and thermosets in prescription eyewear applications
- UV blocking OQ4 grades formulated for use in custom color sunwear applications
- Provide optical properties similar to glass and thermosets
- Meets international impact standards for eyewear
- High refractive index and low specific gravity result in thinner, lighter optical lenses

Lexan*
resin

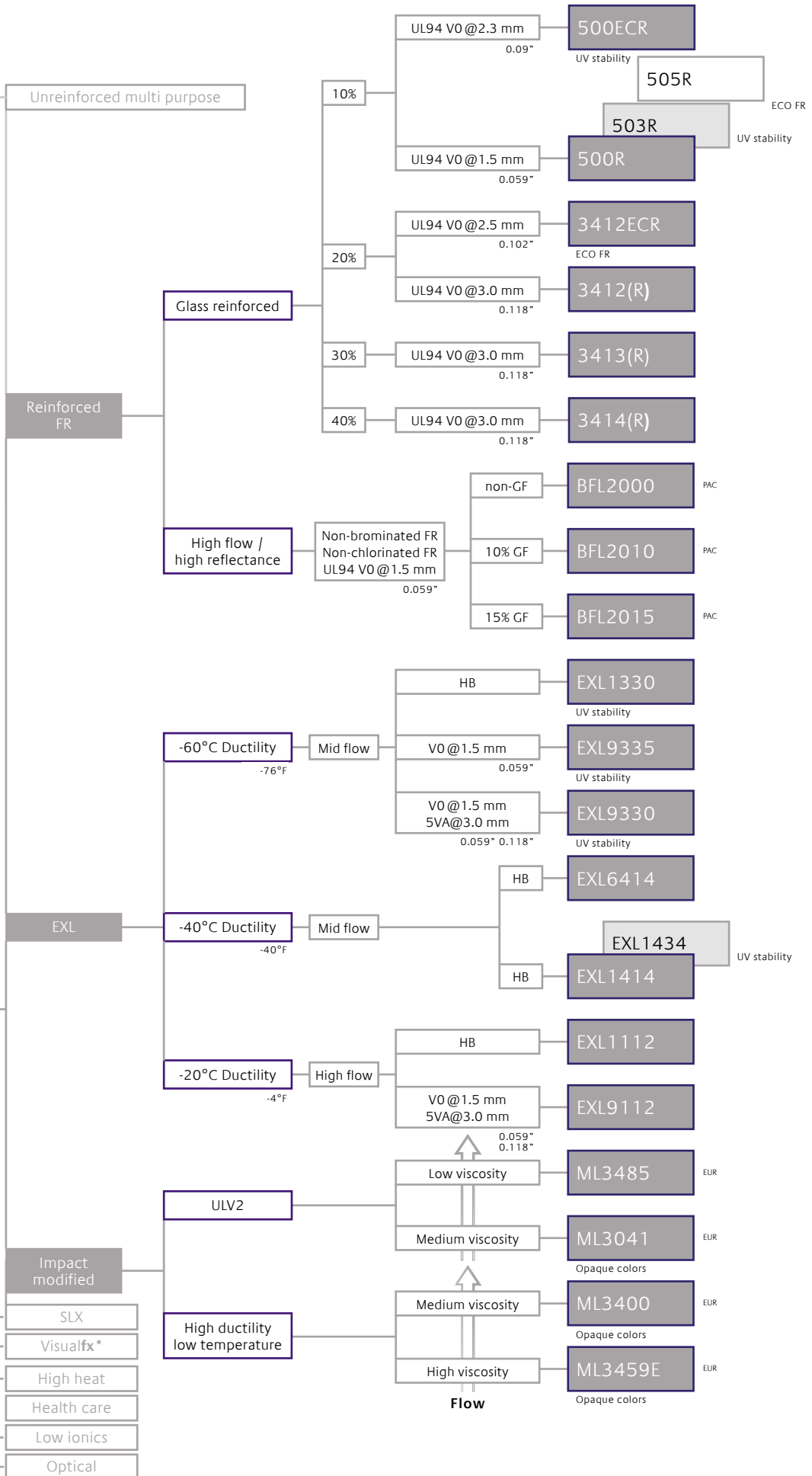
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4. Product selection overview

4.1.m Extreme Lexan* resin

4.1.m.1 Lexan SLX resin

Lexan SLX resin 2000 series

- Medium Viscosity
- UL94 listed
- UV resistant
- Available in transparent or opaque colors
- Can be ideal for outdoor weatherable applications
- Ease of process (similar to Lexan medium viscosity grades)

Lexan SLX resin 5000 / 6000 Series

- Medium Viscosity
- High gloss
- UV resistant
- Available in opaque colors
- Can be ideally suited for outdoor paint replacement
- Ease of process

4.1.m.2 Lexan EXL resin

• Opaque colors only

Non-FR grades

EXL14X4 series medium viscosity
EXL1112 series low viscosity
EXL1330 grade medium viscosity
EXL6414 grade medium viscosity

- EXLXX3X grades are UV stabilized

FR grades

EXL933X series medium viscosity
EXL9112 grade low viscosity

- EXLXX3X grades are UV stabilized
- All grades have easy release properties

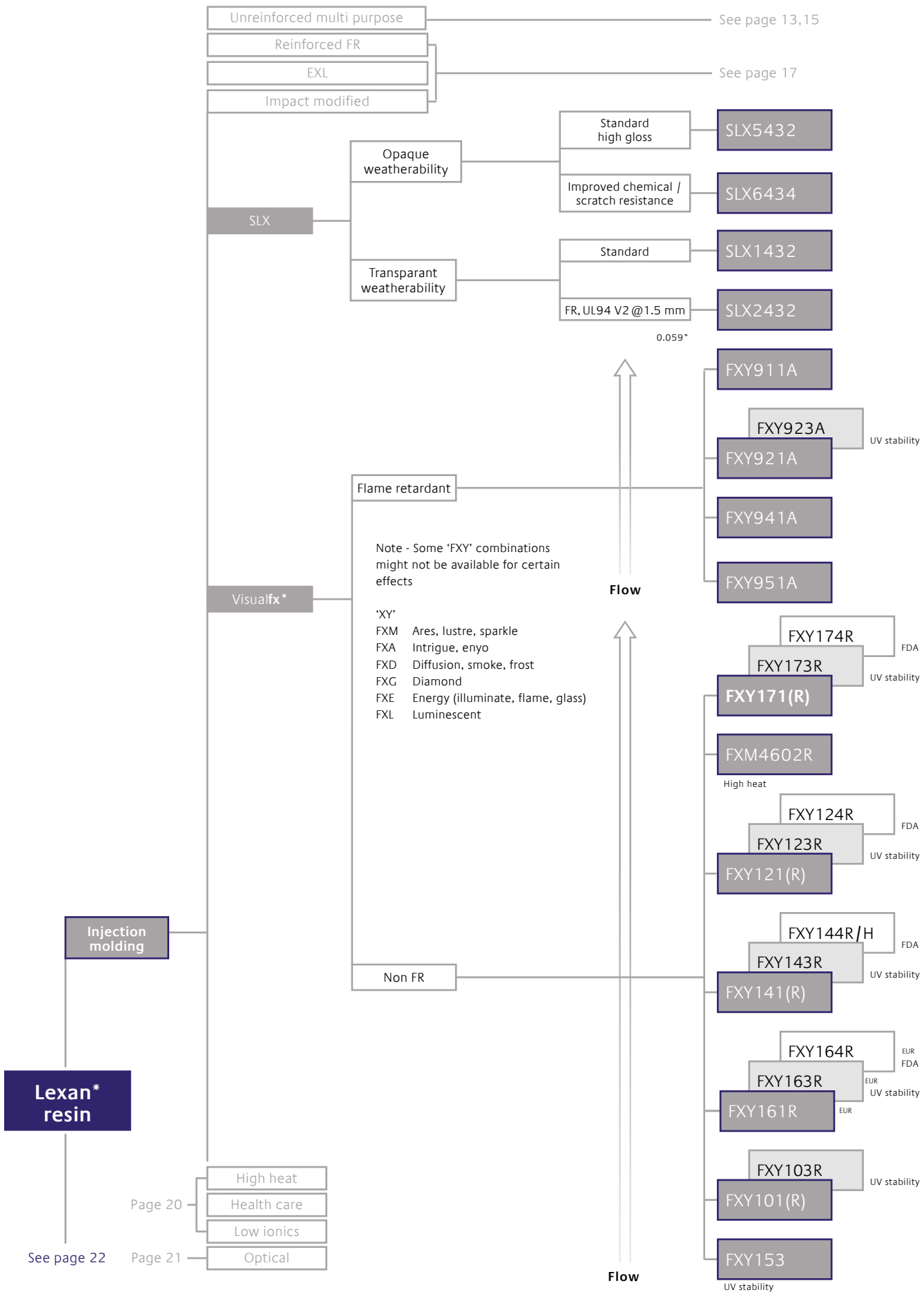
4.1.m.3 Lexan Visualfx* resin

The following series is available in a broad spectrum of product performance

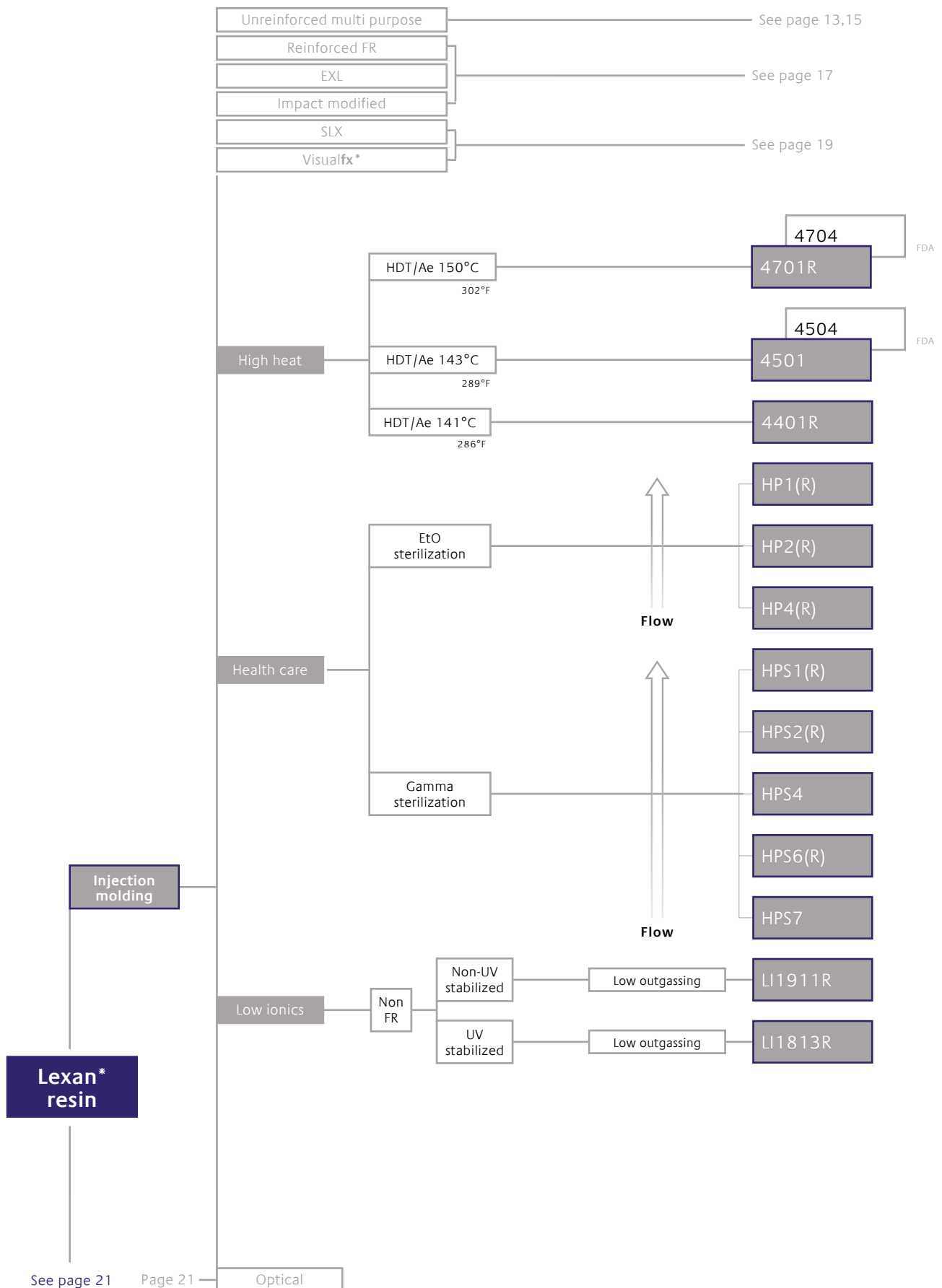
- FXM for Metallic effects
(Ares, Lustre and Sparkle)
- FXA for Angular Metameric effects (Intrigue and Enyo)
- FXD for Diffused effect
(Diffusion, Smoke and Frost)
- FXG for Diamond effect
- FXE for Energy effect
(Illuminate, Flame and Glass)
- FXL for Luminescent effect

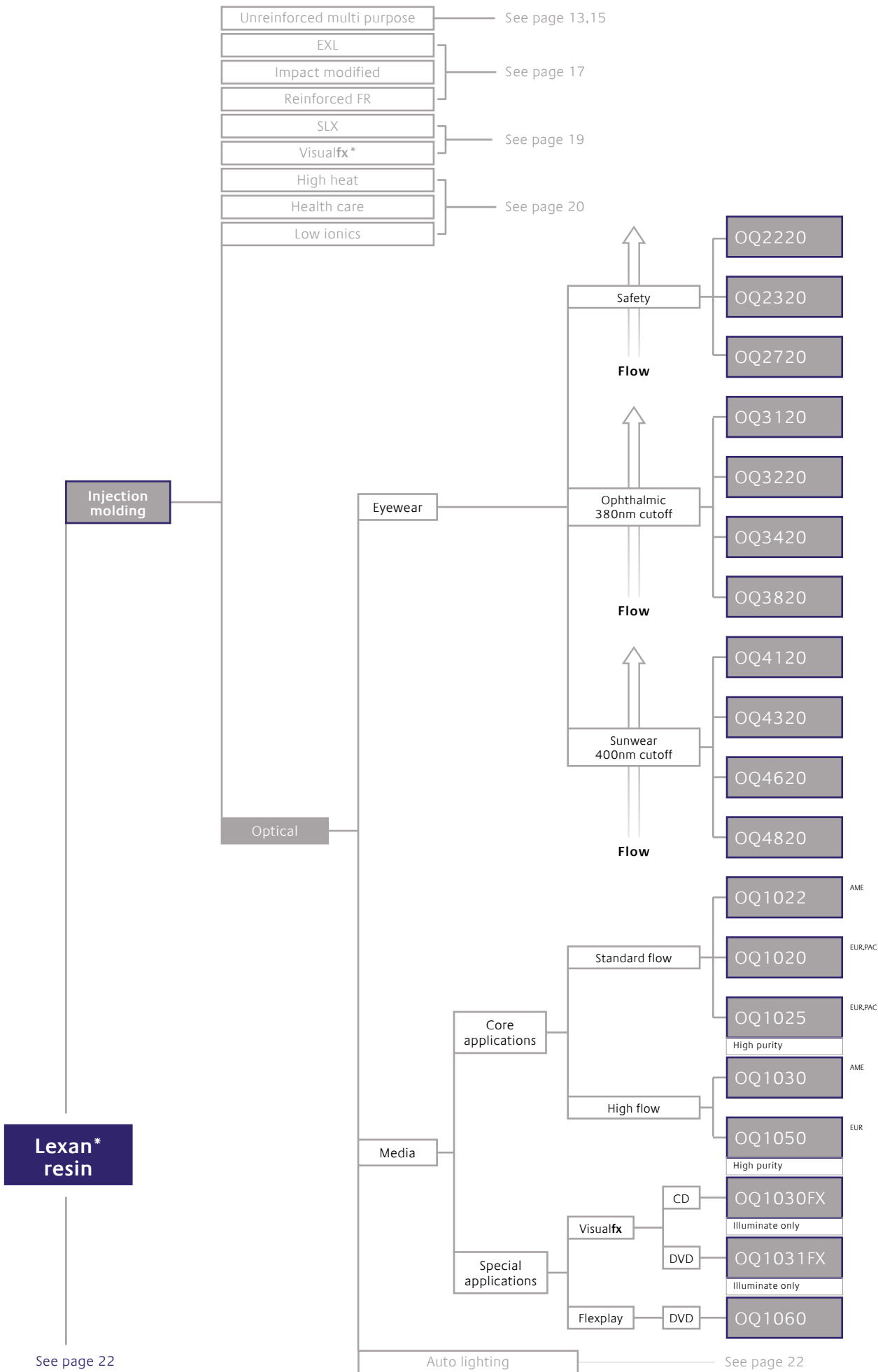
4.1.m.3 Low-Ionics series

- Ultra clean resin for applications requiring low outgassing
- Leachable ions in the parts-per-billion levels
- UV stabilized grades to provide effective UV filtering



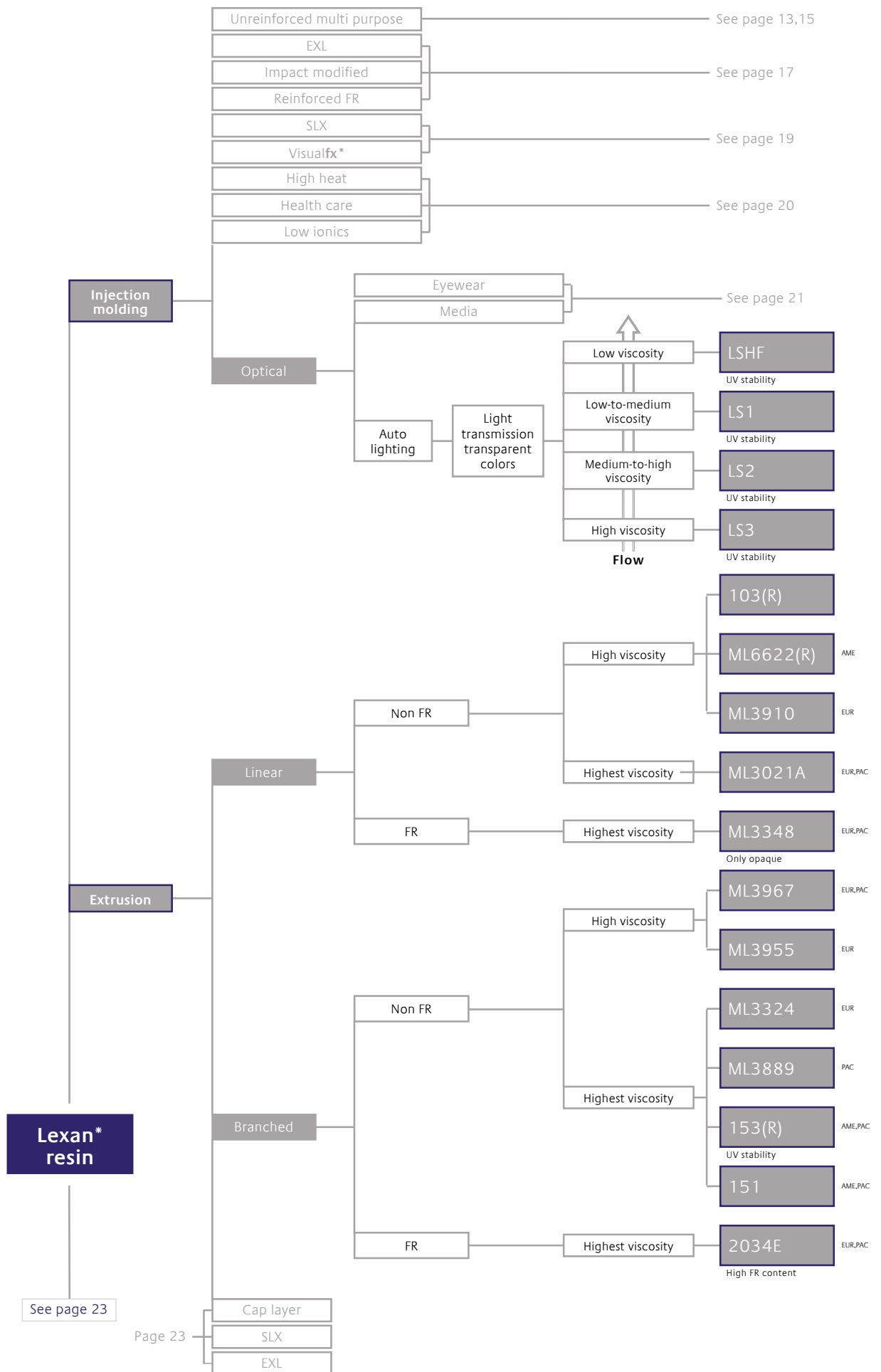
4. Product selection overview





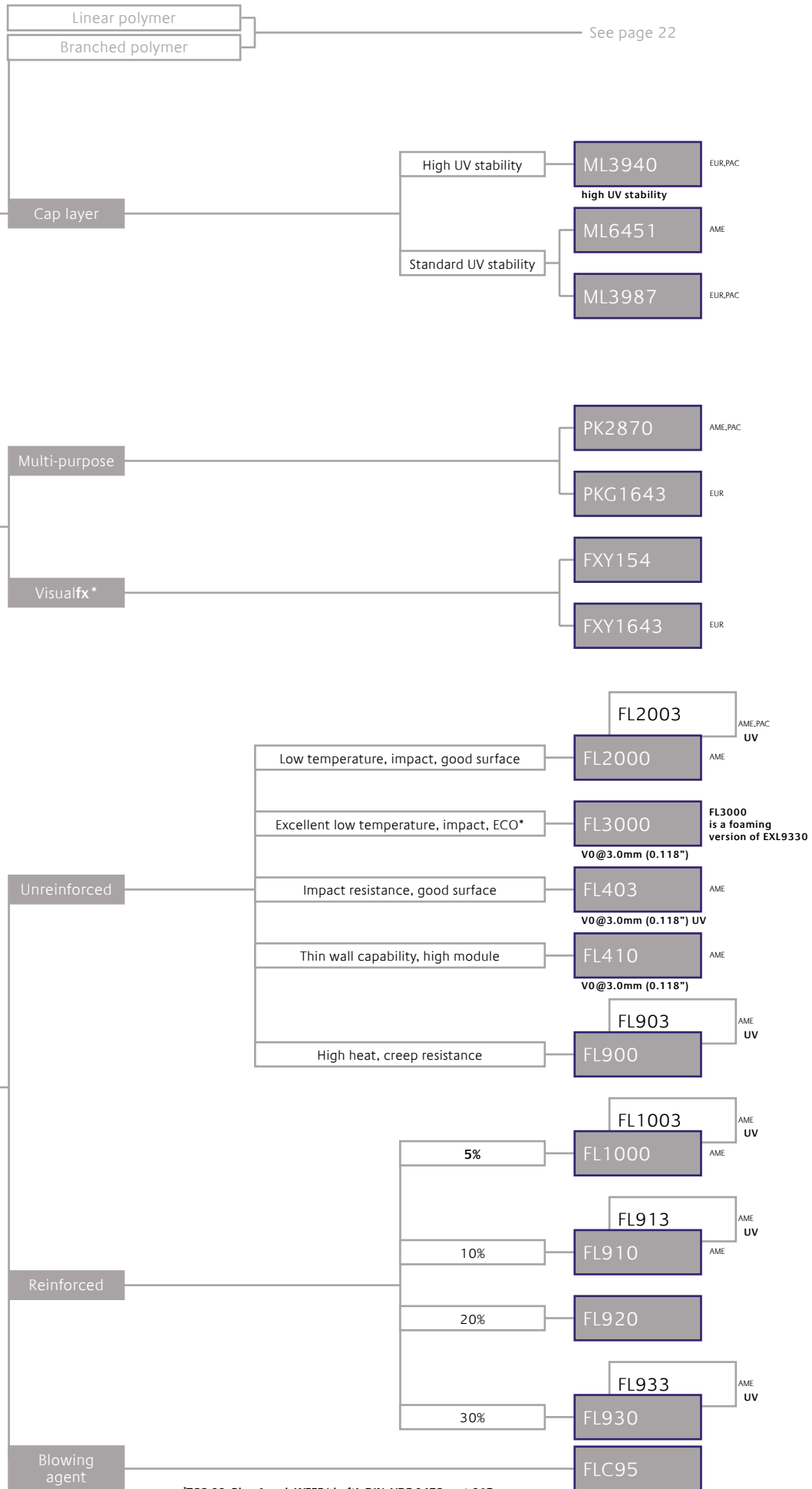
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Lexan[®] resin



*TCO 99, Blue Angel, WEEE 'draft', DIN, VDE 0472 part 815

5. Properties and design

5.1 General properties

Lexan* polycarbonate resin is an amorphous engineering thermoplastic which displays high levels of mechanical, optical, electrical and thermal properties.

Its unique property profile includes outstanding impact strength over a wide range of temperatures, from subzero to more than 80°C / 176°F.

- A characteristic Lexan resin offers
- High transparency
 - Extreme toughness
 - Low uniform shrinkage
 - Dimensional stability
 - Consistent processibility
 - UV stability
 - Flame retardancy
 - Heat resistance
 - Wide color availability

Lexan resin's exceptional impact strength and practical toughness establish it as a first-choice material for a variety of very demanding applications across diverse industries.

Design calculations for Lexan resin are no different than for any other material. Physical properties of plastic are dependent on the expected temperature and stress levels. Once this dependency is understood, and the end-use environment has been defined for an application, standard engineering calculations can be used to accurately predict part performance. However, in designing for Lexan resin, it is important to take into account the notch sensitivity and lower hydrolytic stability of polycarbonate resin.

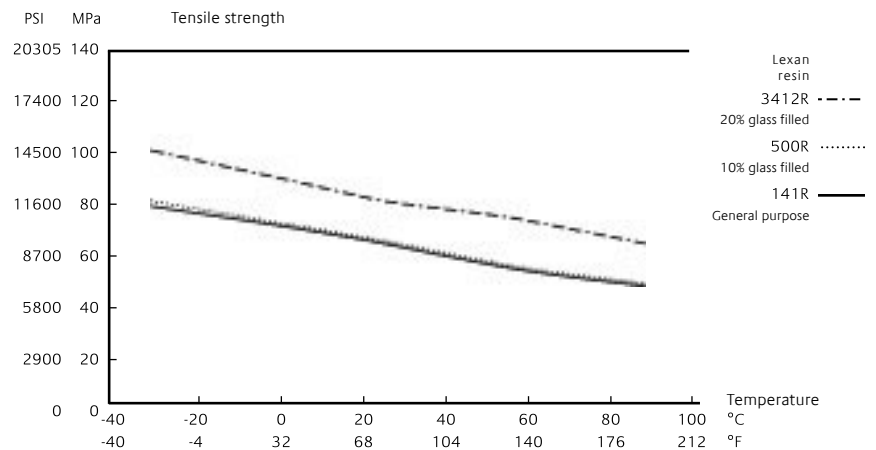
5.2 Mechanical properties

In General, Lexan resin exhibits excellent mechanical property retention over a wide temperature range.

As illustrated in figures 1 and 2, Lexan resin's tensile strength and flexural modulus decrease slightly as temperature increases. However, the effect of temperature on impact resistance is the reverse as the temperature decreases, Lexan resin becomes slightly stiffer and slightly more brittle.

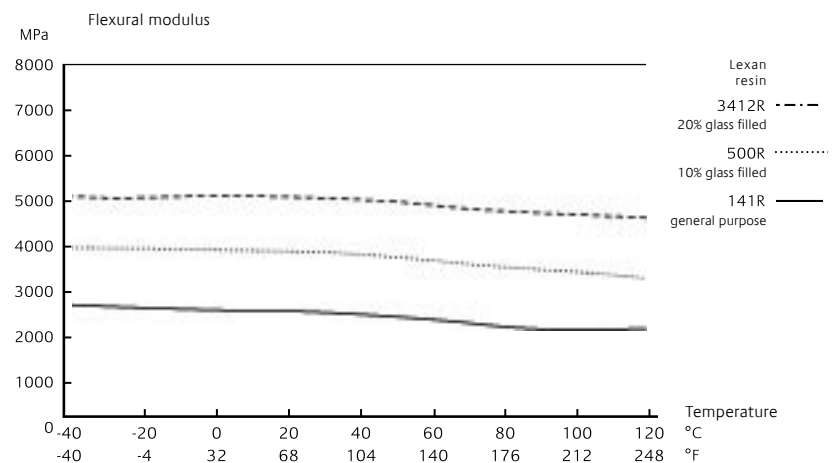
■ Figure 1

Tensile strength as a function of temperature (ISO) ASTM shows the similar trend



■ Figure 2

Flexural modulus of Lexan resin grades as a function of temperature (ISO) ASTM shows the similar trend



5.2.a Impact strength

Lexan® resin's exceptional impact strength and practical toughness make parts virtually shatter-resistant, providing a high degree of safety and durability in service in the toughest of environments.

At very low temperatures, impact resistance can be further improved by blending with other resins such as ABS, as in Cyclooy® PC/ABS alloy resins, or by blending with impact modifiers.

Figure 3, for example, compares the Izod notched impact strength of impact modified Lexan resin with a standard unmodified Lexan grade. Lexan impact modified resin offers superior impact retention after painting with various paint systems.

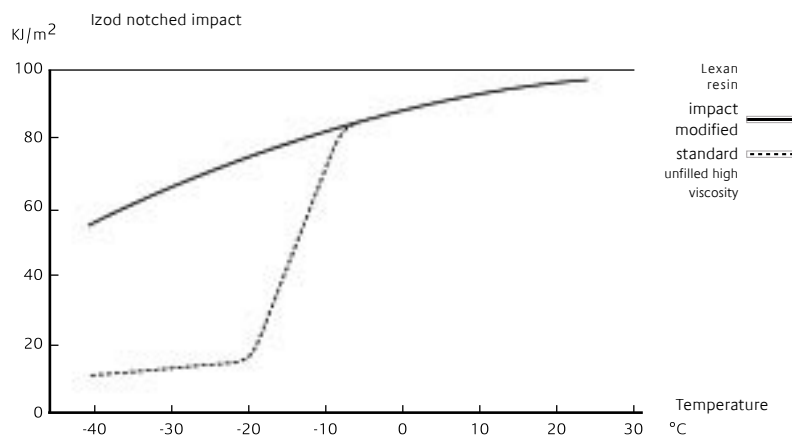
There are several factors which determine the ability of a plastic part to absorb impact energy. In addition to the type of material these factors include

- Wall thickness
- Geometric shape and size
- Operating temperature and environment
- Rate of loading
- Stress state induced by loading

For ductile polymers such as Lexan® resin, the load at which yield occurs in a part is affected by the last three factors. Of even more significance to design is the fact that, under the appropriate circumstances, the impact behavior of a ductile polymer will undergo a transition from a ductile and forgiving response to a brittle and catastrophic one. Usually this change in behavior is described in terms of a transition temperature above which the failure is more ductile by nature, and below which it is more brittle, as illustrated in figure 4.

■ Figure 3

Izod impact strength of Lexan resin as a function of temperature (ISO 180/4A 3.2 mm)



Interpretation of ISO & ASTM impact values

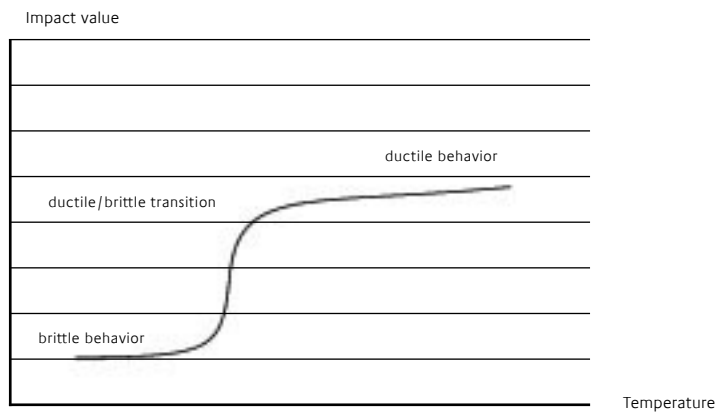
Impact properties can be very sensitive to test specimen thickness and molecular orientation. The differences in specimen thickness as used in ASTM and ISO may have an important effect on impact values. A change from 3 mm / 0.118" to 4 mm / 0.157" thickness can even provide a transition of the failure mode from ductile to brittle behavior at a given temperature, through the influence of molecular weight and specimen thickness on Izod notched impact. This is illustrated in figure 5.

Materials which already exhibit a brittle fracture mode at 3 mm / 0.118", such as mineral and glass-reinforced grades, will not be affected. Impact modified grades will also not be affected as they still exhibit a ductile failure mode at greater than 4 mm / 0.157".

Therefore, ISO and ASTM impact values may be radically different for exactly the same material. However, the ductile brittle transition described rarely plays a role in real life as almost all parts are designed with less than 3-mm / 0.118" wall sections.

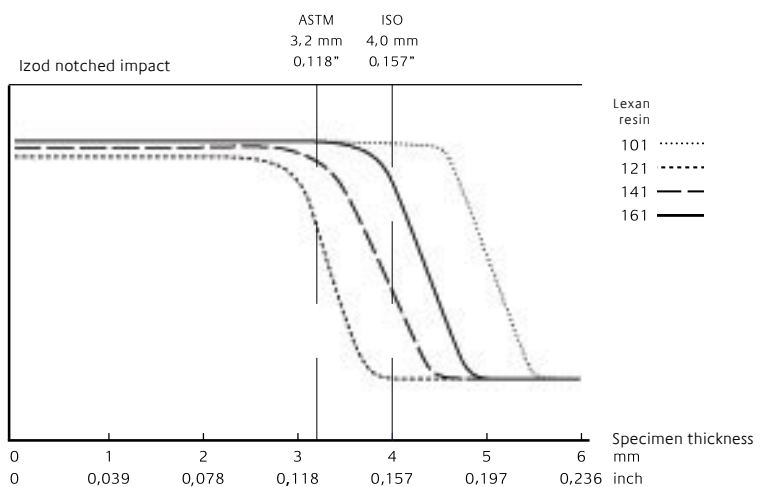
■ **Figure 4**

Graph illustrating effect of temperature upon impact response (ISO 180/4A) (3.2 mm / 0.126")



■ **Figure 5**

Influence of specimen thickness and molecular weight on Izod notched impact properties of Lexan® resin



5.2.b Stiffness

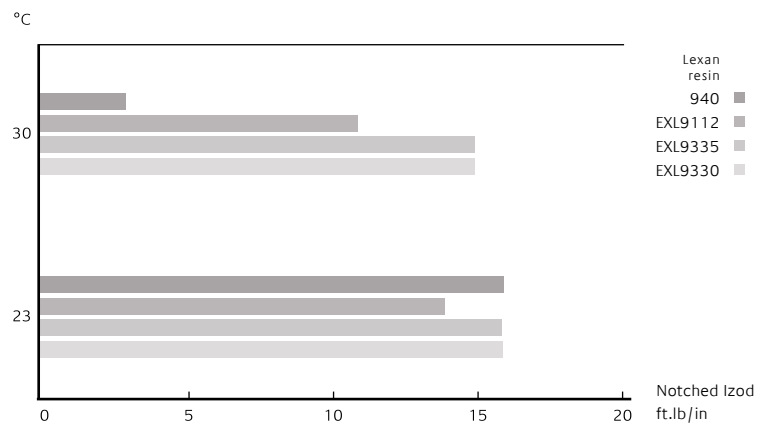
The Lexan[®] resin family offers designers a great deal of choice as far as stiffness is concerned.

While stiffness values can vary greatly from one grade to another, the stiffness properties for an individual grade will remain constant over a wide temperature range from subzero to 120°C / 248°F.

Figures 5.1, 5.2, 5.3 and 5.4 show the Notched Impact values of Lexan EXL grades for different temperatures compared to other Lexan and Cyclooy[®] resin grades (see page 26 for figures 5.3 and 5.4).

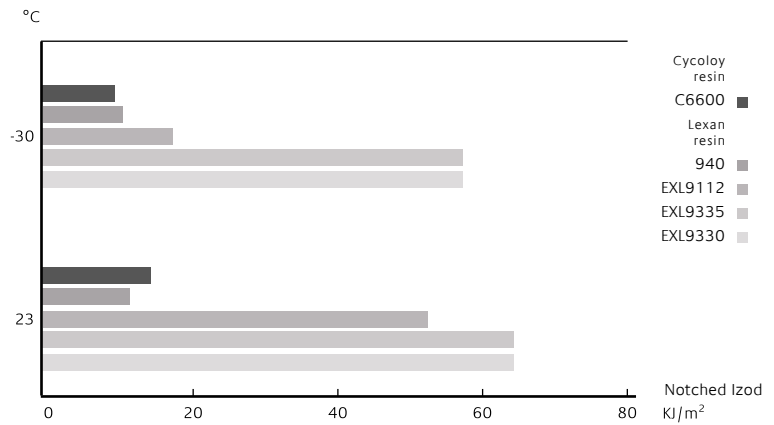
■ **Figure 5.1**

EXL ASTM Notched Izod - FR



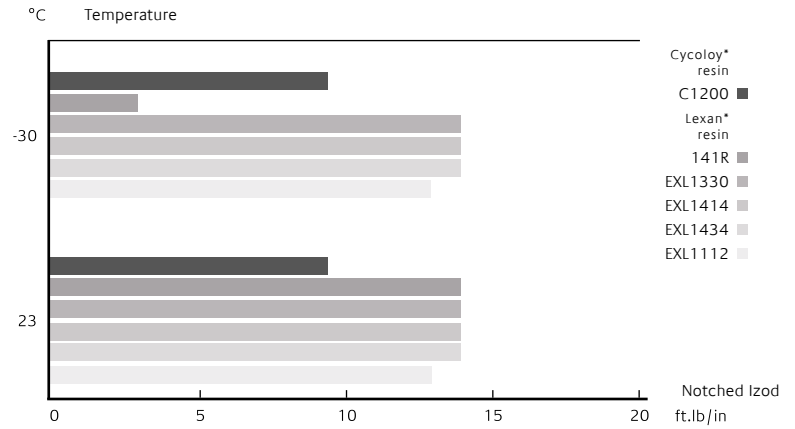
■ **Figure 5.2**

EXL ISO Notched Izod - FR



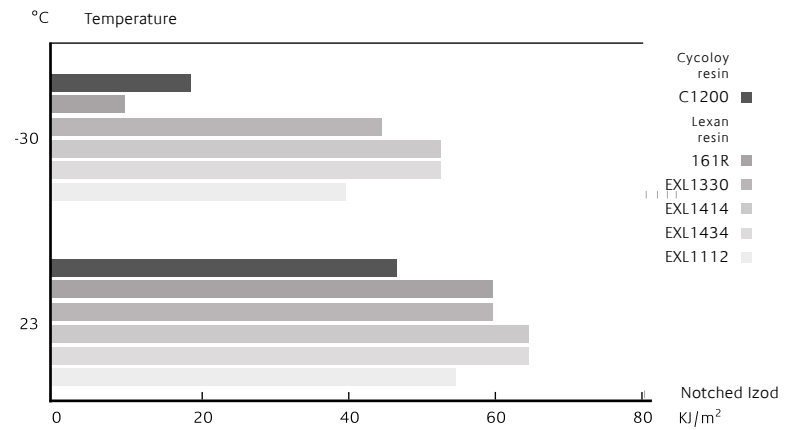
■ **Figure 5.3**

EXL ASTM Notched
Izod Non-FR



■ **Figure 5.4**

EXL ISO Notched Izod
Non-FR



The stiffness of a part is defined as the relationship between its load and deflection. The most important material property for stiffness is the stress/strain curve. In general, the Young's modulus (ISO 527), which is determined from the stress/strain curve, is the best parameter to be used when comparing the stiffness of materials.

Figure 6 compares the tensile stress and strain, showing modulus of unreinforced Lexan* resin 141R with 10% glass-reinforced Lexan resin 500R and 20% glass-reinforced Lexan resin 3412R. Lexan resin 500R shows an excellent combination of energy absorption and modulus, while Lexan resin 3412R can have an ideal fit in high modulus applications.

A further important consideration in the calculation of part stiffness is the temperature at which the load is applied. As can be seen in figures 7 and 8, the stress/strain curves of thermoplastics are strongly influenced by temperature.

Figure 6
Stress-strain curve of Lexan resin
(23°C/73°F)

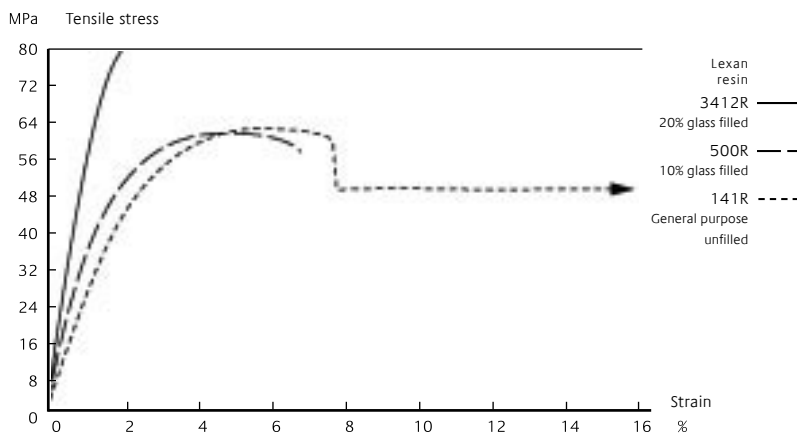


Figure 7
Stress-strain curve of Lexan resin 141r (iso 527)
astm shows the similar trend

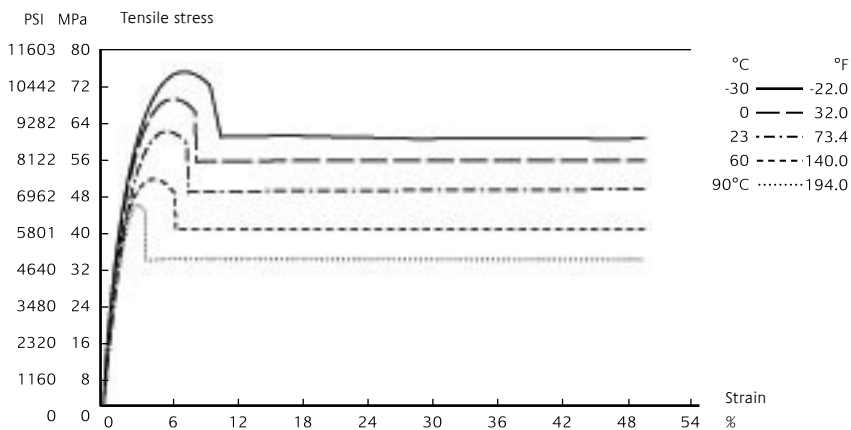
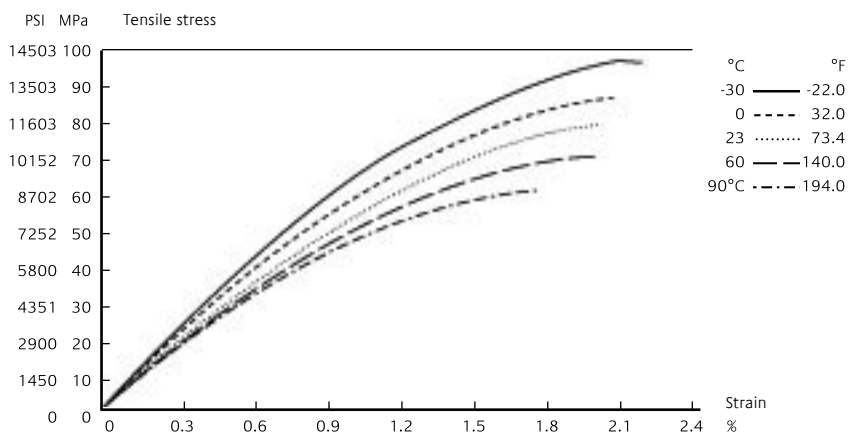


Figure 8
Stress-strain curve of Lexan resin 3412R (20% glass filled)
(ISO 527) ASTM shows the similar trend



5. Properties and design

5.2.c Strength

The strength of a part is defined as the maximum load that can be applied to a part without causing part failure under given conditions.

In order to be able to determine the strength of a part, failure has to be first defined. The right definition of failure depends on the application and how much deformation is allowed.

Material strength is a stress/strain related property which is inherent in the material. The tensile test provides the most useful information for engineering design.

For unfilled Lexan* resin grades subjected to small strains, the stress increases proportionally with the strain. However, early in the test non-linearity will occur. In fact, a close observation of the stress/strain curve shows that a proportional part does not exist. With larger strains, yield will occur and the maximum stress is reached. If the strain is further increased, necking will occur. The neck will propagate through the structure until the material fails.

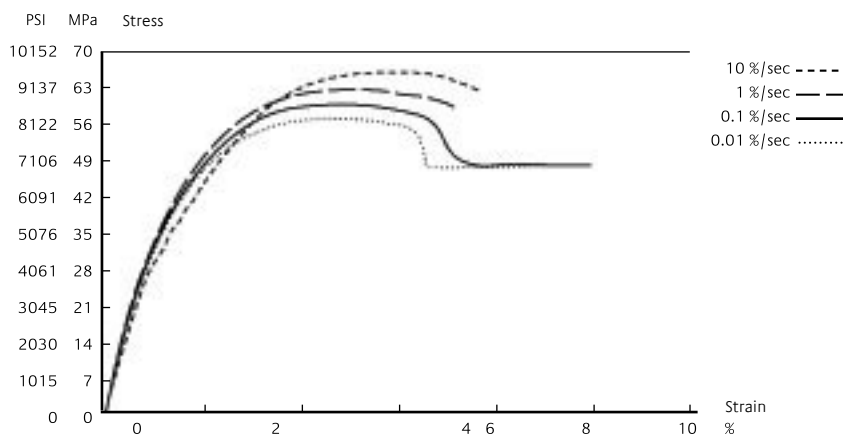
The speed of deformation in the application is vital. The differences are shown for Lexan resin 500R in figure 9.

5.2.d Behavior over time

There are two types of phenomena which should be considered. Static-time dependent phenomena such as creep are caused by the single, long-term loading of an application. Dynamic-time dependent phenomena such as fatigue, on the other hand, are produced by the cyclic loading of an application. Both types of behavior are heavily influenced by the operating environment and component design.

■ **Figure 9**

Stress-strain curve of Lexan resin 500R (10% glass filled) 23°C / 73.4°F (ISO 527) ASTM shows the similar trend



5.2.d.1 Creep behavior

Creep is defined as the increasing rate of deformation of a geometrical shape when subjected to a constant long-term load. With plastics, the creep rate is dependent on temperature, load and time. At a certain stress level, creep becomes minimal and can be disregarded in long-term, continuous-load applications.

Figure 10 shows that a key property of Lexan* resin is its predictable, low creep behavior even at higher loads. This is due to the amorphous structure and its inherent high heat resistance. At higher temperatures, the creep behavior is increased as can be seen in figure 11.

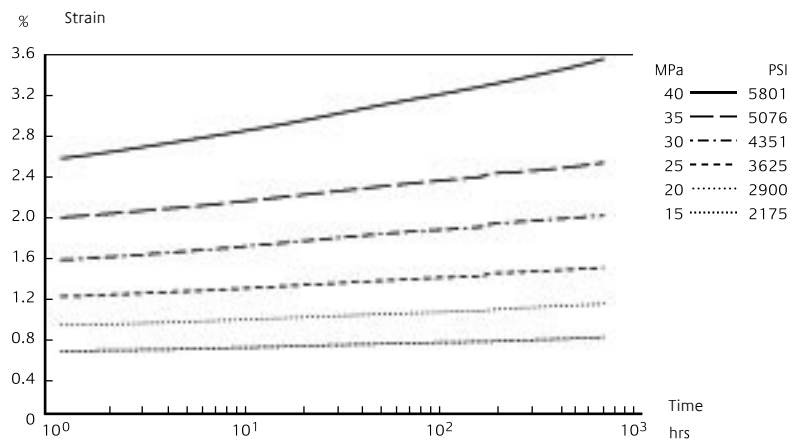
5.2.d.2 Fatigue endurance

Fatigue is an important design consideration for parts subjected to cyclic loading or vibration. Structural components subjected to vibration, components subjected to repeated impacts, reciprocating mechanical components, plastic snap-fit latches and molded-in plastic hinges are all examples where fatigue can play an important role. Cyclic loading can result in mechanical deterioration and fracture propagation through the material, leading to ultimate failure. When parts are subjected to cyclic loading, fatigue failure can occur, often at a stress level considerably below the yield point of the material.

In such applications, an uniaxial fatigue diagram could be used to predict product life. These curves can be used to determine the fatigue endurance limit or the maximum cycle stress that a material can withstand without failure.

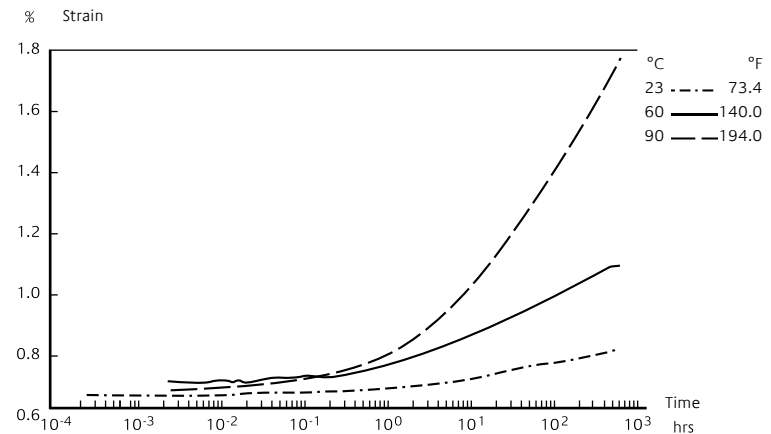
■ Figure 10

Deformation at constant load (creep) of Lexan resin 141R (ISO 899-1) (23°C / 73.4°F)
ASTM shows the similar trend



■ Figure 11

Deformation at constant load (creep) of Lexan resin 141R (15 MPa / 2175PSI) (ISO 899-1) ASTM shows the similar trend



5. Properties and design

Figure 12 compares the fatigue behavior of an unfilled and a filled Lexan® resin grade.

Fatigue tests are usually conducted under flexural conditions, though tensile and torsional testing is also possible. A specimen of material is repeatedly subjected to a constant deformation at a constant frequency and the number of cycles to failure is recorded.

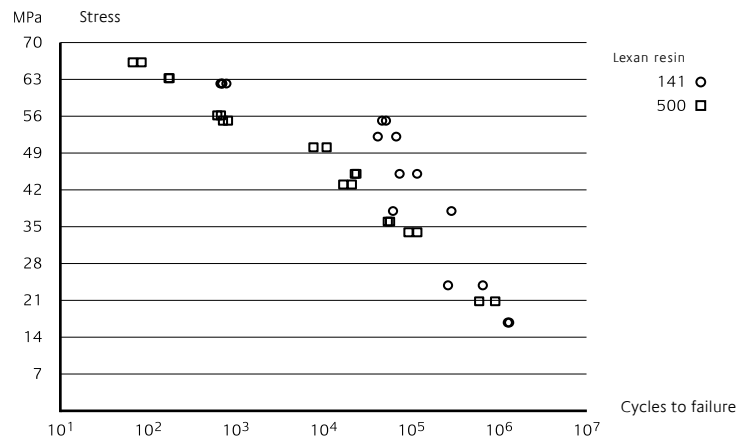
The procedure is then repeated over a range of deflections or applied stresses. The test data are usually presented as a plot of log stress versus log cycles; this is commonly referred to as an S-N curve, as shown in figure 12. S-N curves obtained under laboratory conditions may be regarded as “ideal”.

However, practical conditions usually necessitate the use of a modified fatigue limit, as other factors may affect performance, including most notably the type of loading, the size of the component and the loading frequency.

However, fatigue testing can only provide an indication as to a given material's relative ability to survive fatigue. It is therefore essential that tests are performed on actual molded components, under actual end-use operating conditions.

■ Figure 12

Uniaxial fatigue test of Lexan resin 141 and Lexan resin 500 (frequency 5 Hz, 23°C / 73.4°F)



5.3 Thermal properties

The property profile of Lexan* resin includes very good thermal properties. However, all thermoplastics will soften at elevated temperatures. The most common thermal test is the Vicat Softening Temperature, which measures the temperature at which a plastic starts to soften rapidly.

A second commonly used thermal test is the Heat Deflection Temperature, which in amorphous materials such as Lexan resin is strongly related to the glass transition temperature (T_g).

Other thermal tests include the Ball Pressure Test (IEC 60695-10-2) according to which almost all Lexan resins pass at 125°C / 257°F.

In accordance with UL746B, Lexan resin is granted a Relative Thermal Index (RTI) between 80°C / 176°F and 130°C / 266°F. There can be up to three independent RTI ratings assigned to a material electrical, mechanical with impact and mechanical without impact.

5.4 Flammability

The most widely accepted flammability performance standards for plastics are UL ratings which identify a material's ability to extinguish a flame once ignited. A complete overview of the UL 94 classifications for Lexan resin is given in table 1. It should be noted that each Lexan resin tested may receive several ratings depending on color and/or thickness.

In addition, Glow Wire Test results, according to IEC 60695-2-1, are dependent on the thickness of the material sample and the actual test temperature. Almost all Lexan resin grades pass the 850°C / 1562°F test at 1 mm / 0.039", while most of the flame retardant grades will pass the 960°C / 1760°F test at 1.6 mm / 0.063". Special grades are available which pass the 960°C test at 1 mm / 0.039".

■ **Table 1**

UL recognition for flammability

UL rating	Thickness		Lexan resin grades
UL94 5VA	> 3.0 mm	> 0.118 inch	500R, 503R, 3412R, 505R, 3412ECR, 945, 955, EXL9330, EXL9112
	< 1.5 mm	< 0.059 inch	940, B PL1000, 915R, 945
UL94 V0	1.5 - 2.5 mm	0.059 - 0.098 inch	920, 923, 943, 950, 953, 500R 9x5R series, 505R, 3412ECR, BFL series ,EXL9335
	> 2.5 mm	> 0.098 inch	9x0A series, 3412R, 3413R, 3414R, FL3000, FL403, FL410 9x5A(U) series, 2034, 2034E
UL94 V1	1.5 - 3.0 mm	0.059 - 0.118 inch	500ECR, 9x5A series
UL94 V2	< 1.5 mm	< 0.059 inch	BPL1000, BFL2000, 201(R), 203(R), 221(R), 241R, 243R, 261R, HF1110R, HF1130R, HF1140R
	1.5 - 3.0 mm	0.059 - 0.118 inch	9x0A series, 9x5A(U) series, 2XY Series, SLX2443
UL94 HB	< 1.5 mm	< 0.059 inch	101R, 103R, 121R, 123R, 124R, 141R, 143R, 144R, 161, 163R, LS1, LS2, LS3, EXL1414
	1.5 - 3.0 mm	0.059 - 0.118 inch	1XY series

If you would like to get detailed information, please check the UL web site at www.data.ul.com/ULIQ_Link

For Visualfx* UL rating, please check the root grades (Ex FXY921 has same UL rating with 921)

5. Properties and design

In accordance with ISO 4589, Lexan* resin general purpose grades have a Limited Oxygen Index (LOI) of 25-28%, while Lexan resin 900A grades have an LOI of 38%. This means that all Lexan resins are self-extinguishing. [Figure 13](#) compares the LOI of various SABIC Innovative Plastics' resins.

This combination of properties can make Lexan resin an ideal material for a variety of electrotechnical applications.

5.4.a Transportation industry regulations

Lexan resin is widely used in a variety of transportation applications. Stringent flammability requirements are enforced depending on the industry and the country.

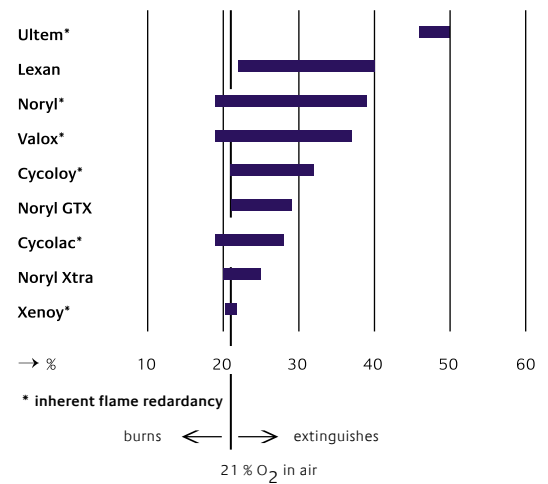
In railway industry applications in France, for example, the I, F, M classification according to NF F 16-101 is important, while in Germany applications are subject to DIN 5510.

For aircraft applications, Lexan resin's compliance with the requirements of Airbus standard ABD003 1 for smoke evolution and toxicity is detailed in [table 2](#).

According to the US federal motor vehicle safety standard FMVSS302, all Lexan resin grades pass at thicknesses >1.5 mm / 0.059", while flame retardant grades pass at thicknesses below 1.5-mm / 0.059".

■ **Figure 13**

Limited Oxygen Index (ISO 4589)



■ **Table 2**

Typical values for Lexan resin according to Airbus standard ABD003 1

	FAR25853	Smoke D4min	Toxicity
Lexan resin 500R	b	< 200	pass
Lexan resin 940	b	< 200	pass
Lexan resin 950	b	< 200	pass
Lexan resin 950A	b	< 200	pass

5.5 Electrical properties

As an organic material, Lexan[®] resin is an excellent electrical insulator.

5.5.a Dielectric strength

As can be seen in figure 14, the dielectric strength is non-linear with the thickness. Standard Lexan resin typically exhibits a dielectric strength of 17 kV/mm at 3.2 mm / 0.126", 27 kV/mm at 1.5 mm / 0.059", 35 kV/mm at 1 mm / 0.039" and 67-kV/mm at 0.25 mm / 0.0098" thickness.

5.5.b Relative permittivity

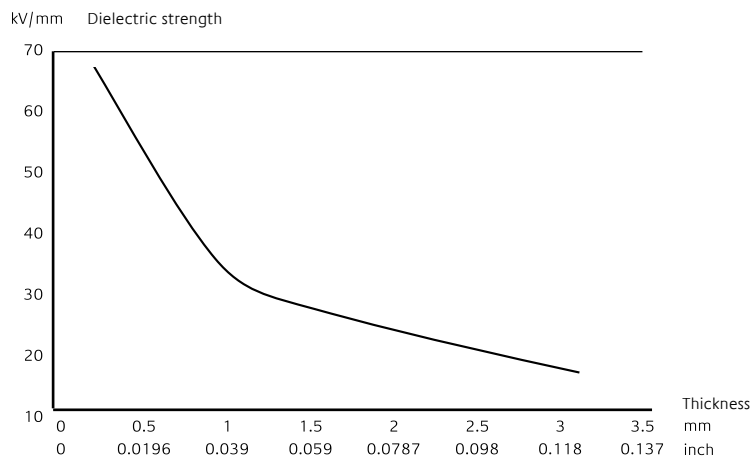
Figure 15 shows that the relative permittivity values of Lexan resin are intermediate to low when comparing to other SABIC Innovative Plastics polymers. A low relative permittivity is desired for plastic components used to insulate and isolate electric components from one another. (Relative permittivity is also called dielectric constant in literature).

5.5.c Dissipation factor

As can be seen in figure 16, the electrical dissipation factor of Lexan resin is considered to be relatively low over a wide temperature range. Parameters which influence dissipation factor is where favorable for antenna housing where a high electromagnetic transparency is needed.

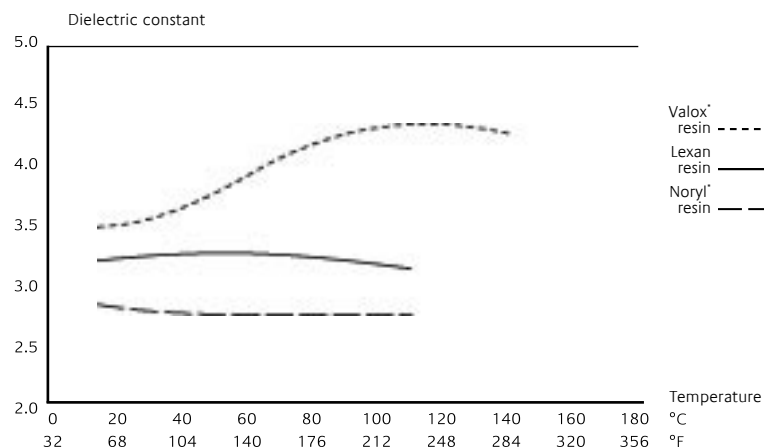
■ Figure 14

Dielectric strength of unfilled Lexan resin as a function of thickness



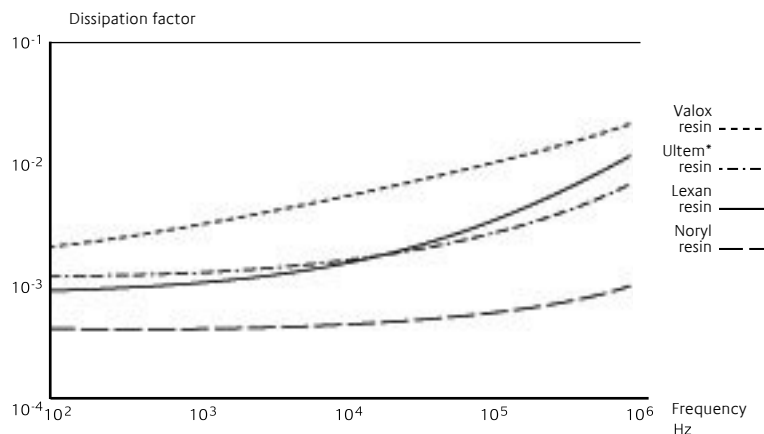
■ Figure 15

Relative permittivity at 60Hz and 50% RH of unfilled materials



■ Figure 16

Dissipation factor at 23°C (73.4°F) of unfilled materials



5. Properties and design

5.6 Aesthetics and optical properties

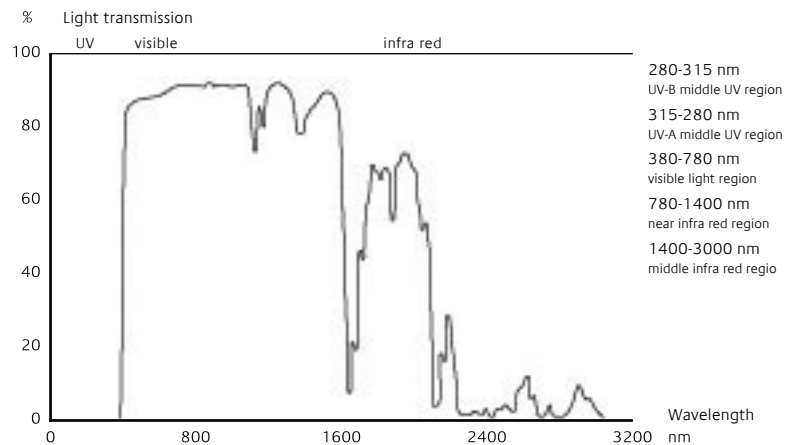
Lexan® resin is a naturally transparent, 'water white' material with excellent aesthetic properties. It is available in a wide choice of colors, many of which have transparent, translucent, opalescent and opaque versions. In addition, Lexan resin consistently reproduces mold surface finish with great accuracy. This provides designers with top quality, high gloss or textured surface finishes.

Lexan resin has excellent light transparency, which is close to that of glass, and a very high refractive index of 1.586. Its highest transmission rate is in the visible light and infrared region, as shown in figure 17.

Figure 18 shows the excellent light transmission of standard natural color Lexan 141R resin at different thicknesses. The light transmission of transparent Lexan resin can be changed if required. Grades such as Lexan 143R-111 and Lexan LS2-111 have a built-in UV screen to filter out UV radiation up to 380 nm. Modified grades such as Lexan OQ4320 resin will even reach 400 nm, thereby providing additional sun protection without affecting the transmission in the visible region.

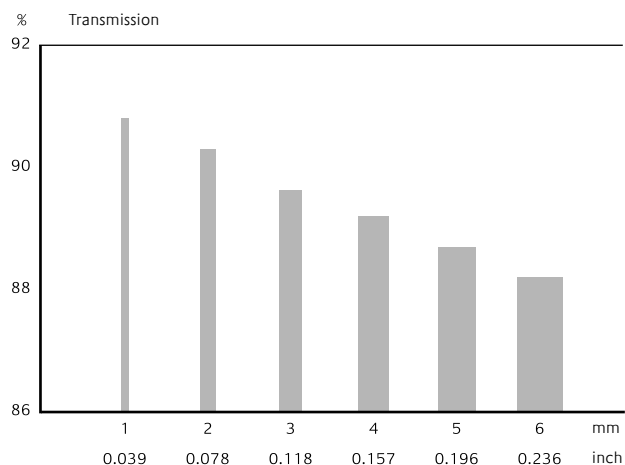
■ Figure 17

Light transmission of UV stabilized Lexan resin



■ Figure 18

Light transmission of Lexan resin 141R as a function of thickness for standard natural color



Special colors provide a high light transmission in the infrared region only, which blocks all light in the visible light region for applications such as remote control panels, as illustrated in figure 19.

Opalescent colors provide partial light diffusion for the lighting industry. The transmission at a given thickness is critical. Lexan® resin can be produced in a wide range of opalescent colors with different transmission values.

5.7 Environmental resistance

5.7.a Chemical resistance

Lexan resin can be adversely affected by certain combinations of chemical environment, temperature and stress. For this reason, lubricants, gaskets, O-rings, cleaning solvents or any material which may come into contact with the finished part should be carefully evaluated for compatibility.

In all cases extensive testing of the finished part under actual service conditions is strongly recommended.

The performance and interpretation of the results of end-use testing are the end-producer's responsibility.

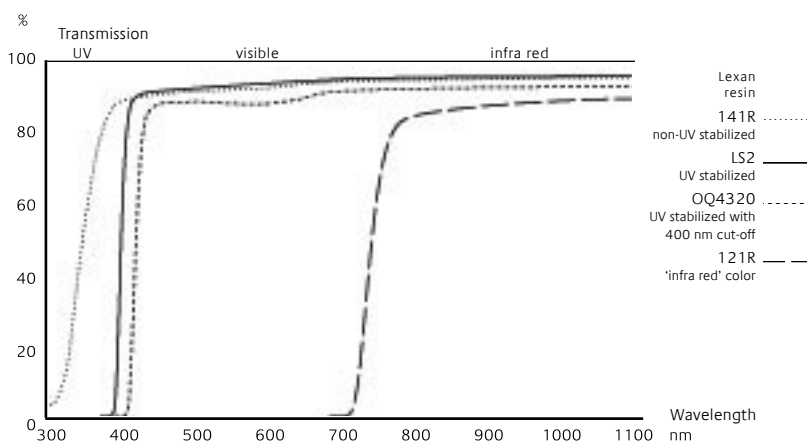
While Lexan resin generally displays good property retention when exposed to water, mineral acids and organic acids, crazing and/or embrittlement may occur if the Lexan resin part is highly stressed and exposed to hot water or a humid environment.

Lexan resin is insoluble in aliphatic hydrocarbons, ethers and alcohols. It is partly soluble in aromatic hydrocarbons, soluble in chlorinated hydrocarbons and will slowly decompose in strong alkaline solutions.

Table 3 (see next page) provides a comprehensive overview of the chemical compatibility of Lexan resin according to the specified SABIC Innovative Plastics test conditions.

■ Figure 19

Light transmission of transparent Lexan resin



5. Properties and design

■ **Table 3**

Chemical compatibility of Lexan* polycarbonate

This overview shows the chemical resistency of Lexan polycarbonate sheet. Chemical compatibility of thermoplastics e.g. Lexan is dependent on contact time, temperature and stress (external stress to which the application is subjected). Chemical exposure can result in discoloration, softening, swelling, crazing, cracking or loss of properties of the thermoplastic. The chemicals listed have been evaluated for Lexan sheet according to a very stringent SABIC Innovative Plastics test method. This test incorporates exposure to the chemical under defined conditions including temperature (20°C / 68°F and 80°C / 176°F) and stress (0.5% and 1% strain) for a time period of seven days.

This information should be used as indicative only. The true chemical compatibility can only be determined under conditions as in the final application. Please contact your local representative in case additional information is required.

Key to performance

- poor, not recommended; will result in failure or severe degradation
- 0 fair, found marginal; only for short exposures at lower temperatures or when loss of properties is not critical
- + good, found unaffected in its performance when exposed with regards to time, temperature and stress according the SABIC Innovative Plastics test method

Acid, mineral		Glycerine	+
Boric acid	+	Hepthyl alcohol	-
Hydrogen chloride 20%	+	Isobutanol	0
Hydrogen chloride 25%	-	Nonyl alcohol	-
Hydrogen fluoride 25%	+	Octyl alcohol	+
Nitric acid 70%	-	Oxydiethanol 2.2	+
Perchloric acid	-	Phenetyl alcohol	-
Phosphorus pentoxide dry	+	Polyalkylene glycol	-
Phosphoric acid 1%	+	Polyethylene glycol	+
Phosphoric acid 10%	-	Propylene glycol	-
Phosphorus pentachloride	+	Sorbitol	+
Sulphuric acid 50%	+	Thiodiglycol 5%	-
Sulphuric acid 70%	-	Triethylene glycol	+
Sulphurous acid 5%	-	Tripropylene glycol	-
Acid, organic		Aldehyde	
Acetic anhydride	-	Acetaldehyde	-
Formic acid concentrate	-	Butyraldehyde	-
Gallic acid	+	Formaldehyde solvent 37%	+
Maleic acid	+	Formalin	+
Mercapto acetic acid	-	Propionaldehyde	-
Murctic acid 20%	+	Amide	
Muristic acid 25%	-	Dimethylformamide	-
Oleic acid	+	Amine	
Palmitic acid	+	Aniline	-
Phenol sulphonic acid	-	Diphenylamine	-
Phenoxyacetic acid	+	Methylaniline N	-
Phthalic anhydride	+	Methylene dianiline	-
Salicylate acid	+	Phenylhydrazine	-
Tannic acid	+	Pyridine	-
Tannic acid 20%	-	Triethanolamine	+
Thiodiacetic acid	+	Hydroxylamine	+
Trichlor acetic acid	-	Base	
Sulphamine acid 5%	0	Aluminum hydroxine powder	+
Alcohol		Ammonia concentrate	-
Allyl alcohol	-	Ammonium hydroxide 0.13%	-
Amyl alcohol	-	Calcium hydroxide	-
Butoxyethanol	-	Potassium hydroxide 10%	-
Chlorethanol 2	-	Sodium hydroxide dry	+
Decyl alcohol	-	Sodium hydroxide 10%	-
Dodecyl alcohol	-	Sodium thotalamate	+
Ethanol	-		
Ethyl glycol 100%	-		
Ethyl glycol 60%	+		
Furfuryl alcohol	-		

Ester	Isobutane	-	Salt, inorganic	Potassium nitrate	+	
Benzyl benzoate	- Methane	-	Aluminum ammonium sulphate	- Potassium permanganate	-	
Buthyl cellosolve acetate	- Oxygen	+	Aluminum chloride	- Potassium persulphate	+	
Buthyl stearate	- Ozone 2%	-	Aluminum fluoride	+	Potassium sulphate	+
Cello acetobutyrate	- Propylene	+	Aluminum potassium sulphate	- Silver chloride saturated	-	
Cellulose acetate	- Sulphur dioxide	-	Aluminum sodium sulphate	+	Silver nitrate	+
Cellulose propionate	- Sulphur hexafluoride	-	Ammonium bicarbonate	+	Sodium bicarbonate saturated	0
Dibutyl phthalate	-		Ammonium bromide	+	Sodium bicarbonate 13%	-
Didecyl carbonate	- Halogenated HC		Ammonium carbonate	-	Sodium bisulphate	+
Disodecyl phthalate	- Acetylene dibromo	-	Ammonium dichromate	+	Sodium bromate	+
Disononyl phthalate	+ Acetylene tetrabromide	-	Ammonium persulfate	+	Sodium bromide	+
Diocetyl phthalate	- Bromochloromethane	-	Arsenic trioxide	-	Sodium carbonate	+
Diocetyl sebacate	- Carbon tetrachloride	-	Barium carbonate	+	Sodium carbonate solvent	-
Ditridecyl carbonate	- Chlorethanol 2	-	Barium chloride	+	Sodium chlorate	+
Ditridecyl phthalate	- Chlorobenzene	-	Barium sulphate	+	Sodium etherlaurylsulphate	0
Ethyl bromoacetate	+ Chlorobutane	-	Calcium carbonate paste	-	Sodium ferricyanide	+
Ethyl butyrate	- Chloroform	-	Calcium chloride	+	Sodium fluoride	+
Ethyl cellusolve 5%	- Dibromomethane	-	Calcium sulphate	+	Sodium hypochlorite 6%	+
Ethyl chloracetate	- Dichloroethane	-	Cesium bromide	+	Sodium hypochlorite 15%	-
Ethyl cyanoacetate	- Dichlorohydroxybenzene	+	Copper (II) chloride 5%	+	Sodium nitrate 10%	-
Ethyl lactate	- Dichloromethane	-	Iron (II) chloride	-	Sodium perborate	+
Ethyl salicylate	- Ethyl bromoacetate	+	Iron (III) ammonium sulphate	+	Sodium phosphate	+
Isopropyl myristate	-		Iron (III) chloride saturated	+	Sodium sillicate	+
Methyl acetate	+ Ketone		Iron (III) nitrate	-	Sodium sulphide	-
Methyl calicylate	- Methyl ethyl ketone	-	Iron (III) sulphate	+	Sodium sulphite	+
Methylbenzoate	-		Lithium bromide	+	Strontium bromide	+
Triacetine	- Metal & metal oxide		Lithium hydroxide powder	+	Tin (II) chloride	+
Tributoxyethyl phosphate	- Aluminum oxide	+	Magnesium bromide	+	Tin (IV) chloride	+
Tributyl cello phosphate	- Arsenic trioxide	-	Magnesium chloride	+	Titanium tetrachloride	+
2 dodecyl phenyl carbonate	+ Calcium oxide paste	-	Magnesium nitrate	+	Trisodium phosphate 5%	-
Ether	Cuprous oxide	+	Magnesium sulphate	+	Zinc bromide	+
Ether	- Mercury metallic	-	Mercury (I) nitrate	+	Zinc carbonate	+
Ethyl cellosolve 5%	- Phenol		Mercury (II) chloride	-	Zinc chloride	-
Methyl cellosolve	- Allyl 4 methoxyphenol	-	Mono ammonium phosphate	+	Zinc oxyde	-
Polyalkylene glycol	- Cresol	-	Nickel nitrate	+	Zinc sulphate	+
Polyethylene glycol	+ P-Phenylphenol	-	Potassium bicarbonate dry	+	Salt, organic	
Polyethylene sulfide	- Pentachlorophenol	-	Potassium bisulphate	+	Alluminum acetate	+
Propylene oxide	- Phenol sulphonic acid	-	Potassium bromate	+	Ammonium acetate	-
Gaseous	Phenol 5%	-	Potassium bromide	+	Ammonium oxalate	+
Ammonia concentrate	- Phenoxyacetic	+	Potassium carbonate	+	Aniline sulphate	+
Bromine	-		Potassium chlorate	+	Potassium acetate 30%	-
Chloracetophenone	-		Potassium chloride saturated	-	Quinine sulphate	-
Chlorine	-		Potassium chloride 15%	+	Sodium acetate 30%	-
Iodine	-		Potassium chormium sulphate	-	Valine bromide dl	+
			Potassium cyanide powder	+		
			Potassium dichromate	+		
			Potassium iodide	+		

5. Properties and design

5.7.b Sterilization

Lexan® resin health care products meet the requirements of multiple sterilization options and biocompatibility standards of USP Class VI and ISO 10993 commonly required for medical applications. Lexan products are available which are suitable for sterilization by Gamma radiation, EtO gas and steam autoclave.

5.7.c Cleaning and degreasing

Cleaning or degreasing of Lexan resin finished parts can be performed using methyl or isopropyl alcohol, mild soap solutions, heptane or hexane. The parts should not be cleaned with partially hydrogenated hydrocarbons, with ketones such as MEK, with strong acids or with alkalines such as sodium hydroxide.

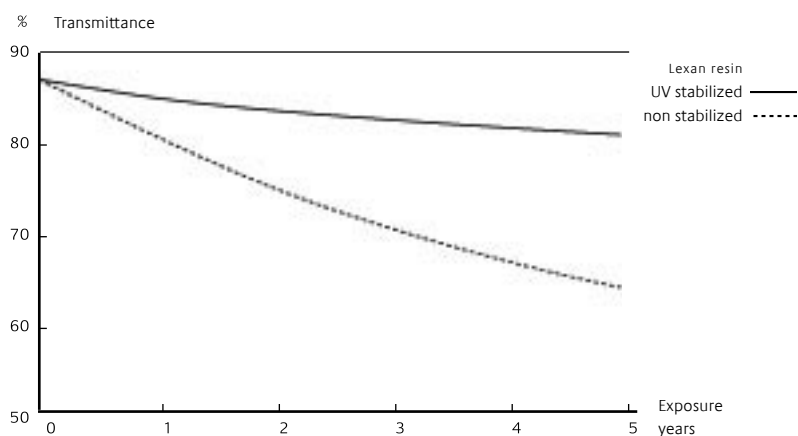
5.7.d Ultraviolet exposure

Lexan resin may be sensitive to long-term exposure to ultraviolet light and weathering. The degree of sensitivity is very much dependent on the specific grade, the specified color and the weathering conditions.

Lexan resin can be ideally suited to a range of both indoor and outdoor applications. Figures 20 and 21 show that UV stabilized Lexan resin grades maintain high light transmission after prolonged UV exposure and offer a good resistance to yellowing after prolonged exposure to harsh climatic conditions.

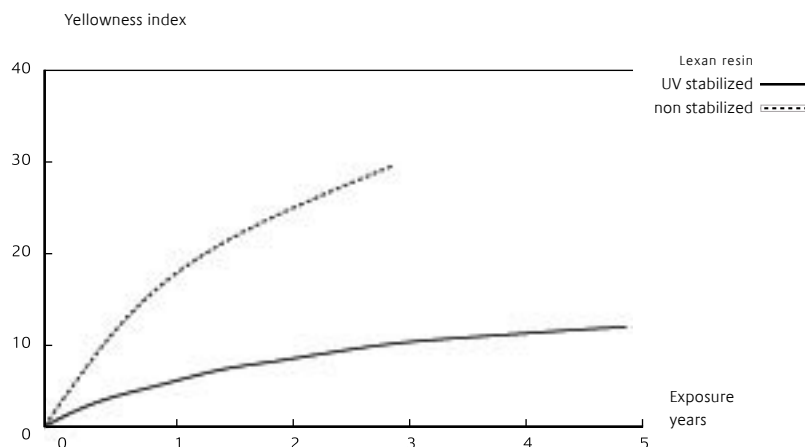
■ **Figure 20**

Transmittance of transparent Lexan resin after natural exposure acc. ASTM G7, at Florida (USA)



■ **Figure 21**

Yellowness index of transparent Lexan resin after natural exposure acc. ASTM G7, at Florida (USA)



For applications which are exposed to critical environments of intense sunlight and high humidity, Lexan® resin can be additionally protected in various ways. Tailor-made glass clear UV cap-layers further improve the weathering resistance of extruded Lexan sheet, while for injection molded parts a variety of coatings, including a range of silicone hardcoats, enhance weathering, scratch and abrasion resistance.

Figures 22 and 23 illustrate the enhanced resistance to haze and yellowing which can be obtained through the application of a silicone hardcoat.

Figure 22

Haze of transparent Lexan resin, coated and uncoated, after accelerated outdoor exposure

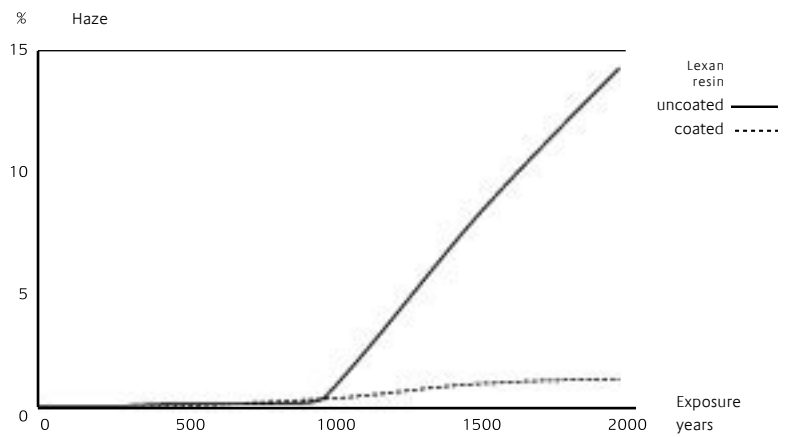
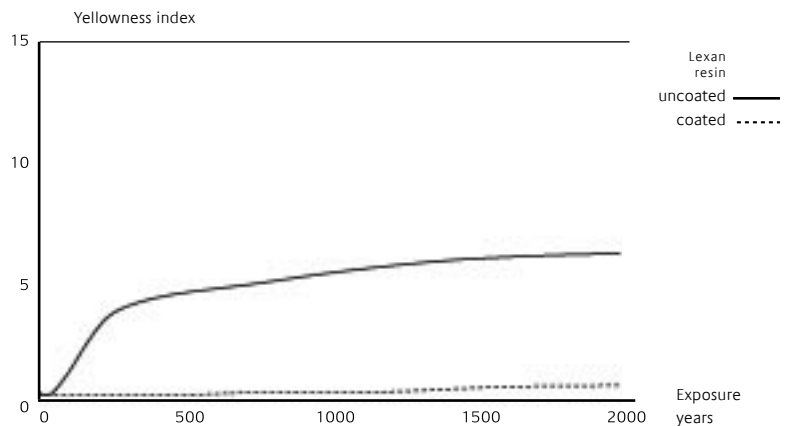


Figure 23

Yellowness Index of transparent Lexan resin, coated and uncoated, after accelerated outdoor exposure



5. Properties and design

Figures 23.1, 23.2 and 23.3 show SLX2431 YI shift compared to UV stable PC resin

Figure 23.1
YI Shift with Xenon Arc Weathering

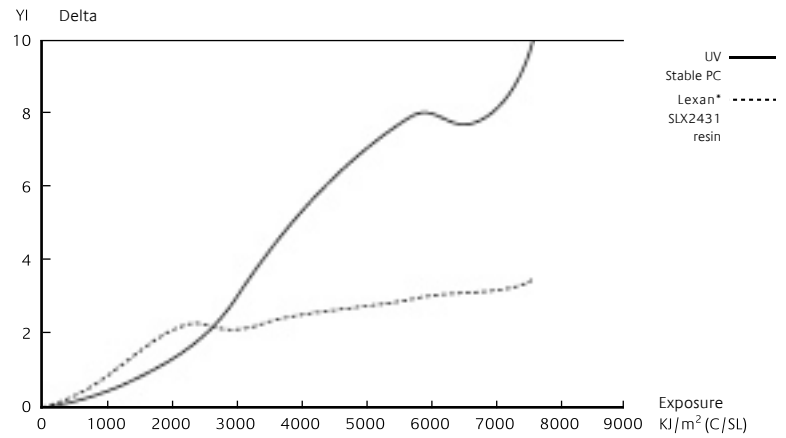


Figure 23.2
DeltaYI in Whirlygig (400W Mercury, 90°C)

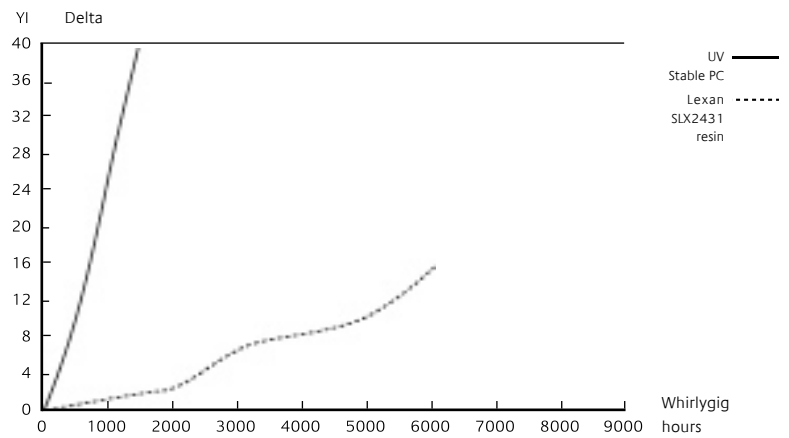
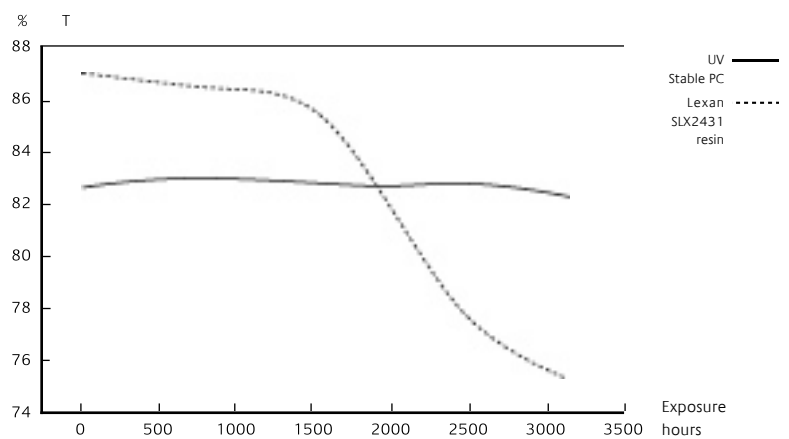


Figure 23.3
T Change with Whirlygig Weathering (400W Mercury, 90°C)



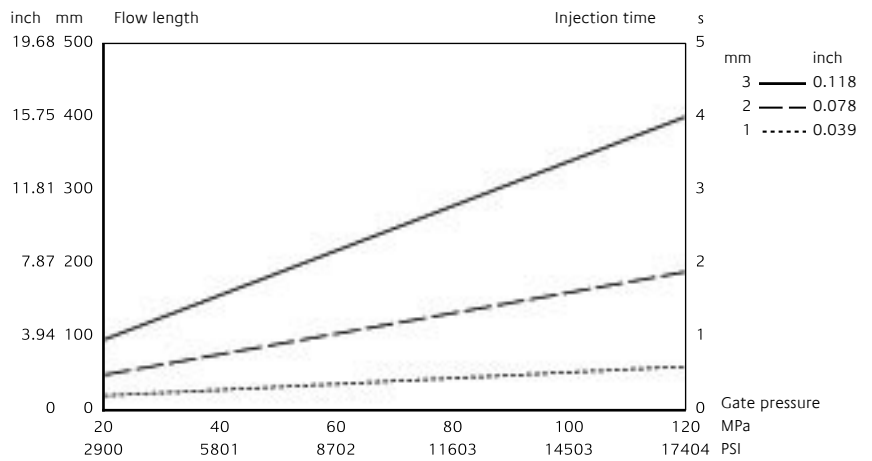
5.8 Processability

To obtain extruded sheet, blow molded or injection molded parts, the material's flow properties are critical. These are measured based on melt flow length and melt temperature. The flow lengths of SABIC Innovative Plastics are given as calculated disk flow lengths, where the injection pressure is plotted against the radial flow length. Determination of the calculated disk flow length is important when trying to predict whether or not a part can be filled.

As an example, figure 24 shows the calculated disk flow lengths of Lexan* resin 141R. The melt flow length of a material is a function of viscosity, shear properties and thermal properties.

■ Figure 24

Calculated flow length indication of Lexan resin 141R



5. Properties and design

5.8.a Viscosity

Lexan* resin is available in a wide range of viscosities which are obtained by producing polycarbonate with different molecular weights higher molecular weight grades have a higher viscosity. The portfolio ranges from ultra-low viscosity Lexan resin OQ grades for the DVD format, to very high viscosity grades for multiple wall extrusion, as depicted in figure 25.

Figure 26 shows the range of melt viscosities for various glass-filled grades, while figure 27 relates specifically to selected flame-retardant grades. Common viscosity tests include melt viscosity, MV and melt volume rate, MVR and measurements.

5.8.b Shear properties

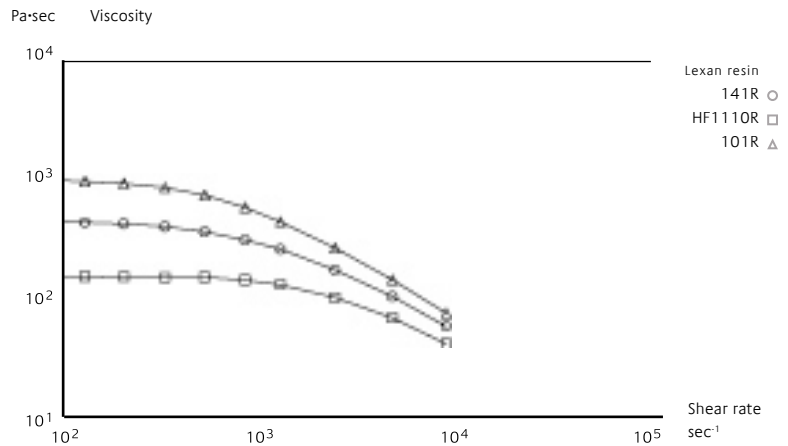
MV tests are carried out over a large range of shear rates. As materials show significantly different MV curves, comparisons should be made according to the MV curves rather than on the MVR.

Lexan resin exhibits a very low degree of shear thinning when compared with other thermo plastics. Unlike most thermoplastic materials, polycarbonate shows an almost Newtonian behavior, which means that the viscosity is hardly influenced by the shear rate.

Shear curves showing the relationship between shear rate and viscosity at different temperatures are required for accurate injection molding simulation.

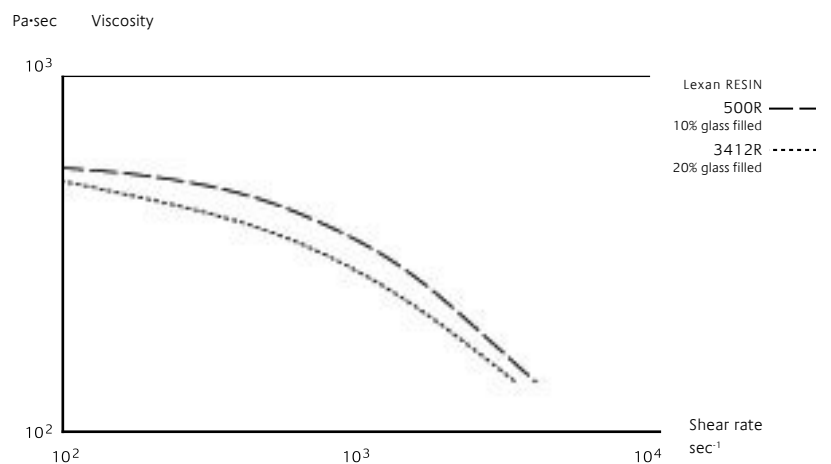
■ **Figure 25**

Capillary melt viscosity of Lexan resin showing a wide range of available viscosities (300°C / 572°F)



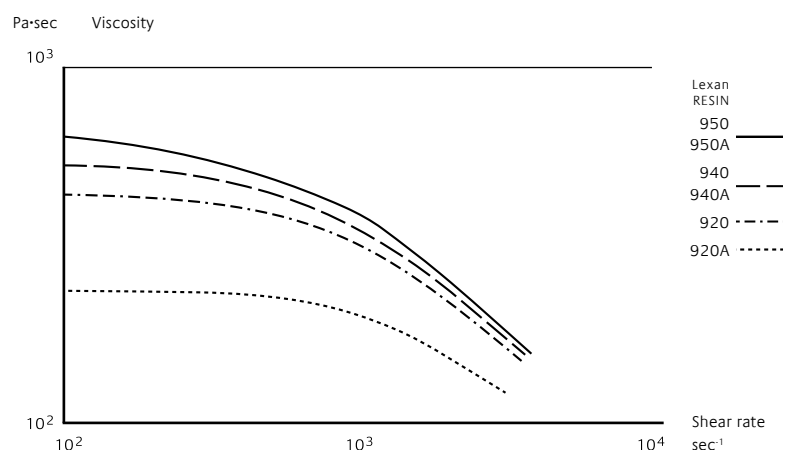
■ **Figure 26**

Capillary melt viscosity of standard glass filled Lexan resin (300°C / 572°F)



■ **Figure 27**

Capillary melt viscosity of standard flame retardant Lexan resin grades (300°C / 572°F)



5.9 Mold shrinkage

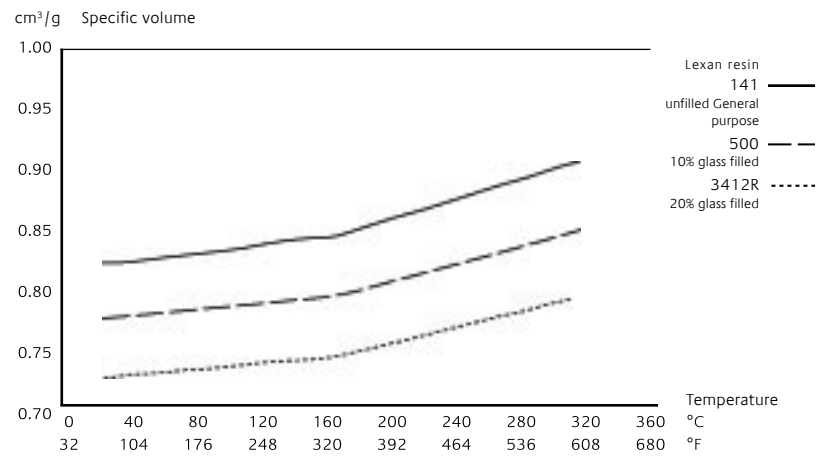
Mold shrinkage refers to the shrinkage that a molded part undergoes when it is removed from a mold and cooled at room temperature. Expressed as an average percentage, mold shrinkage can vary considerably depending on the mold geometry, the processing conditions and the type of resin.

As an amorphous material, Lexan* resin exhibits lower shrinkage than semi-crystalline materials. The levels of shrinkage in both cross-flow and flow direction are also closer to each other for amorphous materials, which makes it easier to produce precise parts. The addition of glass reinforcement increases the degree of orientation but lowers shrinkage. The influence of the material on shrinkage is usually expressed by the PVT (Pressure-Volume-Temperature) relationship. This relationship is illustrated for both unreinforced and glass-fibre reinforced Lexan resin grades in figure 28.

The packing or holding pressure phase in the injection molding process also has a significant effect on shrinkage. In general, the higher the holding pressure and the longer it is effective, the smaller the shrinkage. This is illustrated in figure 29.

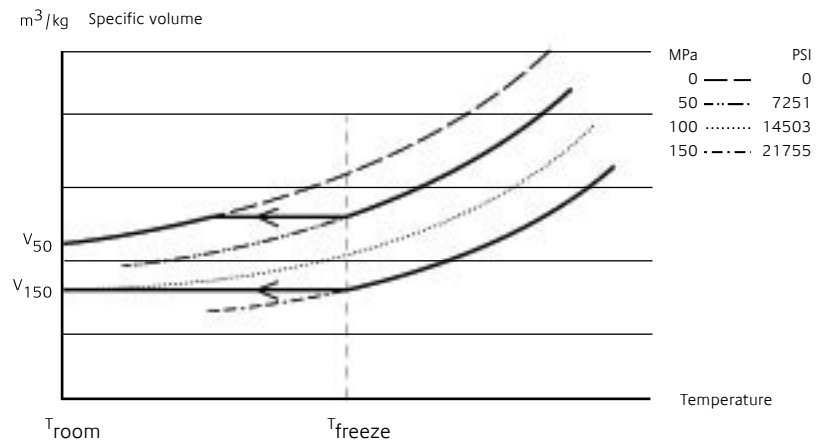
■ Figure 28

PVT relationship for unreinforced and glass reinforced Lexan resin (80MPa) (ISO) ASTM shows the similar trend



■ Figure 29

Typical PVT relationship for Lexan resin PC. Higher holding pressure reduces volumetric shrinkage



6. Processing

Lexan* polycarbonate resin can be successfully processed by injection molding, structural foam molding, extrusion, injection (stretch) blow molding and extrusion blow molding. Extruded sheet from Lexan polycarbonate resin can be thermoformed. Standard equipment can be used and the processing range is very broad. Fast cycle times are possible and any rejects can be ground and reused, providing contamination has not occurred during processing. There are no major changes to processing for Visualfx*.

6.1 Pre-drying

Most thermoplastic materials absorb atmospheric moisture which, at normal processing temperatures, can cause polymer degradation. This consequently lowers property levels, in particular impact strength. Lexan polycarbonate resin therefore must be thoroughly dried before molding to ensure optimum part performance and appearance. The recommended drying temperature is 120°C / 248°F; the time required to achieve sufficient drying is dependent on the type of dryer and varies from two to four hours. Target moisture content should be a maximum of 0.02%. Excessive drying times of over 24 hours will not affect the properties of the polymer but they might decrease release performance during processing.

6.2 Equipment

- High compression ratio screws or those with a short compression zone should not be used. It is recommended to use a conventional 3-zone screw with a L:D ratio of 20:1 - 25:1 and a compression ratio of 2:1 - 2.5:1.
- Conventional construction materials for screw and barrel are acceptable for the processing of Lexan resin. However, screws and cylinders of a bimetallic type with high abrasion and corrosion resistance are preferred, especially for glass-filled grades.
- A vented barrel and screw is not a satisfactory alternative to pre-drying and is therefore not recommended for Lexan resin. If a vented barrel is used, then the level of moisture which is present in the material, and the percentage of the shot capacity, will have a considerable influence on whether any degradation is encountered as a result of hydrolysis.
- A free-flowing nozzle with its own heater band and control is recommended. Nozzle openings have to be as large as possible.
- It is possible to mold with as little as 35 N/mm² clamping force but more common pressures are between 40 and 50 N/mm². For complex thin wall components requiring fast injection speeds combined with high injection pressures, a clamping force of up to 80 N/mm² is required.

Careful attention to the right tool/equipment combination is critical for complex thin wall components which require fast processing and high injection pressures.

6.3 Processing conditions

Melt temperature

It is important not to create long residence times which can result in material degradation. For Lexan[®] resin, the ideal maximum residence time is between six and 12 minutes, depending on the selected melt temperature. When processing Lexan resin on the upper limit of the melt temperature range, it is recommended that the shot size is 60%-80% of the barrel capacity to minimize residence time. Higher melt temperature yields the best aesthetics for Visualfx[®].

Back pressure

A machine back pressure of five- 10 bar (72-145 PSI) is recommended in order to improve melt quality and maintain a consistent shot size. For glass reinforced grades, careful monitoring of back pressure is advisable in order to minimize fibre damage.

Screw rotation speed

Screw surface speeds should not exceed 250-300 mm/s (9.8-11.8 inch/s). For reinforced grades a screw speed at the lower end of the range is recommended.

Suck back

The suck back stroke should be just enough to keep the resin in and the air out, to avoid melt degradation and subsequent molding problems.

Screw cushion

A screw cushion of 3-10 mm / 0.118"-0.393" is recommended, depending on the screw diameter. Without a cushion it is not possible for the after pressure to have an effect.

Injection speed

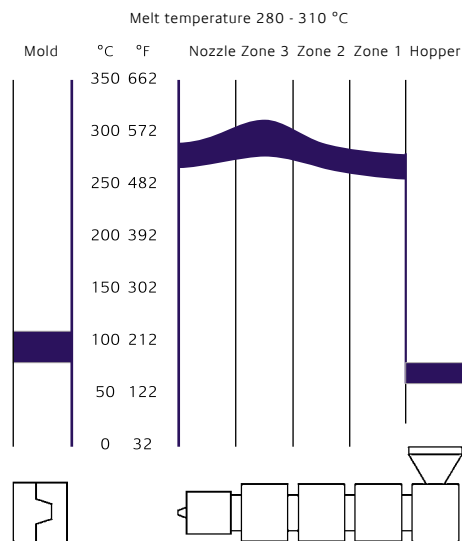
The fastest possible injection speed is desirable due to Lexan resin's fast set-up times, especially when using glass-reinforced grades. Adequate venting is essential when selecting a fast injection speed. Low injection speed is recommended for Visualfx grades.

Mold temperature

Lexan resin should always be molded in temperature-controlled molds. High mold temperatures are desirable for optimum flow, minimum molded-in stress and optimal surface appearance and Visualfx grades.

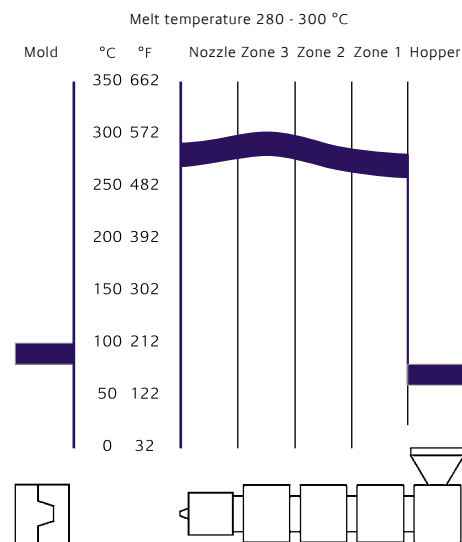
■ **Figure 30**

Typical molding temperatures for Lexan resin general purpose 141R



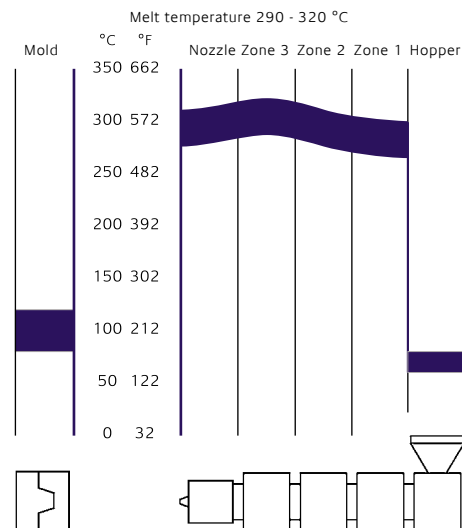
■ **Figure 31**

Typical molding temperatures for Lexan resin flame retardant 940



■ **Figure 32**

Typical molding temperatures for Lexan resin flame retardant, glass filled 500R



6.4 Venting

Good mold venting is essential to prevent blistering or burning and to aid cavity filling. Ideally the vents should be located at the end of the material flow paths. Inadequate or poorly located venting can result in incomplete filling, poor weld line strength, uneven shrinkage, warping and the need for excessive injection pressure to fill the cavity.

6.5 Interruption of production

Keeping Lexan* resin in the cylinder overnight or over a weekend is generally not recommended. If production delays are unavoidable, the following precautions are recommended.

- Reduce cylinder temperature to 170°C - 180°C / 338°F - 356°F
- Leave heaters on
- Ensure that the temperature never drops below 160°C / 320°F. This is to prevent the resin from adhering to the cylinder walls which may pull off metal particles and degraded resin as it cools and contracts, causing black specks in the moldings when production is restarted
- During production delays, empty the screw to prevent overheating

6.6 Purging of the barrel

Thorough purging of the barrel is required when changing materials. The best purging material for Lexan resin is PMMA. PA or ABS should not be used as a purging material directly after Lexan resin. The cylinder temperature should be lowered if the resin to be molded afterwards are POM, ABS or PA. The transitioning to/from Visualfx* purge the machine thoroughly.

6.7 Recycling

Sprues and faulty moldings can all be reground with minimal reduction in resin properties. Care must be taken to ensure that the regrind is free from impurities and that proper pre-drying of the regrind has been carried out. Blends of regrind and virgin material are possible in the ratio of 20:80. Regrind should not be used in applications where impact performance and/or agency compliance are required.

Note

Further information on the processing of engineering thermoplastics can be found in SABIC Innovative Plastics brochures

- Injection Molding Mini Guide
- Engineering Thermoplastics in the Extrusion Industry via sabic-ip.com

7. Secondary operations

Although most Lexan* resin parts are molded as finished components, the design and ultimate use of certain parts may require machining, assembly or finishing operations. Lexan resin makes a wide variety of secondary operations available to the design engineer.

7.1 Welding

Welding is a commonly used permanent assembly technique for engineering thermoplastics. Lexan parts can be welded using different processes. Selecting the right process depends on the size, shape and function of the part.

- Hot Plate welding allows excellent weld strengths to be achieved at temperatures of 260°C-300°C/500°F-572°F
- Friction welding can be applied, using either the vibration, orbital or rotation method
- Ultrasonic welding is commonly used, in particular for mobile telephone components. Welding amplitudes with 20 kHz ultrasonic processes should be in the range of 25 - 40 µm (0-peak)
- Induction welding

7.2 Adhesives

Lexan resin parts can be bonded to other plastics, glass, aluminum, brass, steel, wood and other materials. A wide variety of adhesives can be used, sometimes with the addition of a suitable primer (see table 4). In general, Lexan resin parts can be easily solvent bonded to parts made from Lexan, Cycolac* ABS or Cycoloy* PC/ABS alloy with Methyl Ethyl Ketone (MEK) or in mixtures of MEK with Cyclohexanone, ideally 50:50.

Cleaning parts

Thorough cleaning of Lexan resin parts before bonding is essential in order to avoid part failure. All oil, grease, paint, mold releases, rust oxides, etc., must be removed by washing with solvents which are compatible with Lexan resin. These solvents include isopropyl alcohol, heptane or a light solution of non-alkaline detergents. Bond strength is further improved by sanding, sand blasting or vapour blasting the bonding surfaces.

■ Table 4

Compatibility of adhesives with Lexan resin

	Epoxy 2K	PUR 1K	PUR 2K	PUR hot melt reactive	MS polymer	Silicone 1K	Silicone 2K	Acrylic 2K	Cyano-acrylate
primer	no	yes	no	no	no	yes/no	no	no	no
aggressive	at high t°	no	no	no	no	alkoxy	no	yes	yes

7. Secondary operations

7.3 Mechanical assembly

Mechanical assembly techniques are widely used with Lexan* resin parts. To achieve optimum results, mechanical fasteners should be kept free from oil and grease. Depending on the type of fastener, a permanent stress or deformation is applied locally. Clamp forces should be controlled or distributed over a large surface area. This is in order to decrease local stresses in the part after assembly and to minimize the risk of loosening the fasteners through creep and relaxation. Notches in the design as well as notches resulting from mechanical fasteners should also be avoided.

Recommended assembly techniques

- Thread-forming screws rather than thread cutting screws are recommended. Screws with a maximum flank angle of 30° are preferred for minimal radial stresses
- Inserts which leave low residual stresses can be used. Installation by heat or ultrasound are the preferred techniques. Press and expansion inserts produce high hoop stresses in bosses and should therefore be used with caution
- Snap fit assembly
- Rivets
- Staking

7.4 Painting

A wide variety of colors and textures can be applied to Lexan resin using commercially available organic paints and conventional application processes. Painting is an economical means of enhancing aesthetics and providing color uniformity.

Pre-treatment

- Handwashing the part with cleaning agents based on alcohol or aliphatic hydrocarbons or
- Powerwashing the part with cleaning agents based on detergents dissolved in water. These detergents can be either acidic by nature, (pH 3 - 4), or neutral, (pH 8 - 9). Alkaline-based detergents (pH >11) should be avoided.

Paint selection

Paint selection is determined by the desired decorative effect, specific functional needs and the application technique to be applied. A variety of conventional and waterborne paints can be successfully applied to Lexan resin. Generic types include

- Acrylic
- Epoxy
- Polyester
- Polysiloxane
- Polyurethane

Special coatings

- A range of siloxane-based coatings with inherent glass-like optical properties have been developed to provide Lexan® resin transparent parts with optimum chemical and scratch resistance and UV protection. These special coatings can be easily applied by dip coating, flow coating or by spraying.
- Acrylic-based coatings can be used in applications such as compact discs where only UV protection and moderate scratch resistance is required
- Coatings can be used to help minimize color degradation
- Conductive coatings offer shielding against radio frequency interference (RFI) or electromagnetic interference (EMI)

Paint solvents

It is important that solvent formulations are carefully considered when selecting a paint for use with amorphous resins such as Lexan resin. It should be stressed that it can be difficult to achieve an ideal match between solvent and substrate.

Although it is generally difficult to give rules for balancing solvent mixtures, there are some basic guidelines. For example, strong solvent action can be balanced with a non-dissolving liquid like butanol or dipentene. Solvents with strong embrittlement effects, on the other hand, can be balanced by adding stronger dissolving solvents. It should be noted that lower boiling point solvents cause embrittlement effects more quickly.

The occurrence of stress cracking is a result of solvent action on the one hand and stresses in the part on the other. The level of stress in the part should be ideally below 5 MPa. This is achieved through optimal part and tool design and proper molding procedures. In general, if stress levels are above 10 MPa, painting will become critical. In case of doubt, Lexan resin parts should be tested using a mixture of toluene and n-propanol or propylene-carbonate.

7. Secondary operations

7.5 Metalization

Properties usually associated with metals such as reflectivity, abrasion resistance, electrical conductivity and decorative surfaces can be added to plastics through metalization. Three of the more commonly applied metalization techniques are discussed here.

Vacuum metalization

Vacuum metalization through Physical Vapour Deposition involves the depositing of an evaporated metal, mostly aluminum, on a substrate. To achieve evaporation, the pure metal is heated in a deep vacuum. To ensure a good result when using this method with Lexan* resin, a glow discharge pre-treatment is highly recommended.

After vacuum metalization, the aluminum must be protected against environmental influences. This is because of the ultra-thin layer thickness combined with the reactive nature of aluminum to humidity. Most commonly this protection is provided through the application of a Plasil/Glipoxan top layer, (a silicone-based monomer layer which is applied in the vacuum), or a clear coat top layer.

In general, unreinforced Lexan resin does not require a basecoat or lacquer primer layer before metalization because of the good surface quality of Lexan parts after molding. However, in certain cases, application of a basecoat is recommended to enhance reflectivity, in particular where a glass-filled Lexan resin material has been specified.

In most cases a surface activation pre-treatment is required. Cleaning with a cloth or solvents is not recommended because of the sensitivity to scratches that can be seen after metalization. The best method is to keep the moldings clean and to metallise the parts as soon as possible after molding, or to store them in clean containers.

Plating

This can be done by two methods. In the first, electro plating, current is used to effect an electrolytic deposition of metals derived from a dissolved metal salt. Most frequently used metals include chrome, nickel or gold.

The second method, electroless plating, is executed without the addition of current to the galvanic process. Electroless plating can be further divided into non-selective (double-sided) and selective (single-sided) plating.

- For non-selective or all-over electroless plating, a pre-etch is generally required with Lexan* resin
- Selective electroless plating starts with the masking of those areas of the part which must remain metal-free A catalytic lacquer is then applied to seed the exposed surface to initiate the deposition of metal after immersion in the metal salt solution
- If only EMI shielding is required, an electroless copper layer of 1 - 2 μm is applied with a finish of electroless nickel

Hot foil stamping

In this dry metalization technique, the metal foil is impressed on the plastic surface with a heated die or rubber roll. Standard foils are available for use with Lexan resin parts, but it is recommended to test each grade and new application for compatibility and melting point.

7.6 Laser marking

The laser marking of thermoplastics is a complex process. The differing demands of applications, together with a diverse range of materials, pigments and additives, as well as the equipment itself, provide a large number of variables. Through its advanced research and development programme, SABIC Innovative Plastics has gained valuable insight into the thermal, optical, mechanical and chemical processes which take place during laser marking. An important result of this has been the development of a broad tailor-made range of materials using proprietary combinations of pigments and additives. These include Lexan resin grades 121R and 141R which provide light on dark contrast laser marking.

Note

General information on Secondary Operations like painting and metalization of engineering thermoplastics can be found in the following SABIC Innovative Plastics brochures

- Assembly Guide
- Design Guide
- Painting Guide
- Metalization Guide via sabic-ip.com





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