

SABIC
Innovative
Plastics™

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Ultem* and Siltem* resins



Products and markets guide

Sharing our futures



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1. Introduction

Ultem[®] polyetherimide and
Siltem[®] polyetherimide-siloxane resins
Are you struggling to find a solution to get your application
to work? Is it difficult for you to find the right material,
application design and production process?

As a leading supplier of a wide variety of high-performance
resins, film and sheet, SABIC Innovative Plastics' business serves
customers around the world. We back our portfolio of high-
quality materials with advanced technical support to assist
in providing value-added solutions across a wide variety of
industries. Our list of services is long, encompassing most
aspects of application development from design reviews,
prototyping and testing, to thermoforming, injection molding,
extrusion, and in-mold decoration. We complement these
services further with local hands-on support.

Plus, world-class research talent at SABIC Innovative Plastics' four
corporate research centers is hard at work to help advance new
product and process technologies that will help to address the
challenges of the future.

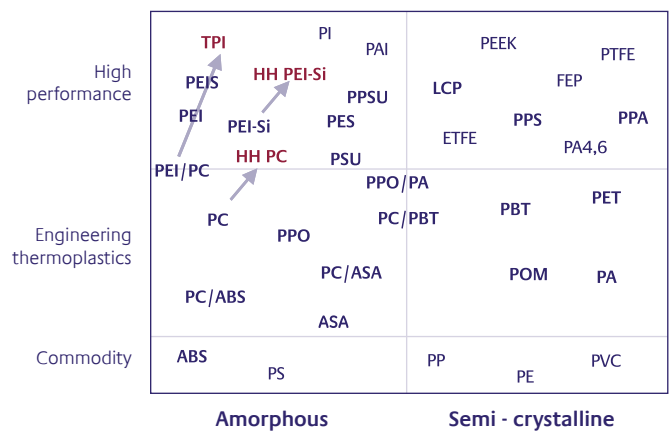


Figure 1 Overview of various polymers that are available on the market today.

SABIC Innovative Plastics materials
New products from SABIC Innovative Plastics.



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1. Ultem*, Extem* and Siltem* resins

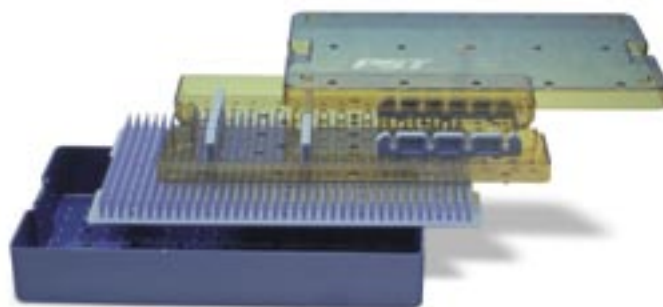
1.1. Ultem polyetherimide resin

SABIC Innovative Plastics' Ultem polyetherimide [PEI] resin is an amorphous, high-performance polymer that combines excellent thermal properties, exceptional dimensional stability, inherent flame retardancy, and good chemical resistance.

Also, unlike semi-crystalline materials, Ultem resin offers a high glass transition temperature (T_g), enabling it to deliver outstanding performance properties even at high temperatures.

This combination of properties enables Ultem resin to offer new options for replacing metals, thermosets and ceramic materials in your application design. Plus, the Ultem portfolio includes a variety of grades to provide the versatile balance of performance properties that you need. General purpose Ultem grades are based on Ultem 1000 and 1010 resins. Key properties of the products derived from these resins may include

- Excellent long-term heat resistance with a relative thermal index (RTI, UL 746B) of 170°C [338°F] for some unfilled grades, and up to 180°C [356°F] for some reinforced grades
- Good short-term heat resistance due to a T_g temperature of 217°C [423°F]
- Inherent flame resistance with low smoke evolution and low smoke toxicity
- Excellent dimensional stability (low creep sensitivity and low, uniform coefficient of thermal expansion) and highly reproducible part-to-part dimensions
- Exceptional strength and modulus, even at elevated temperatures
- Good resistance to a broad range of chemicals, such as automotive fluids, fully halogenated hydrocarbons, alcohols, and aqueous solutions
- Stable dielectric constant and dissipation factor over a wide range of temperatures and frequencies
- Transparency to visible light, infrared light, and microwave radiation
- Ability to comply with FDA, EFSA and other national food contact regulations and various potable water standards
- Intended for medical compliance to USP Class VI and ISO 10993 for several grades
- Ability to comply to WEEE/RoHS and various ECO labels for most grades
- Compatible with vacuum metallization and selected galvanic/plating processes
- Outstanding processability on conventional process equipment
- A transparent amber base color, but available in a wide range of opaque and transparent colors. New colors can be matched on request



Ultem® CRS5001 and CRS5011 resins are the Ultem grades most useful to choose for applications needing improved chemical resistance and increased glass transition temperatures (Tg) of 227°C [440°F]. These materials have not been listed for food contact or medical applications that require ISO10993 and USP compliance.

In 2002, XH6050 resin was added to the Ultem portfolio, where it now offers elevated heat resistance. It is a particularly suitable thermoplastic material for directly metallized reflectors used in high heat lighting applications. XH6050 resin is characterized by a transparent amber brown color, and delivers a Tg temperature of 247°C [476°F]. The material is FDA and European EFSA listed. It has not been listed for medical applications that require ISO10993 and USP compliance.

1.2. Extem® thermoplastic polyimide resin

In November 2006 SABIC Innovative Plastics proudly announced the new Extem resin brand in its High Performance Polymers portfolio. The Extem resin family consists of an exciting new class of thermoplastic Polyimide polymers (TPIs). These materials allow for an unmatched combination of extreme high heat, dimension stability and chemical resistance in a meltprocessable, fully recyclable, amorphous resin. Various unfilled grades, blends and a filled portfolio are commercially available.

1.3. Siltem® polyetherimide-siloxane copolymer resin

Siltem resins are amorphous, materials that combine the high-heat resistance of Ultem PEI resin with the flexibility of silicone elastomers. They have a transparent brown base color.

The materials' flexibility make them an excellent choice for both primary and secondary isolation in wire and cable applications. The material can also be used in injection molding, profile extrusion and blowmolding.

Siltem resins are characterized by

- Excellent thermal properties, with a thermal index of 125°C [257°F].
- New products STM1600 and STM1700 are expected to have a thermal index of up to 150°C [302°F]
- Inherent flame resistance due to a high LOI of 48%
- Low smoke density and toxicity
- Neutral pH and low corrosivity of combustion gases
- Halogen free formulation
- Excellent radiation resistance
- Excellent electrical properties
- Flexibility and a soft texture
- Easy processing on conventional wire and cable extruders
- Colorable with Siltem resin based color masterbatches



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2. Markets and applications

2.1 Food service

The design flexibility and outstanding performance qualities of Ultem® resins enable the manufacture of a wide variety of high-quality, reusable food service applications that may be recycled after their service life. Representative applications include food trays, soup mugs, steam insert pans, gastronorm containers, cloches, microwavable bowls, ovenware, cooking utensils, and reusable airline casseroles. The excellent hydrolytic resistance of Ultem resins makes them an excellent material for hot water contact components in coffee-and vending-machines.

Ultem resins for food service applications may offer

- Temperature resistance up to 220°C [428°F] for hot air ovens
- Excellent infrared and microwave transparency for fast reheating of food
- Proven property retention despite exposure to detergents used in industrial washing machines
- Excellent stain resistance, even against stain-prone products like tomato ketchup, carrots and mustard
- Resistance against most cooking oils and greases
- Compliance with FDA, NSF, EFSA, JHOSPA and other national food contact regulations
- Long-term hydrolytic stability
- Excellent processability, allowing complex designs and low residual stresses
- Practical level of impact resistance, from subzero to 220°C [428°F].
- Cold touch compared to parts made from metal and ceramic
- Ultem ATX resin series offer superior impact behavior and intermediate thermal performance
- A wide range of food-contact-compliant opaque and transparent colors is available and new colors can be matched on request



2. Markets and applications

2.2 Healthcare

Ultem® resins are an excellent material of choice for durable healthcare applications. They can provide outstanding performance for reusable medical devices like sterilization trays, stopcocks, dentist devices, surgical instruments, animal cages, surgical lighting components, and laboratory equipment like pipettes and petri dishes.

Ultem resins for healthcare applications may offer

- Compliance with ISO 10993, FDA, and USP Class VI regulations
- Ability to withstand multiple cleaning cycles for various sterilization methods, including steam autoclaving, chemoclaving, EtO gas, gamma radiation, and dry heat
- Excellent chemical resistance against most lipids, detergents and disinfectants
- Excellent mechanical performance, allowing thin wall designs
- Available in opaque and transparent colors. Newcolors can be matched on request.



INSORB 20 skin subcuticular stapler using SABIC Innovative Plastics' Ultem resins 1000F and 2200F. photo courtesy of Incisive Surgical, Inc

2.3 Transportation

The excellent balance of flame retardancy, low smoke emission, and low smoke toxicity of Ultem resins make them excellent material candidates for aerospace and aircraft applications. They also offer superb specific strength and stiffness, enabling thinner wall designs that may contribute to lower part weights and reduced fuel consumption.

Ultem resins are found in applications, such as personal service units, oxygen panels and components, ventilation system components, connectors, cable ducts, latches, hinges, food tray containers, door handles, and interior cladding parts.

For semi-structural component applications, Ultem resins can contribute to intermediate products, such as thermoplastic composites reinforced with glass, carbon or aramid fibers or fabrics; or to sandwich core materials, like foams and honeycombs.

Ultem resins are used in ground transportation applications due in part to their compliance with various norms on flame retardance and smoke toxicity. Select grades can be found in injection molded components, such as seating, lighting trims, waste bins, and ashtrays.

Lastly, Ultem resins may provide an excellent materials solution for profile extruded applications, including trimming, sheets for walls, ceilings and cabin dividers.



Depending on grade, Ultem* resins comply with several regulations in transportation

- Several grades in the Ultem 9000 series offer full compliance with industry regulations for aircraft interiors, including ABD 0031, BMS, FAR25.853, OSU 55/55 heat release tests, and NBS smoke density tests
- The Ultem 1000, 2000 and CRS 5000 resin series offer compliance with aircraft industry regulations such as ABD 0031, FAR25.853, OSU 100/100 heat release tests, and NBS smoke density tests
- Select Ultem grades comply with F1, I2, and M2 classifications, according to the French standard for transportation NF F 16-101



Goodrich made this Personal Service Unit using Ultem resin.

The material also may offer the transportation industry many other benefits, including

- Very low smoke and toxic gas emission
- Low density and high specific stiffness and strength, often allowing lower weight solutions compared to metal and many other plastics
- Excellent processibility often allowing thinner wall constructions and reduced weight
- Chemical resistance against various fuels and fluids
- Ultem CRS 5000 resin series delivers improved resistance against hydraulic aircraft fluids, such as Skydrol
- Availability in various colors. New colors can be matched on request
- Ability to manufacture Ultem-resin-based thermoplastic composites, which may allow increased productivity in component manufacturing over traditional composite materials
- Ability to manufacture Ultem honeycomb or foam cores for tough, lightweight sandwich panels

2.4 Automotive

Ultem resins provide automotive manufacturers with a high performance, cost-effective alternative to metal that is strong enough to replace steel in some applications and light enough to replace aluminum in others. For applications like transmission components, throttle bodies, ignition components, sensors and thermostat housings, Ultem resins may offer

- Heat resistance up to 220°C [428°F], and RTI up to 180°C [356°F]
- Chemical resistance against automotive fuels, fluids and oils
- Excellent dimensional stability with low creep sensitivity, and low uniform coefficient of thermal expansion
- Excellent strength and stiffness
- Excellent processibility with very tight molding tolerances
- Elimination of secondary operations like machining and anodizing



2. Markets and applications

2.5 Lighting

The Ultem® resin product family may be an excellent material for lighting applications in the automotive and transportation industries, as well as in domestic, office, street and industrial applications. Ultem resins' high-heat stability helps them deliver outstanding performance in certain reflectors, bezels, bulb sockets, brackets, and housings. Potential benefits include

- Heat resistance up to 220°C [428°F] for medium term exposures, and long term RTI of 170°C to 180°C [338°F to 356°F]
- Excellent molded surface quality, allowing direct metallization without the need for base-coats or primers
- Excellent dimensional stability with a low, uniform coefficient of thermal expansion, and good modulus at high operating temperatures. This can allow automotive reflectors made from Ultem resin to comply with ECE regulation on beam pattern, and beam shift regulations
- Competitive system cost versus conventional metal or thermoset materials
- Design and processing flexibility, which allows efficient and complex reflectors
- Transparency to near-infrared light, allowing heat dissipation
- Weight savings may result from thinner-walled reflectors than those made with thermoset materials or metals
- Easier recyclability compared to metals or thermosets
- Improved cleanliness from Ultem 1010K, may reduce the need for mold cleaning
- Improved heat resistance from Ultem XH6050 resin may enable high temperature reflectors for projector lamps and fog lights
- For bulb sockets and brackets, glass-filled materials like Ultem 2310 resin may provide enhanced modulus and strength, plus lower outgassing versus PPA, PPS, and LCs
- Good choice for reflectors with dichroic coating without primer



2.6 Telecom and Molded Interconnect Devices (MIDs)

Its unique plating capabilities make Ultem® resin an excellent material choice for telecom and MID applications. Ultem resin allows the combination of electrical functions with the advantages of injection molded, three-dimensional mechanical components and may be useful in electrical control units, computer components, mobile phone internal antennae, RF-duplexers or microfilters, satellite antennas and fiber optic connectors.

Ultem resins may offer telecom the following benefits

- Unique plating results via a chemical bonding with copper, which may provide long-term, reliable adhesion of functional metal layers to an Ultem resin substrate
- Enhanced productivity through component integration, and streamlined assembly options such as snap-fit parts
- Stable dielectric constant and dissipation factor over a wide range of temperatures and frequencies
- Substantially lower CTE with Ultem 3452 and ATX3562R resins
- Excellent dimensional stability, with low creep sensitivity and low uniform coefficient of thermal expansion (CTE). Filled grades may match the CTE of various metals
- Consistent processibility and reproducibility of parts
- EPR grades offer enhanced flow and platability compared to filled Ultem grades
- High heat resistance up to 220°C [428°F]



2.7 Electrical

Ultem resin may be an excellent material choice for today's demanding electrical applications, including connectors, MCB components like housings, shafts and levers, hard disk drive internals, FOUP's, BiTS, PCB's, MCCB internals, Plenum devices, LCD projector internals, fuel cell components and many other applications.

Potential benefits may include

- Temperature resistance up to 220°C [428°F] RTI according to UL746B, and up to 180°C [356°F] for ball pressure tests at 125°C [257°F]
- Inherent flame retardancy, as well as UL94 V0 and 5VA listings for many grades
- Passing UL2043 for Plenum space applications
- Excellent dimensional stability, with low creep sensitivity and low, uniform CTE
- Compatibility with UL file E75735 for use as insulation materials in transformers and motors of up to 600 V
- Passes glow wire test at 960°C (1-3.2 mm) and GWIT 850°C at 1.6 mm according to EN 60695
- Low water absorption
- Compliance to WEEE/RoHS and various ECO labels
- UL94 F1 listing for all colors at 1.5 mm is available from Ultem 2000 grades. GF ATX grades are listed F1 for black materials
- Higher heat with Ultem XH6050 resin for connectors



2. Markets and applications

2.8 HVAC and fluid handling

Ultem* resins can offer an good balance of properties for applications where heat and fluids combine. Examples include water tap cartridges, water-pump impellers, expansion valves, hot water reservoirs, and heat exchange systems. Ultem resins are excellent candidates because they may offer

- Long-term heat resistance, RTI of 180°C [356°F]
- Excellent weld line strength needed to resist high temperatures and dynamic pressures
- Potable water approval up to 90°C [194°F]. Various grades and colors have KTW, WRAS and ACS approvals
- Excellent mechanical properties under hot water conditions
- Good hydrolytic stability
- Excellent dimensional stability (low creep sensitivity and low, uniform coefficient of thermal expansion.

2.9 Extrusion

Ultem resin maintains its outstanding properties when extruded into film, sheet, profiles, rods, slabs, foam, fiber or wires. Ultem film and sheet is available in different grades and gauges from SABIC Innovative Plastic's Specialty Film and Sheet business.

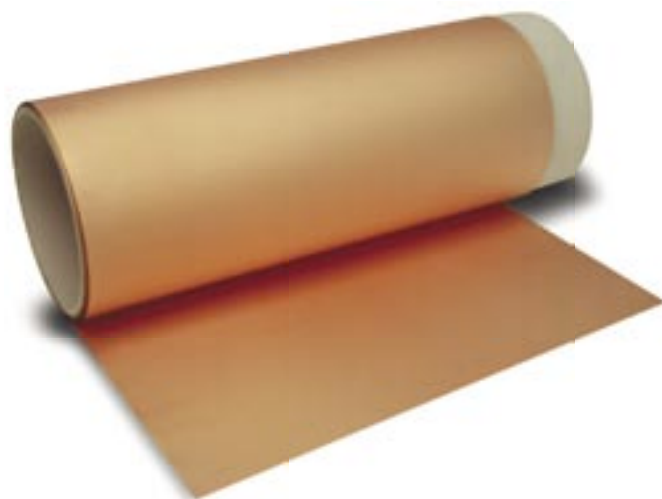
Stock shapes (rod's and slabs) made from Ultem resin are excellent alternatives for applications where building an injection molding tool is not economical. Shaping can be done through various machining techniques. Machining of stock shapes is also a possible alternative to making prototypes for performance testing.

Siltem* resins are flexible copolymers comprising Ultem resin hard blocks and siloxane flexible soft blocks. They may be a good choice for wire and cable applications requiring a halogen free flame retardant material.

Siltem resins are found back in both primary and secondary isolation. Cables may be suitable for use in transportation, military, marine and nuclear applications. Siltem resins are also used as flame retardant additives to other thermoplastics used in wire and cable production.

Siltem resins may provide

- Thermal index (20000 hrs) of 125°C [257°F] and for new grades possibly up to 150°C [302°F]
- Excellent flame retardancy (LOI of 48%)
- Low smoke density and toxicity
- Halogen free
- Low corrosivity of combustion gases
- Flexible, shore D hardness of 69
- Excellent electrical properties
- Excellent extrudability on conventional wire extrusion lines
- Material is self colorable



3. Product selection

3.1 Product Description

3.1.1 Ultem® 1000 resin series

- General purpose
- Unreinforced
- Global food contact compliant grades available
- USP Class VI and ISO10993 compliant grades available
- Various viscosity grades available
- Processable via injection molding, extrusion and blow molding

3.1.2 Ultem 2000 resin series

- Glass fiber reinforced, 10% to 40% fill
- Greater rigidity and strength versus unfilled Ultem resins
- Lower coefficient of thermal expansion over unfilled Ultem resins
- Low viscosity grades available
- Milled glass fiber-reinforced grades are available, offering more isotropic behavior
- EPR series for strongly improved flow over standard Ultem 2000 filled products
- Processable via injection molding and extrusion

3.1.3 Ultem 3000 resin series

- Glass- and mineral-filled
- High strength and modulus
- Improved dimensional stability versus Ultem 2000 series

3.1.4 Ultem 4000 resin series

- Improved wear resistance
- Reduced coefficient of friction
- Unreinforced and glass reinforced grades
- Processable via injection molding and extrusion

3.1.5 Ultem CRS 5000 resin series

- Superior chemical resistance over Ultem 1000 resin
- Better resistance against hydraulic aircraft fluids compared to Ultem 1000 resin
- Unreinforced and glass-reinforced grades
- Processable via injection molding, blow molding and extrusion

3.1.6 Ultem XH6050 resin series

- Ultem XH6050 resin has the highest heat resistance of all Ultem grades
- Processable via injection molding, blow molding and extrusion

3.1.7 Ultem 9000 resin series

- Fulfill aircraft industry regulations (ABD, BMS, FAR, OSU and NBS)
- Can be delivered with individual lot certification
- Unreinforced and glass reinforced grades
- Extrusion and injection molding grades

3.1.8 Ultem ATX resin series (polyetherimide blend)

- Intermediate heat performance
- Improved ductility
- Improved flow
- Metallizable without base-coating or lacquer
- Food contact compliant grades available
- Glass fiber and glass/mineral reinforced grades available

3.1.9 Ultem DT resin series transparent ductile blends

- Improved flow
- Improved practical ductility
- Intermediate heat performance
- Transparent



3. Product selection

3.2 Siltem* resins

- Flexible resins which may be useful for primary and secondary isolation of wire and cables
- Halogen free
- Thermal index of 125°C [257°F], pending 150°C [302°C]
- Low corrosivity

3.3 Extem* resins

- Extem UH resin family for
 - Improved heat (short term and continuous use)
 - Improved chemical resistance
- Extem XH family for
 - Improved heat

For further detail please consult the Extem resin brochure

3.4 Ultem* film and sheet

SABIC Innovative Plastics' Specialty Film and Sheet (SF&S) business offers Ultem-resin-based products, including

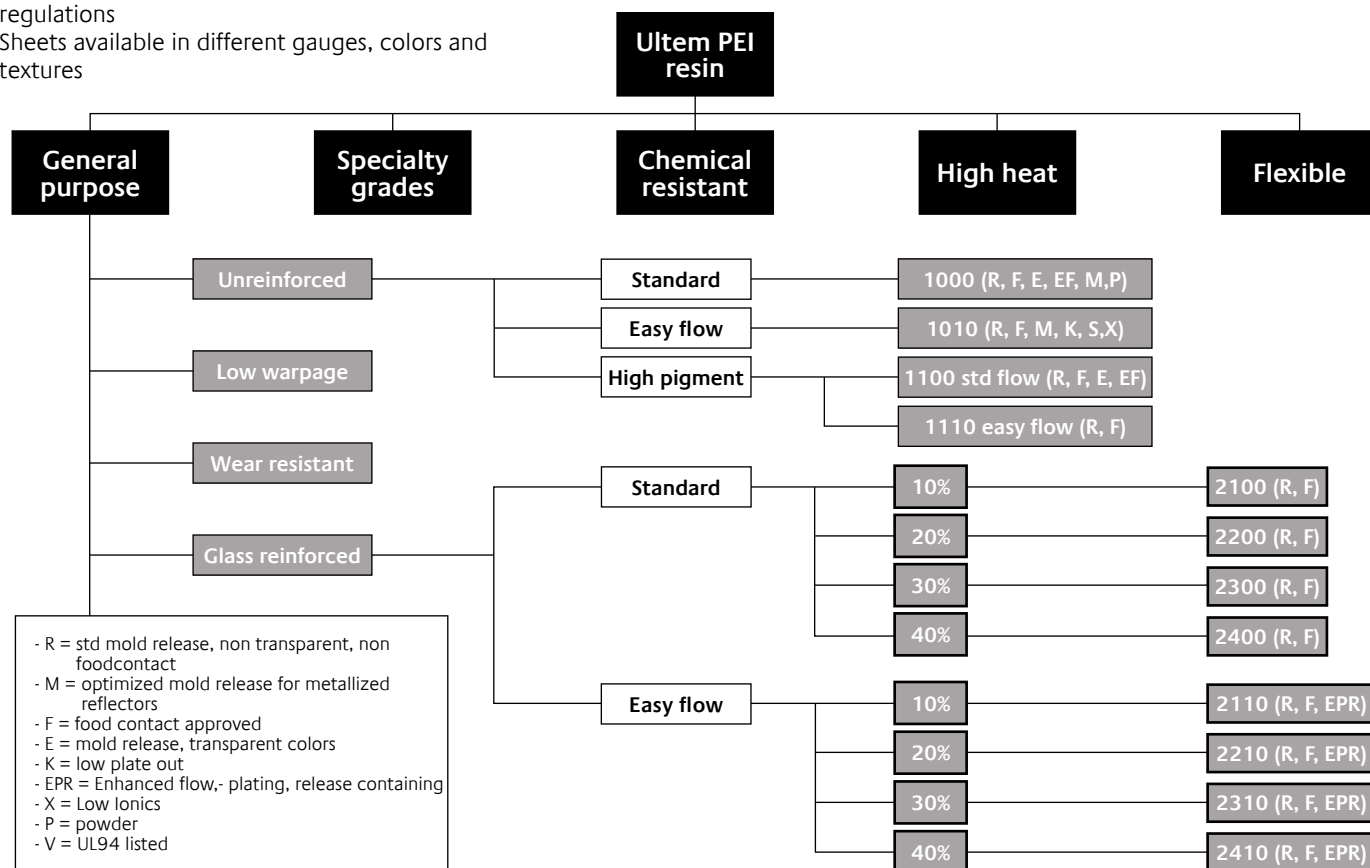
- Ultem 1000B and 5000B film in gauges from 25 to 750 microns. Available in transparent natural and opaque black color
- Ultem WH217 white film in gauges from 25 to 175 microns
- Ultem 1668A sheet which may be suitable for aircraft interiors, passing stringent aircraft regulations
- Ultem R16SG29 sheet which may be suitable for ground transportation, meeting various local regulations
- Sheets available in different gauges, colors and textures

For further details, contact an SF&S representative in your local area

3.5 Ultem specialty compounds from LNP*

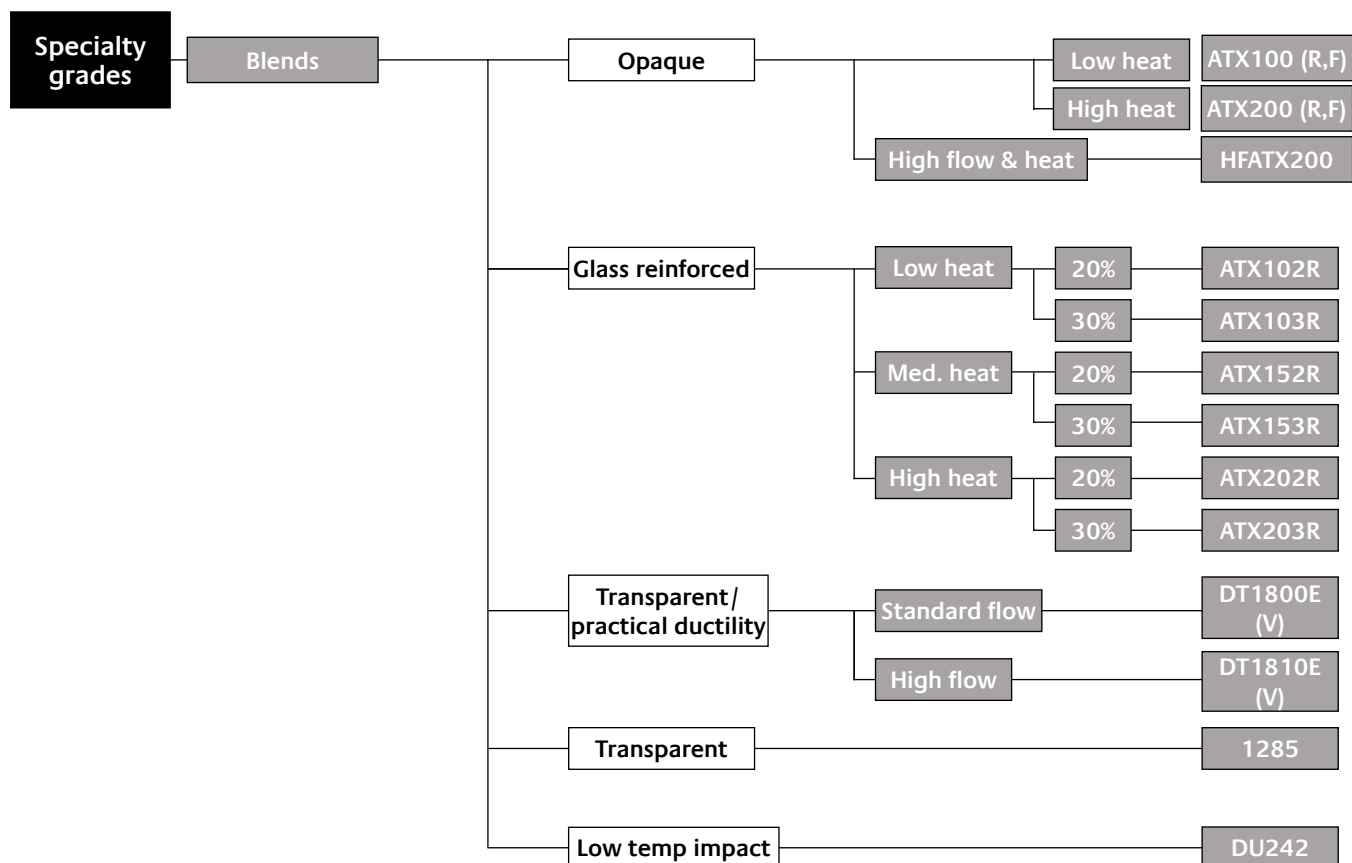
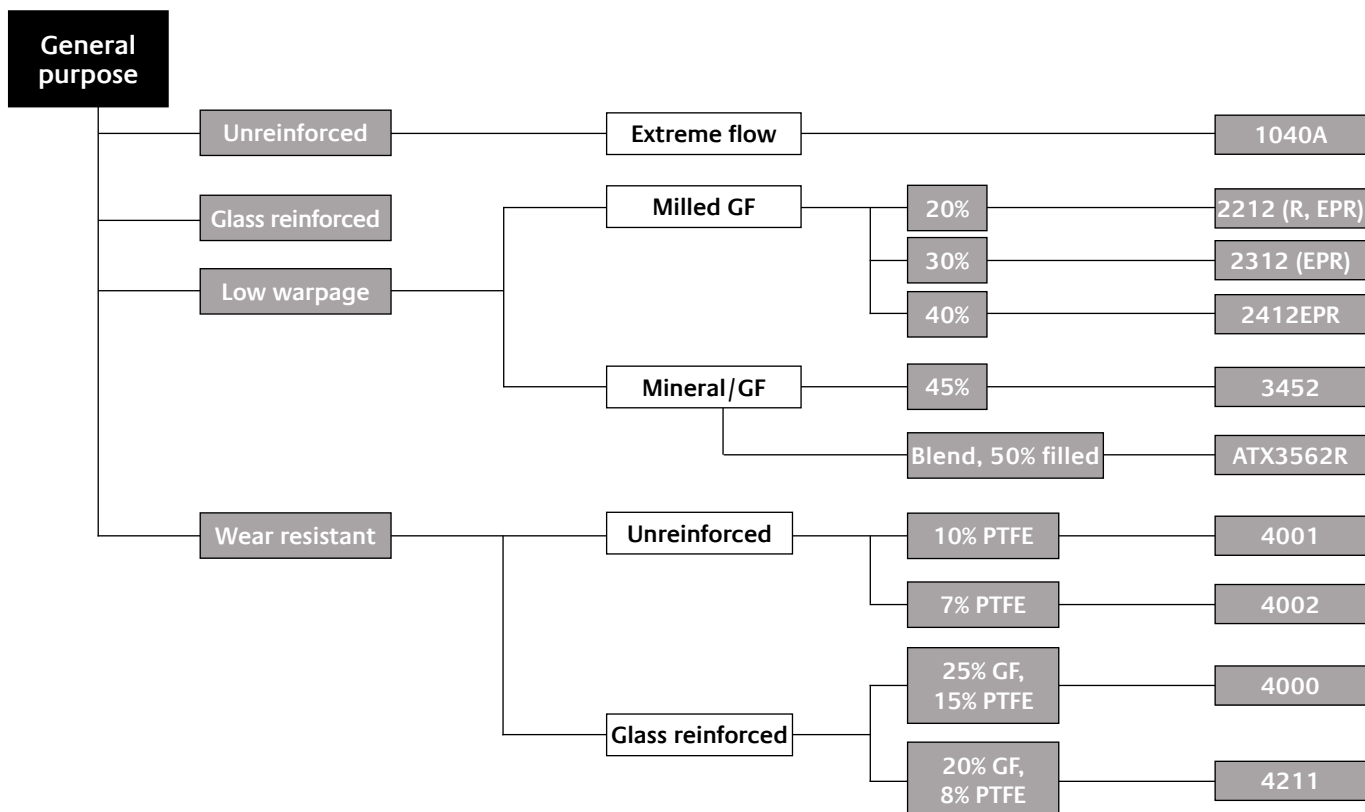
SABIC Innovative Plastics' LNP organization is specialized in adding special features to a wide variety of resins amongst other Ultem resin. Various Ultem resin based compounds are available. Typical features that are achieved are specialty reinforcements like carbon fiber reinforced grades to provide extreme stiffness and strength or electrostatic dissipation in the Thermocomp* and Stat-Kon* product ranges. Also an extensive number of lubricated grades based on Ultem resin are available in the Lubricomp* portfolio.

For further details please consult the LNP literature and representatives

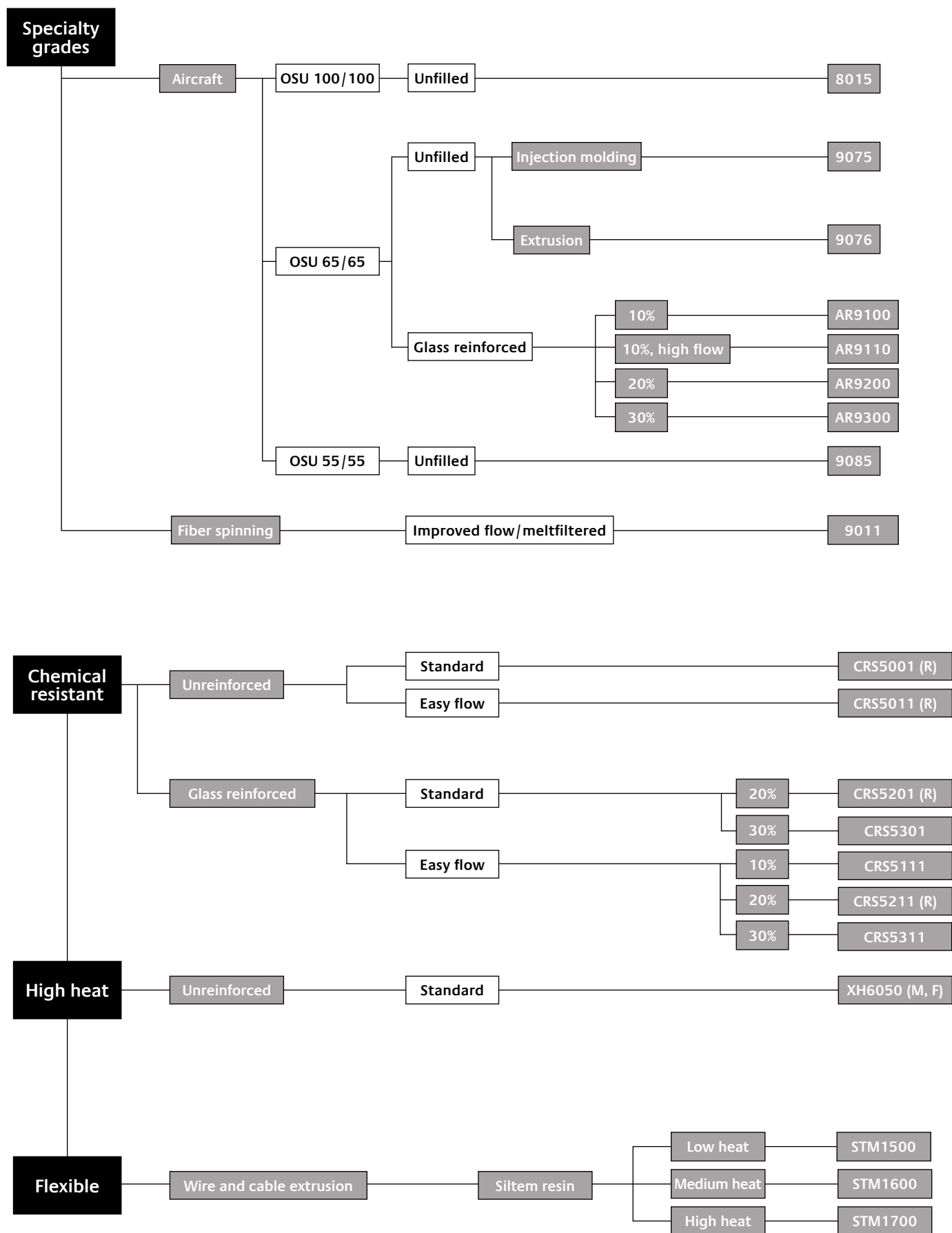


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3. Product selection



4. Properties

4.1 Thermal properties

In recognition of its inherent thermal stability, UL has granted Ultem® 1000 resin a relative thermal index (RTI) of 170°C [338°F] according to UL746B.

The polymer's high glass transition temperature (Tg) of 217°C [423°F] coupled with its high heat deflection temperature (HDT/Ae 1.80 MPa) of 190°C [374°F] contributes to its excellent retention of physical properties at elevated temperatures. For glass-filled Ultem 2300 resin, and glass mineral filled Ultem 3452 resin, the RTI rating reaches 180°C [356°F].

For short term higher heat performance, Ultem XH6050 resin provides a Tg of 247°C [477°F], and an HDT/Ae 1.8 MPa of 220°C [428°F].

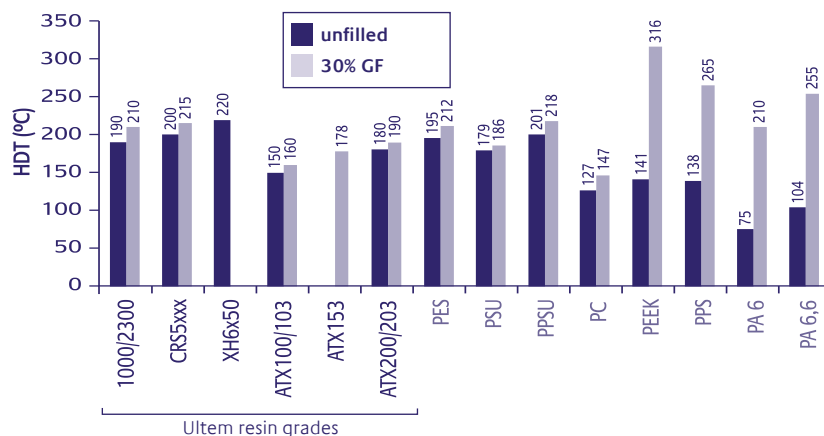


Figure 4.1 Compares the high heat deflection temperature of various Ultem resins with those of other high performance engineering thermoplastics.

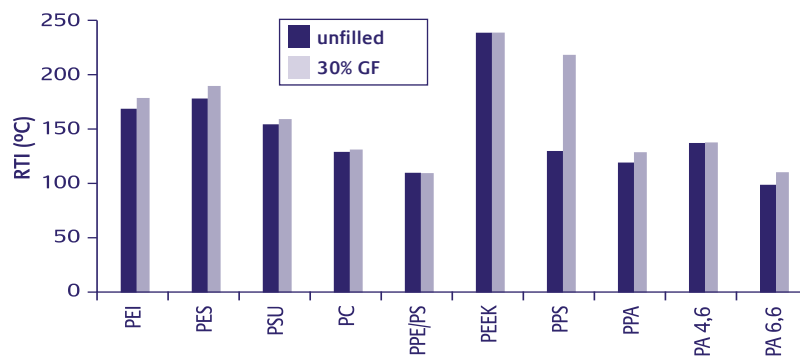
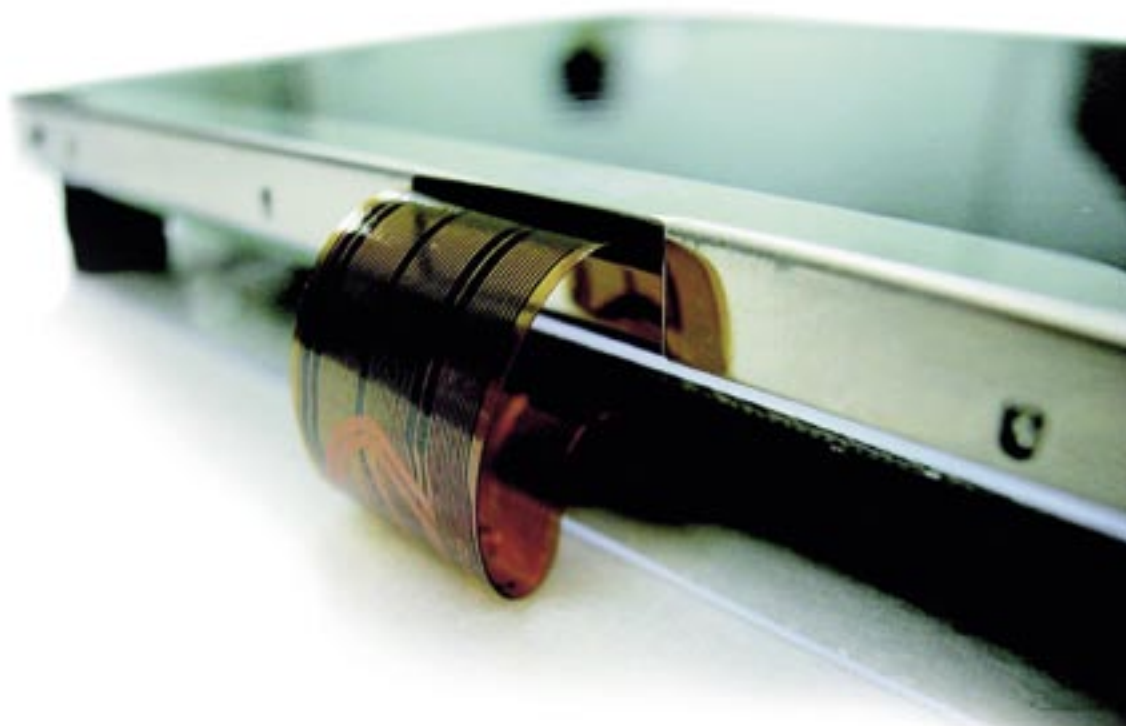


Figure 4.2 Compares the long term RTI performance according to UL746 B of various Ultem resins with those of other high performance engineering thermoplastics.



4. Properties

4.2 Coefficient of thermal expansion

Another important design consideration is the thermal expansion of a material, particularly in applications where plastic parts are mated with metal parts or have metal inserts. Table 4.1 lists the coefficient of thermal expansion (CTE) for the Ultem® resin family, and demonstrates the capability of matching the values of several metals.

Due to their high glass transition temperatures (T_g), Ultem resins maintain their low CTE up to high temperatures. They may therefore be excellent choices when dimensional stability is required at higher temperatures – especially compared to many semi crystalline materials.

Material	CTE fow direction ppm/°C	CTE cross flow direction ppm/°C
Ultem 1000 resin	50	50
Ultem XH6050 resin	50	50
Ultem 2100 resin	26	60
Ultem 2300 resin	20	60
Ultem 2312 resin	23	27
Ultem 2400 resin	15	45
Ultem 3452 resin	17	34
Ultem ATX3562R resin	16	38
PSU	56	56
PSU 10%GF	36	
PPSU	56	56
PC	75	75
Aluminum	20-24**	
Brass	16-18**	
Steel	12-15**	
Zinc	27**	

Table 4.1 Coefficient of linear thermal expansion

4.3 Flammability

Flame resistance

Ultem resins exhibit exceptional flame resistance without the use of additives. For example, in electrical applications, Ultem 1000 resin (unfilled) is rated under UL94 V0 at 0.8 mm for all colors; in natural color grades, it is rated V0 at 1.5-mm, and 5VA at 3.0 mm.

Glass filled Ultem 2300 has been rated V0 at 0.25 mm and 5VA at 1.2 mm. For actual information on all UL-listed grades, see the UL yellow cards. In addition, as shown in figure 4.4, Ultem - and Siltem* grades offer very high limited oxygen indices.

Aircraft industry regulations

Ultem resins are widely used by the aircraft industry due to their ability to enable compliance with industry regulations, and their unique balance of flame retardancy, low heat release, low smoke development, and low toxicity.

OEM spec	Verticle burn FAR 25.853	OSU heat release FAR 25.853	Smoke Ds, 4min ASTM F814/ E662 ABD0031 BSS7238	Toxicity draeger tube ABD0031 BSS7239
Ultem 1000 series	a(60s), Pass	100/100, Pass	<50, Pass	Pass
Ultem 2000 series	a(60s), Pass	100/100, Pass	<50, Pass	Pass
Ultem CRS5000 series	a(60s), Pass	100/100, Pass	<50, Pass	Pass
Ultem 9000 series	a(60s), Pass	55/55, Pass	<50, Pass	Pass

Table 4.2 Aircraft regulation compliance according ABD0031, FAR 25.853, OSU.

ABD0031 contains requirements for smoke, toxicity and FAR 25.853, which classifies materials for flammability. OSU (Ohio State University) calorimeter classifies materials for their heat release characteristics.

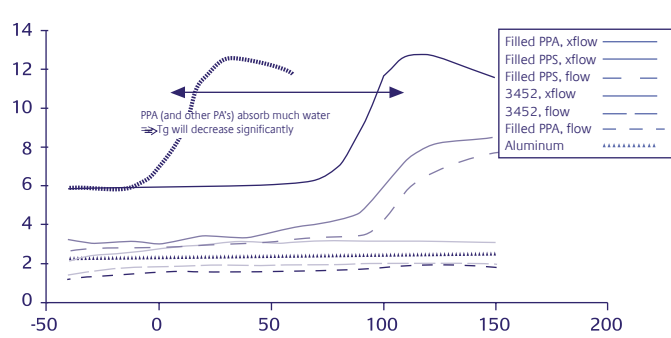


Figure 4.3 CTE of highly filled Ultem resin vs PPA and PPS as function of temperature

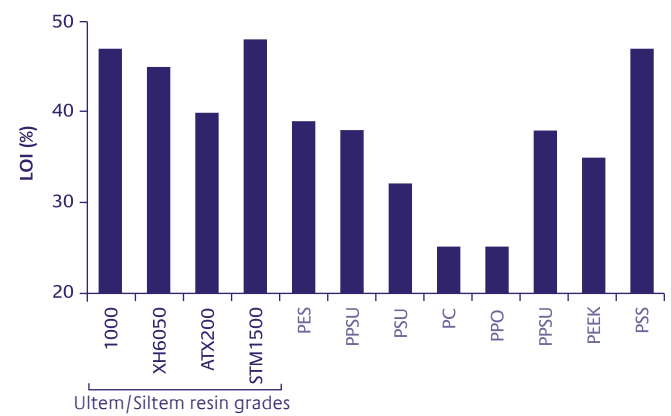


Figure 4.4 Limited oxygen index of various unfilled polymers.



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4.4 Mechanical Properties

Strength

At room temperature, Ultem® resin exhibits strength well beyond that of most engineering thermoplastics, with a tensile stress at yield of 105 MPa (ISO R527), and a flexural strength at yield of 160 MPa (ISO 178). Figure 4.5 demonstrates the higher tensile stress of Ultem 1000 resin compared to other high performance engineering materials.

The outstanding inherent strength of Ultem resin is further enhanced through reinforcement with glass fibers. Even more impressive is the retention of strength at elevated temperatures. At 190°C [374°F], a temperature well beyond the useful range of most other engineering thermoplastics, Ultem resin retains approximately 50 MPa tensile strength (ISO R527), as illustrated in figure 4.6.

Modulus

Another outstanding mechanical property of Ultem resin is its high modulus. The 3300 MPa flexural modulus (ISO 178) of Ultem 1000 resin is one of the highest room temperature moduli of any high performance engineering plastic. In load bearing applications where deflection is a primary consideration, unreinforced Ultem resin provides structural rigidity approaching that of many glass reinforced resins. Ultem resin maintains a high modulus at elevated temperatures, as shown in figure 4.7. For example, at 175°C [347°F], the modulus of Ultem 1000 resin is higher than that of most engineering plastics at room temperature.

Thus, Ultem resin offers designers the opportunity to achieve desired stiffness with few of the sacrifices associated with glass-reinforced materials, such as increased machine and tool wear and decreased flow. Where greater stiffness is required, the glass-reinforced Ultem 2000 resin series or the glass fiber and mineral reinforced Ultem 3000 resin series provide additional performance with flexural moduli as high as 13500 MPa (ISO 178) at room temperature.

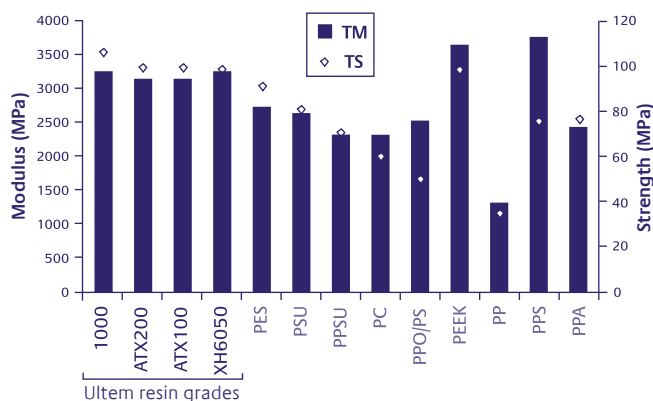


Figure 4.5 Tensile strength and modulus of various materials at 23°C, 5mm/min.

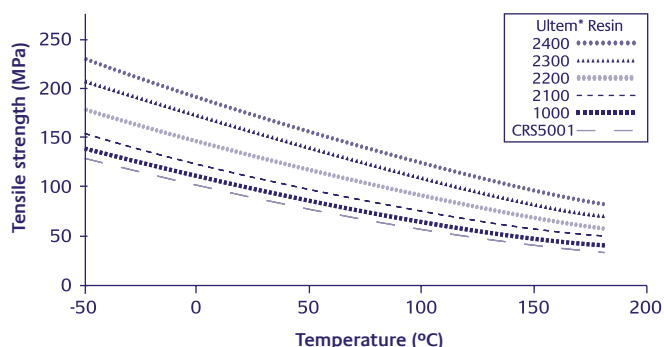


Figure 4.6 Tensile strength as a function of temperature.

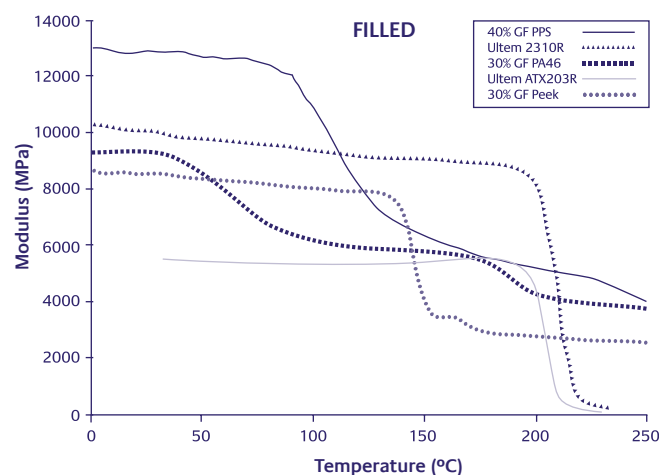


Figure 4.7a Flexural modulus of glass fiber filled Ultem resins versus other glass filled polymers as a function of temperature.

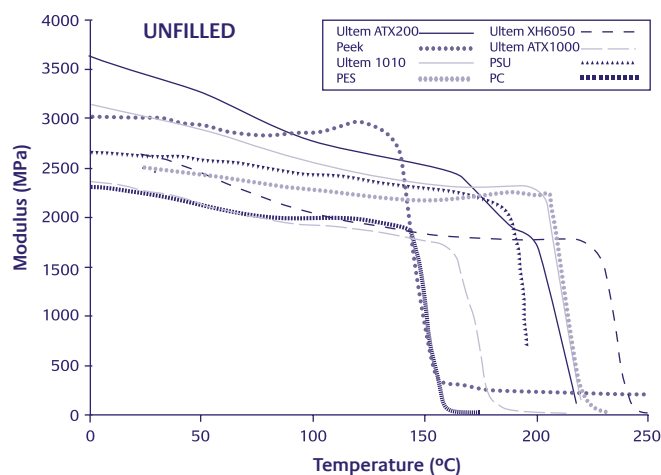


Figure 4.7b Flexural modulus of unfilled Ultem resins versus other thermoplastic resins as a function of temperature.



4. Properties

Ductility

In addition to its unique combination of high strength and modulus, Ultem® resin exhibits good practical ductility. Its tensile elongation at yield affords the freedom to incorporate snap fit designs for ease of assembly. Since Ultem resins display notch sensitivity, adherence to standard design principles is recommended. Stress concentrators such as sharp corners should be minimized to provide the maximum impact strength in molded parts.

Fatigue endurance

Fatigue is an important design consideration for parts subjected to cyclical loading or vibration. In such applications, an uniaxial fatigue diagram (see figure 4.8) 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.

Creep behavior

When considering the mechanical properties of any thermoplastic material, designers must recognize the effects of temperature, stress level and load duration on material performance. Ultem resin displays excellent creep resistance even at temperatures and stress levels which would preclude the use of many other thermoplastics.

4.5 Electrical properties

Ultem resins exhibit excellent electrical properties which remain stable over a wide range of environmental conditions. This stability, together with outstanding thermal and mechanical properties, make Ultem resins excellent candidates for highly demanding electrical and electronic applications.

Relative permittivity

Although either low or high absolute values of the relative permittivity may be desirable depending upon the application, it is also important that the values remain stable over the entire service temperature and/or frequency range.

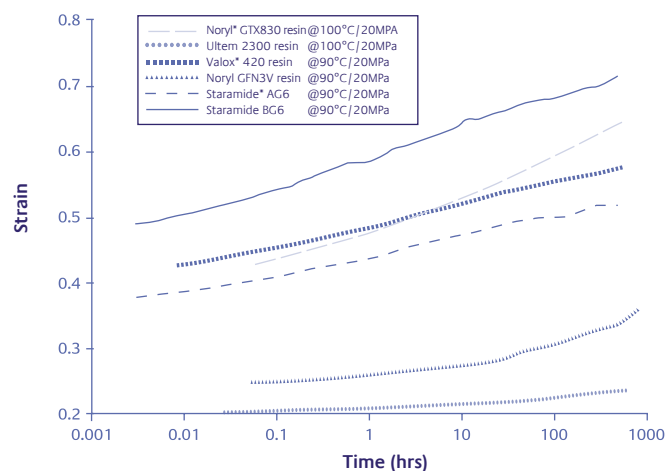


Figure 4.9 Creep strain as function of time of various materials.

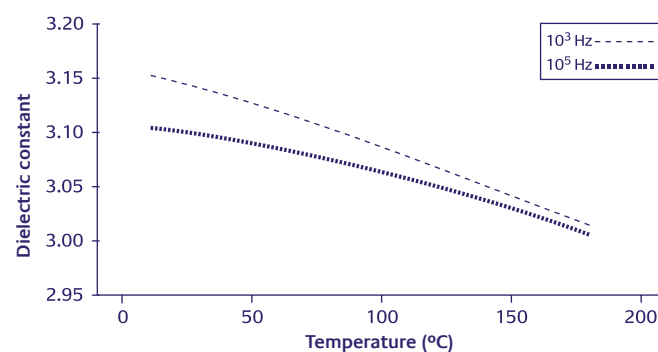


Figure 4.10a Dielectric constant of Ultem 1000 resin vs. temperature at 50% RH.

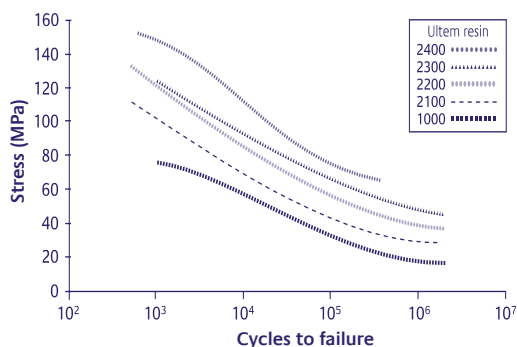


Figure 4.8 Uniaxial fatigue test of Ultem resin at different glass ratios

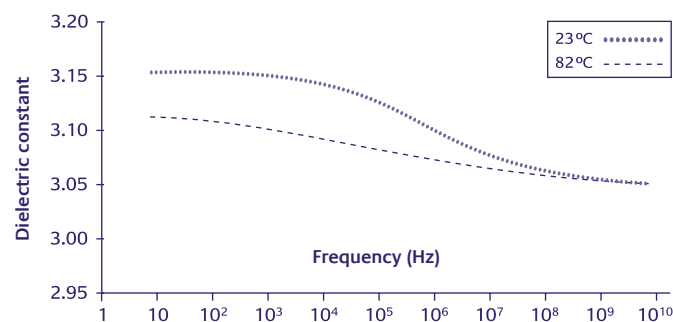


Figure 4.10b Dielectric constant of Ultem 1000 resin vs. frequency at 50% RH.



Dissipation factor

As shown in Figures 4.11, Ultem® 1000 resin exhibits an exceptionally low dissipation factor over a wide range of frequencies, particularly in the kilohertz (10^3 Hz) and gigahertz (10^9 Hz) ranges. In addition, this low dissipation factor remains constant over the resin's entire useful temperature range. This behavior is of prime importance in applications such as computer circuitry and microwave components where the resin provides a minimum loss of electrical energy in the form of heat. The dissipation factor peak around megahertz (10^6 Hz) is caused by moisture in the material and therefore depends on the ambient conditions.

Dielectric strength

An excellent electrical insulator, Ultem resin exhibits a dielectric strength of 25 kV/mm at 1.6 mm (in oil). The effect of thickness on dielectric strength for Ultem 1000 is shown in Figure 4.13.

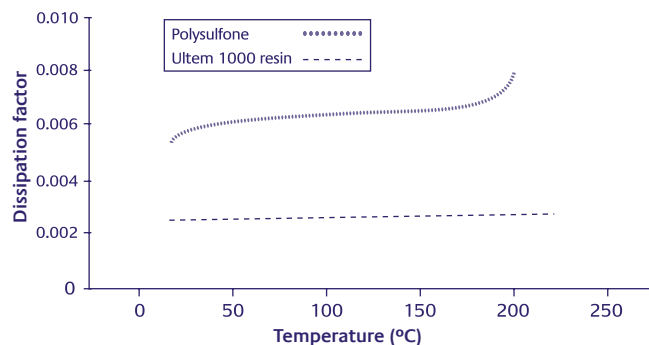
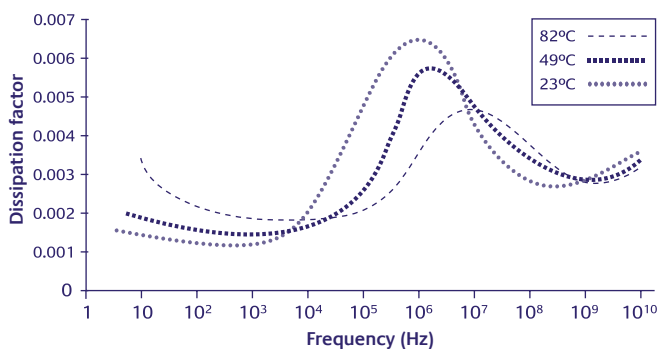


Figure 4.12 Dissipation factor vs. temperature at 2.45×10^9 Hz.



Figures 4.11a Dissipation factor of Ultem 1000 resin vs. frequency at 50%.

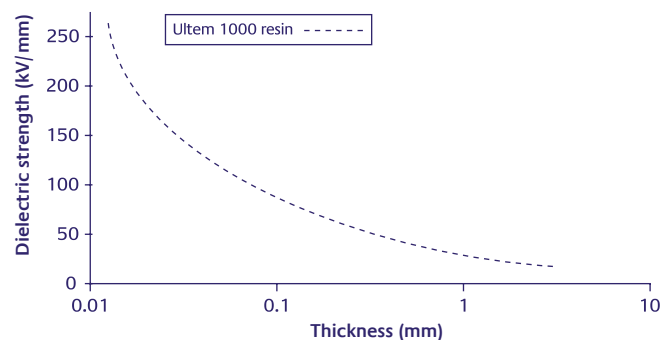
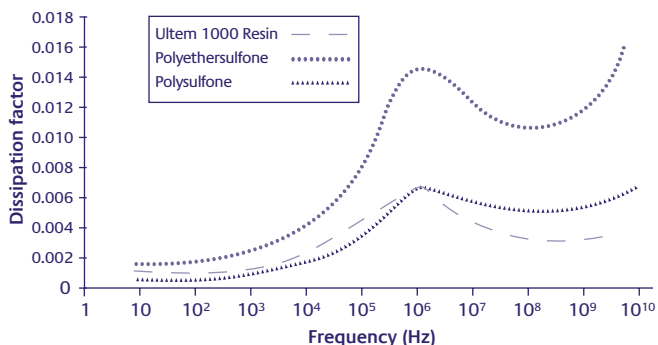


Figure 4.13 Dielectric strength of Ultem 1000 resin versus thickness.



Figures 4.11b Dissipation factor of Ultem 1000 resin vs. frequency at 50% RH and vs. PES and PSU.



4. Properties

4.6 Environmental resistance

Chemical resistance

Unlike other amorphous resins, Ultem* polyetherimide resin demonstrates unusually good resistance to a wide range of chemicals. Table 4.3 lists the performance of Ultem in a variety of common environments. In applications requiring prolonged immersion, finished part performance should always be evaluated on the actual part under actual service conditions.

Ultem resin displays excellent property retention and resistance to environmental stress cracking when exposed to most commercial automotive and aircraft fluids, fully halogenated hydrocarbons, alcohols and weak aqueous solutions. Exposure to partially halogenated hydrocarbons and strong alkaline environments should be avoided.

In an effort to further enhance the inherent chemical resistance of Ultem resin, a chemical resistant Ultem CRS 5000 resin series has been developed. These amorphous materials combine the chemical resistance characteristics often associated with crystalline and specialty materials with the excellent processing characteristics typical of Ultem resins.

Water and moisture absorption

Ultem resins will absorb water and moisture. The magnitude at which this happens is dependent on the environmental conditions. The effect on mechanical performance is small. However for processing the Ultem resins it is recommended to dry the material prior to processing. Also for some secondary operations like soldering and glueing the presence of moisture should be avoided.

Table 4.3 Generic chemical compatibility of Ultem resin vs other SABIC Innovative Plastics' resins.

Reagent	Amorphous materials					Semi-crystalline materials			
	Lexan* resin	Cycloyl* resin	Cyclocac* resin	Noryl* resin	Ultem resin	Xenoy* resin	Valox* resin	Noryl GTX resin	Staramide* / Starflam* resins
Hydrocarbons									
- aliphatic	0/-	0	+	0/-	+	0	+	+	++
- aromatic	-	-	-	-	++	0/-	+	+	++
Halogenated hydrocarbons									
- halogenated, fully	0	0	-	-	+	-	0/-	+	+
- halogenated, partly	-	-	-	-	-	-	-	0	0/-
Alcohols	+	n	+	+	+	+	+	+	0/-
Phenols	-	-	-	-	-	n	-	-	-
Ketones	-	-	-	-	-	-	0/-	0	++
Amines	n	-	n/-	0/-	n	n	n	-	-
Esters	0/-	-	0	+	0/+	-	0/-	+	++
Ethers	-	-	0	0	+	n	+	+	++
Acids									
Acids - inorganic	0/-	0	+	0	0/+	0/+	+	0	-
Acids - organic	0	0	-	0	0/+	0/+	0	0	-
Acids - oxidizing	-	-	-	0	0	0/+	-	0	-
Alkalis	-	0	+	+	-	-	-	+	+
Automotive fluids									
- greases (non-reactive esters)	n	+	+	0/+	+	+	++	+	++
- oils (unsaturated aliphatic mixtures)	n	0/-	0/+	0/+	+	++	++	+	++
- waxes (heavy oils)	n	+	+	0/+	+	+	++	+	++
- petrol	-	-	-	-	+	++	++	+	++
- cooling liquid (glycol)	n	0	0	+	+	++	++	+	++
- brake fluid (heavy alcohol)	n	-	-	+	-	++	+	+	++
Detergents - cleaners	n	0/+	0/+	0/+	+	+	+	++	0/+
Water - hot (<176°F (80°C))	0/-	0/+	0/-	++	+	0	-	0	-

++ very good - found unaffected in its performance with regard to time, temperature and stress according to agency requirements
+ good - found acceptable in normal exposure, long term exposure may result in minor loss of properties, higher temperatures may result in major loss of properties
o fair - found marginal, only for short exposures at lower temperatures or when loss of mechanical properties is not critical
- poor - found unacceptable, will result in failure or severe degradation
n not tested



Hydrolytic stability

Figure 4.14 shows the excellent tensile stress retention of Ultem® 1000 resin after 10,000 hours of immersion in water at 100°C. In addition, tests show that Ultem resin's physical properties remain virtually unchanged after repeated cycling from steam pressure to drying in vacuum at room temperature. Therefore Ultem resin is a very good material for repeated autoclavability.

Ultraviolet exposure

Ultem resin is resistant to UV radiation without the addition of stabilizers. Properties like tensile stress, modulus and Izod notched impact show a negligible change after long-term exposure to UV. However, care should be taken, since color changes and loss of Izod unnotched impact performance might occur after long-term exposure.

Radiation resistance

Parts molded in Ultem resin demonstrate excellent resistance to radiation, as shown in Figure 4.15. A loss of less than 6% tensile strain (ISO 527) was observed after cumulative exposure to 500 megarads at the rate of one megarad per hour using Cobalt 60.

Agency recognition

Ultem resins have been tested and comply with various agency regulations and specifications. The Ultem resins' heat stability and flammability characteristics make them excellent choices for numerous applications which require Underwriters Laboratory, UL, approval. Several grades of Ultem resin are also intended for compliance with regulations such as FDA, EFSA, KTW, WRAS, ACS, USP, DIN, VDE, FAR, ABD, and military regulations. Check details with the local product stewardship teams.

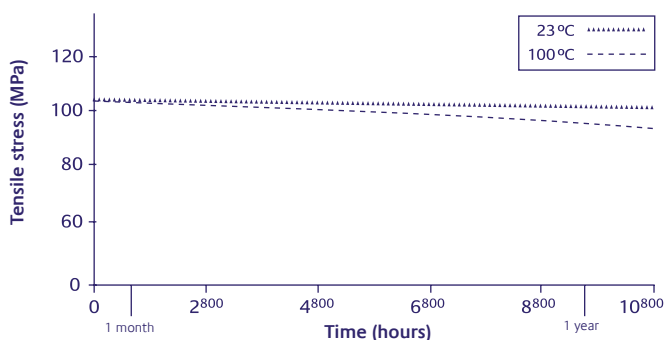


Figure 4.14 Effect of water exposure on tensile stress of Ultem 1000 resin.

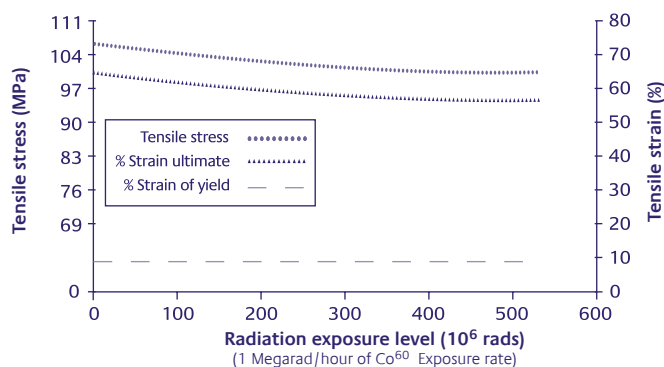


Figure 4.15 Effect of gamma radiation exposure on properties of Ultem 1000 resin.



5. Design

To extract the maximum performance from Ultem® resin, the designer should strive to take full advantage of the excellent physical properties of the material as well as the design freedom offered by the injection molding process. The designer should minimize molded-in stress in applications made from Ultem resin because the higher the stress level in a finished part, the more susceptible it is to chemical attack**.

Molded-in stress in parts can be minimized by

- Avoiding thin walls and sharp corners
- Avoiding large and sharp transitions in wall thickness
- Ensuring balanced and uniform part filling
- Properly designing ribs and coring to increase stiffness without increasing wall thickness

Ultem resins may be well suited for the design of long-term high temperature and mechanically stressed applications.

Color

Ultem resins have a yellow transparent base color. Various grades are available in many different opaque and transparent colors. It is possible to match new colors to RAL and Pantone standards, or any other custom specific color within the capability of the Ultem resin base color.

Note

General information on designing with engineering thermoplastics can be found in the SABIC Innovative Plastics “Design Guide.”

** In all cases extensive testing of the application under the working conditions is strongly recommended. The actual performance and interpreting of the results of end-use testing are the end-producer’s responsibility.



6. Processing

The excellent processing characteristics and the amorphous nature of Ultem* resins make them an ideal material for the precision molding of tight tolerance parts. The unfilled resins shrink isotropically.

Fiber-filled grades will give due to fiber orientation during processing an anisotropic but consistent shrinkage. This provides very consistent parts.

Ultem resins have been successfully molded in parts weighing as little as a fraction of one gram to parts weighing as much as four kilograms. Ultem resins can also be processed in extrusion and blow molding applications.

Optimum processing results start with a correct part and mold design in which the final part performance, the molding process, molding equipment and also final assembly and secondary operations have all been considered and optimized.

6.1 Injection molding

Ultem resins can be molded on most standard injection molding machines provided the heat capability is sufficient. Although Ultem resins are stable at process temperatures, it is recommended to keep residence times minimal by selecting appropriate machine size vs shot size.

Conventional materials of construction for compatible screws and barrels are generally acceptable for processing Ultem resins. The use of bimetallic barrels is suggested. Depending on screw diameter, a compression ratio of about 2.2:1 with a length to diameter ratio of 20-24:1 is preferred. A feed zone of 10D, a compression zone of 5D and a metering zone of 10D are suggested. The compression should be accomplished over a gradual and constant taper since sharp transitions can result in excessive shear and material degradation. If specific screw selection is not possible, general purpose screws with length to diameter ratios from 16:1 through 24:1 and compression ratios from 1.5:1 to 3.0:1 have been used successfully. Vented barrels are not suggested for processing Ultem resins.

The non-return valve should be of the sliding check ring type.

Cold and hotrunners are successfully used for molding Ultem resin parts. For hotrunners it is important to select runners with good control over the manifold temperatures. External heated systems with individual controlled heating zones are preferred.

Direct gating is possible with a good quality valve gate. Pressures up to 2000 bar should be withstood, they can occur occasionally when molding starts at too low temperature. Good temperature control of the nozzle is a must, temperatures up to 400°C (752°F) should be possible. It is recommended to make flow studies of the part including hotrunner and cold runner system. This will provide guidelines for the geometry of the gating system for the moldmaker. Valves must be actuated by hydraulic cylinders, open and close forces can be high due to high viscosity.



6. Processing

6.1.1 Pre-drying Ultem* and Siltem* resins

Ultem and Siltem resins absorb atmospheric moisture which can cause degradation of the polymer during processing. Moisture content higher than 0.02% can be expected to cause appearance issues, brittle parts and an increase in the melt flow of the material. The suggested moisture level can usually be reached by predrying Ultem and Siltem resin at temperatures suggested in Table 6.1.

Table 6.1 Ultem resin drying conditions.

Resin family	Drying temp °C/°F	Drying time hrs
Unreinforced	150/300	4
Reinforced	150/300	4
Blends	120/250	4
Siltem	110/230	4-6

When the resin must stay in the dryer for a longer period, lowering the dryer temperature an additional 20-30 °C [30-50°F] is recommended.

For efficient drying it is recommended to use a dehumidifying drier that can achieve dew point of -30 to -40°C (-20 to -40°F).

6.1.2 Molding conditions

Ultem resins have very good moldability due to their excellent thermal stability. They have been successfully molded in complex and multi-cavity tools. Depending on the required flow length, they can be molded in wall sections as thin as 0.25 mm / 10 mils. The Ultem blends typically have a narrower process window and more care should be taken on optimizing machine versus part size and process settings.

Higher melt temperatures may result in a color shift due to the inability of pigments in some colors to handle higher temperatures. Ultem blends should be processed at lower temperatures. For details on process conditions, reference is made to the datasheets of the individual products as available on sabic-ip.com.

Ultem resins should always be molded in temperature-controlled molds. It is recommended to check on a regular basis the mold temperatures for example with a surface pyrometer.

The midpoint of the datasheets' suggested range of setpoints will generally give good results with respect to part appearance and cycle time. Higher mold temperatures can be used for increased flow, improved knit-line strength, and maximum effective heat and chemical resistance through the reduction of molded-in stresses. Using lower than the suggested mold temperatures can result in surface defects and high molded-in stresses and may compromise part performance.



6.1.3 Screw speed

Screw speeds should be adjusted to permit screw rotation during the entire cooling cycle without delaying the overall cycle. Low screw speeds will help reduce glass fiber damage during plastization when molding reinforced grades. Low screw speeds are also suggested for Ultem* blends.

6.1.4 Purging

Thorough purging is essential when changing to or from Ultem resin in machines used for other plastics. Since Ultem resin's processing temperature is well above the degradation level of many other thermoplastics, it is imperative that all traces of other polymers are removed to avoid contamination resulting in splay, streaks or black specks.

The best purging material for Ultem resin is glass filled or unfilled polycarbonate resin. HDPE can also be used. Drying of the purging material is not required. Begin purging at the processing temperature of Ultem resin and proceed for 10-15 minutes before reducing the barrel temperatures in steps to approximately 260°C/500°F while continuing to purge. Purging can then be completed with HDPE.

Styrenes and acrylic resins should not be used in high-heat purging. Chemical purging compounds are also not suggested.

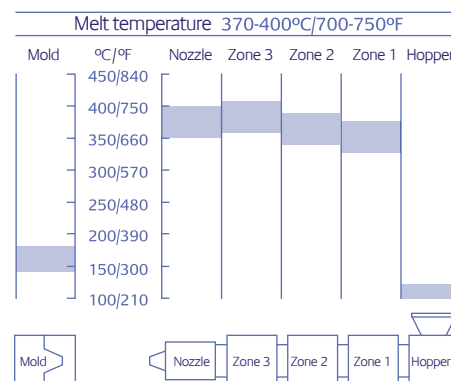


Fig. 6.1
Typical molding temperatures for unreinforced Ultem resin families
• 1xxx
• 4xxx
• CRS5xxx
• XH6xxx

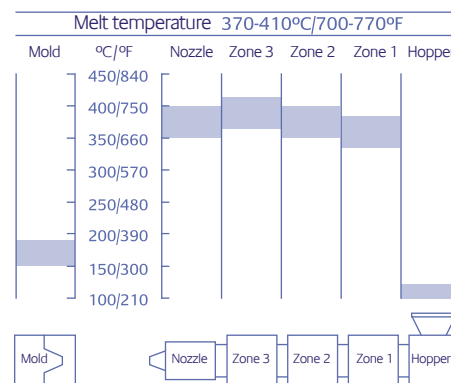


Fig. 6.2
Typical molding temperatures for reinforced Ultem resin families
• 2xxx
• 3xxx
• CRS5xxx
• AR9xxx

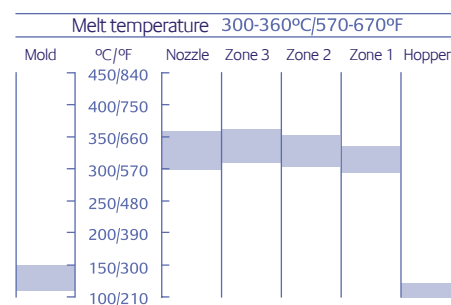


Fig. 6.3
Typical molding temperatures for Ultem resin blends and Siltem resin
• 1285 (melt temp 320°C/610°F)
• 9xxx (melt temp 360°C/680°F)
• ATX1xx (melt temp 320°C/610°F)
• ATX15x (melt temp 340°C/640°F)
• ATX2xx (melt temp 360°C/680°F)
• ATX3562R (melt temp 360°C/680°F)
• DT18xxE (melt temp 345°C/650°F)
• Siltem resin (melt temp 300°C/570°F)



6. Processing

6.1.5 Shutdown and start-up

When shutting down the machine after purging, the hopper should be shut off at the throat and the machine run until all residual resin is run out of the barrel. The screw should be left in its most forward position with the barrel heaters off.

For intermediate stops, during which no purging is considered, the barrel temps should be reduced to about 15-20 degrees above the glass transition point of the Ultem® resins.

When starting up the machine, set the barrel heaters to normal processing temperatures. Allow the machine to reach those settings before turning on the screw. Then extrude until the barrel is completely purged and good parts are being molded. The initial shots should be checked for contaminants in the molded parts.



6.1.6 Regrind

Reground sprues, runners and non-degraded parts may be added to the virgin pellets up to a level of 25%. Grinder screen sizes should be at least 8 mm or 3/8 inch. If a smaller size is used, too many fines could be generated, creating molding problems such as streaking and burning. It is important to keep the ground parts clean and to avoid contamination from other materials. Drying time should be increased since regrind will not be the same size as virgin pellets, and therefore water diffusion may be different.



6.2 Extrusion and blow molding Ultem* resins

6.2.1 Extrusion

Ultem resins are used successfully in many extrusion processes for producing film, sheet, stock shapes, profiles and wire and cables. In general processing temperatures applied in these processes are lower than for injection molding. Care should be taken that the cooling of the extruded part is done slowly to avoid high internal stresses.

6.2.2 Blow molding

Ultem resins are successfully used in many extrusion blowmolding applications to generate hollow parts. In general the material behaves similarly to polycarbonate materials in blowmolding. Typical temperature settings are lower than for injection molding conditions.



6.3 Extrusion of Siltem* resins

Siltem resins can be successfully extruded on most wire and cable equipment. Conventional metals can be used for the construction of the screw, barrel and die, this in contrast to fluoropolymers that require the use of corrosion resistant and much more expensive metals.

Beside using the proper processing conditions and cleaning procedures before and after a Siltem resin run, it is recommended to preheat the wire conductor to at least 80°C. Further it is recommended to apply gradual cooling on the extruded wire. This to minimize internal stress and associated loss in properties.



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7. Secondary operations

After molding, parts may require machining, assembly or finishing operations. Parts made from Ultem^{*} resin can be further treated with many different secondary operations.

7.1 Mechanical assembly

Mechanical assembly techniques are widely used with Ultem resin parts. For unreinforced Ultem resin grades, the classical rules for amorphous engineering thermoplastics apply. For highly reinforced Ultem resin grades, the use of special thread cutting screws is advised because of the low elongation at break.

The different mechanical assembly techniques that can be used can be summarized as follows

- Inserts, installation by heat or ultrasonics are the preferred techniques. Press and expansion inserts give radial stresses. Over molding and external threaded inserts are also possible.
- Screws by thread forming or thread cutting. Thread forming screws with low flank angle for reduced radial stresses are preferred. Hole (0.85 times screw diameter) and screw should be circular (not trilobular/square). Boss diameter should be 2.5 times screw outer diameter.
- All types of rivets can be used; be aware of high stresses with some pop rivets.
- Staking is possible, with ultrasonic staking being more practical than heat staking.
- Snap fit assembly

7.2 Welding

Welding is a commonly used permanent assembly technique for engineering thermoplastics. Ultem resins can be welded by using different processes

- Vibration welding
- Ultrasonic welding, at amplitudes above 30 micron (0-peak)
- Induction welding
- Laser welding
- Hot plate welding is only recommended when measures are taken to avoid sticking of the hotplates to the Ultem resin at melt temperatures.



7. Secondary operations

7.3 Adhesives

Parts made from Ultem* resin can be bonded together or to dissimilar materials using a wide variety of commercially available adhesives. Because adhesive bonding involves the application of a chemically different substance between two parts, the end use environment of the assembled unit is important in selecting an adhesive.

Recommended adhesive types for Ultem resin are

- Epoxy adhesives
- Polyurethane adhesives
- Silicone adhesives
- Care should be taken with cyanoacrylates and acrylic systems. Exposure to these systems might lead to stress cracking. It is recommended to carefully select those systems
- Solvent bonding is successfully done with Ultem resins
- UV curing systems are successfully applied

7.4 Painting

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

It is generally recommended that Ultem resins be pre-treated before painting. The options are

- Hand washing the part with cleaning agents based on alcohol or aliphatic hydrocarbons or,
- Power washing the part with cleaning agents based on detergents dissolved in water, acidic by nature, neutral or alkaline

Paint selection

- Paint selection is determined by the desired decorative effect, specific functional needs and the application technique to be employed
- Coatings can also help to minimize color fading
- Conductive coatings offer shielding against radio frequency interference (RFI) or electromagnetic interference (EMI)
- A variety of conventional and waterborne paints can be successfully applied to Ultem resin. Generic types are - acrylic, alkyd, epoxy, polyester, polyimide, polyurethane

If the Ultem resin application is working under high temperature conditions, the selected paint must offer equal high temperature performance.

Paint solvents

It is important that solvent formulations are considered when selecting a paint for use with Ultem resin. Solvents used in paint formulations may have an adverse effect on the Ultem resin and it is recommended to find solvents that are benign to the substrate.



7.5 Metalization

Metalization of plastics is normally undertaken for decorative or functional reasons. Properties usually associated with metals such as reflectiveness, abrasion resistance, electrical conductivity and decorative surfaces can be added through metalization.

Ultem® resins can be metalized by various techniques like electroless and electroplating, vacuum metalization via PVD and PE-CVD and dichroic coating. Due to the high affinity of Ultem to most metals excellent adhesion levels can be obtained.

General recommendations for the metalization of Ultem resin are

7.5.1 Vacuum metalization methods

Physical Vapor Deposition (PVD)

PVD is the depositing of an evaporated metal, mostly aluminum, on a substrate. To achieve evaporation, the pure metal is heated in a deep vacuum.

Sputtering or Plasma Enhanced Chemical Vapor Deposition (PE-CVD)

Sputtering or PE-CVD also take place in a vacuum. With high voltage equipment, a field is created between the sample's grounded carrier and a negative electrode: the metal target that has the function of a metal or an alloy donor.

Surface activation

For vacuum metalization a surface activation pre-treatment is recommended. This is done via a glow or corona discharge in a vacuum vessel in the presence of a low pressure gas like air or an Argon-oxygen mixture. This method gives an increase in surface energy to the plastic and also cleans the surface of the part. Cleaning the surface with cloth or solvents is not recommended because of sensitivity to scratches that can be seen after metalization. A favorable method is to keep the moldings clean and to metalize the parts as soon as possible after molding, or store them in clean containers.

After treatment

Due to the reactive nature of aluminum to humidity, and the ultra-thin layer thickness, aluminum must be protected against environmental influences. There are two systems that are most commonly used to provide this protection

- Plasil/Glipoxan top layer: this silicon-based monomer layer is applied in the vacuum chamber
- Clear coat top layer

Vacuum metalization techniques are commonly used for lighting reflectors in which aluminum is deposited on a high gloss unfilled Ultem resin surface. This provides excellent adhesion and since no basecoating or lacquer primer is needed prior to metalizing the Ultem resin surface, a costly step in the process of making reflectors can often be eliminated.



7. Secondary operations

7.5.2 Plating methods

Plating can be done by electroless plating without the addition of current to the galvanic process and/or followed by electroplating where an electrical current is used to effect an electrolytic deposition of metals coming from a dissolved metal salt. Better results are obtained with reinforced Ultem® resins.

Electroless plating

The Ultem resin surface is typically swollen by a mild solvent after which the surface is chemically etched. This creates micro cavities which make mechanical interlocking possible to improve the adhesion of the metal layer to the plastic surface. Chemical bond plating is a special etching technique which is particularly suitable for use with Ultem resin. In this technique, a permanganate etch opens the Ultem resin molecule imide ring, and allows copper to enter the molecule and form a chemical bond. A very high level of adhesion can be established with this technology. This technique is often used for EMI shielding and for Molded Interconnect Devices, antennas and microfilters. For EMI shielding an electroless copper layer of 1-2 micron is applied with a finish of 0.5 micron of electroless nickel. For a MID application where the molded part becomes a circuit board, an additional copper layer is applied by electroplating. To achieve even higher electrical conductivity, layers of silver or gold can be deposited via electroplating on top of the copper base layer.

Electroplating

After the application of a conductive metal layer on the plastic, a further electrolytic deposition of selected metals on top of this layer can be done. Most frequently used metals are chrome, nickel, silver or gold in varying thicknesses depending on the requirements.

Dichroic coating

Ultem resin is suitable for use with most dichroic coatings which reflect visible light but allow the transmission of infra-red radiation. This allows heat to dissipate through the backside of the reflector instead of being reflected forward or being absorbed in the reflector itself. This gives a lower resulting temperature of the reflector. An additional advantage is in healthcare lighting where dichroic coatings often give less heat reflection towards the patient.

7.6 Laser marking

Ultem resins can be laser marked using standard laser marking equipment. Typically a light color should be used to obtain sufficient contrast between the laser marked areas.

7.7 Machining

Ultem resins can be machined using conventional metal machining techniques like routing, drilling, sawing and cutting. For production of small series this can be a more economical approach versus investing in an injection molding tool. Machining can also be used to generate prototypes for feasibility studies to replace metal with Ultem resin. Rod's and slabs of various Ultem grades are globally available from various stock shape producers.

Note

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

- Assembly guide
- Design guide
- Painting guide
- Metalization guide





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