SABIC
Innovative
Plastics™

Extem* resins

Extem resins

Products, markets and processing guide
Extreme Performance Made Easy

Sharing our futures

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.

Contents

Why choose between outstanding performance and good processibility?

1.1 Introduction

Available only from SABIC Innovative Plastics, new Extem* thermoplastic polyimide (TPI) resins bridge the gap between extreme part performance and improved productivity facing current high-heat thermoplastics and thermoset materials.

Depending on the grade, Extem resins can deliver powerful resistance to extreme heat and chemicals, superb strength and stiffness in addition to robust dimensional stability. At the same time, this amorphous engineering resin provides the manufacturing productivity of melt processing by injection molding, extrusion, blow molding or thermoforming without requiring any post-cure or crystallization steps to yield maximum performance.

This combination of properties enables Extem resins to offer new options for replacing metals, thermosets and ceramic materials in your application designs; as well as high-performance thermoplastics, such as polyetheretherketone (PEEK), polyamidimide (PAI) and polyimide (PI).

Extem resin's combination of high-end performance and easy processibility changes the rules of the game for thermoplastic polyimides, opening new opportunities for these exotic, low-volume resins in mainstream applications.

- True thermoplastic melt processibility with ultra-high performance as molded. No need for post-cure or crystallization steps to yield its maximum performance unlike PAI and PI polymers
- Tailorable glass transitions up to 311°C (592°F) per application requirements
- Extended application use temperature as high as 250°C (482°F)
- Extreme amorphous chemical resistance
- Exceptional dimensional stability
- High strength, stiffness and creep resistance at elevated temperatures
- Inherent flame retardancy
- Outstanding flame, smoke and toxicity
- High limiting oxygen index

SABIC Innovative Plastics is investigating at least 75 potential products based on Extem resin, including various filled/reinforced compounds and blends with Ultem* resin and other amorphous and semi-crystalline resins.

Working under an exclusive marketing agreement, Victrex and SABIC Innovative Plastics have introduced a new high-performance family blending Extem UH resin and Victrex® PEEK™ resin. The Victrex Max-Series™ polymers offer enhanced performance over a wide temperature range.

Out of the gate, the Extem resin platform currently offers two families of materials: Extem UH and Extem XH resins.

Extem UH resin provides extreme thermal and chemical resistance, while Extem XH resin delivers outstanding strength and creep resistance at high temperatures.

Both families raise the bar for melt processing of polyimides.

1.2 Extem UH resins

The Extem UH resin family offers glass transition (Tg) temperatures up to 311°C (592°F), the highest of any commercially available amorphous thermoplastic. In contrast to semi-crystalline resins, Extem resin's outstanding Tg enables outstanding retention of strength and creep resistance at high temperatures, even for unfilled, as-molded components. Further, Extem UH resins are designed to offer extended application use temperatures as high as 250°C (482°F). Extem UH resins have also demonstrated outstanding thermal-oxidative stability at extreme temperatures.

In addition to its outstandingly high heat resistance, Extem UH resin also exhibits superior chemical resistance to chemicals such as organics and acids, as well as hydrocarbons such as toluene, aggressive solvents like methyl ethyl ketone and chlorinated solvents. Extem UH resins are designed to offer chemical resistance similar to cured PAI or PI.

Extem UH family
Glass transition up to 311°C (592°F)
Extended application use temperatures as high as 250°C (482°F)
Extreme amorphous chemical resistance
Exceptional high-temperature load-bearing performance

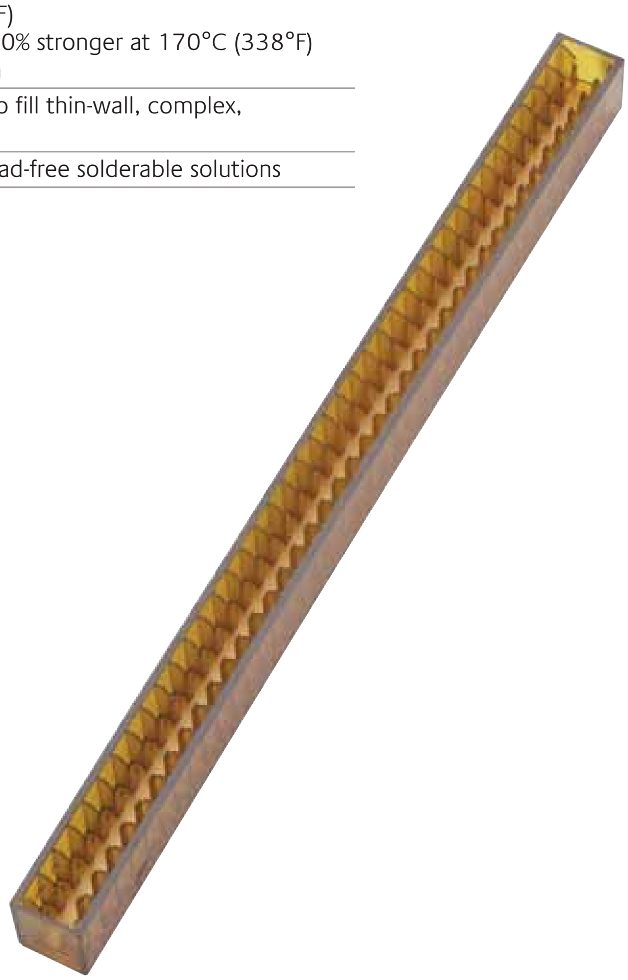
1.3 Extem XH resins

The Extem XH resin family delivers high strength and creep resistance up to 250°C (482°F), outperforming many other engineering plastics at temperatures above 200°C (392°F). In addition, it provides excellent melt flow performance, even for complex, multicavity tools.

The material adapts well to thin-wall injection molding processes, producing parts with 0.010 inch (0.0254 mm) wall thickness at flow lengths of over 0.250 inch (6.35 mm). Longer flows up to 4 inches (100 mm) for wall sections 0.030 inch (0.762 mm) thick have been achieved at injection pressures of 32,000 psi (2,200 bar). Molding cycle times are comparable to those for other SABIC Innovative Plastics, such as Ultem* resin, with minimal warpage at high ejection temperatures.

Unlike many extreme-performance resins, Extem XH resin is transparent in the visible and near infrared region, with a dark amber color in its natural form.

Extem XH family
Glass transition up to 267°C (513°F)
Enhanced creep and strength performance at elevated temperatures – Tensile strength comparable to die cast aluminum at 200°C (392°F) – Approximately 50% stronger at 170°C (338°F) than Ultem resin
Better capability to fill thin-wall, complex, miniaturized parts
Offers potential lead-free solderable solutions



1.4 LNP* specialty compounds made with Extem resins

A world leader in specialty compounded resins, SABIC Innovative Plastics LNP specialty compounds offer customers high-temperature engineering thermoplastic compounds made with Extem TPI resins. LNP is developing a series of products to provide lubricated, conductive and structural performance at elevated temperatures using fillers such as PTFE, carbon fibers and others. Contact your local SABIC Innovative Plastics sales representative to find out more about these new products.

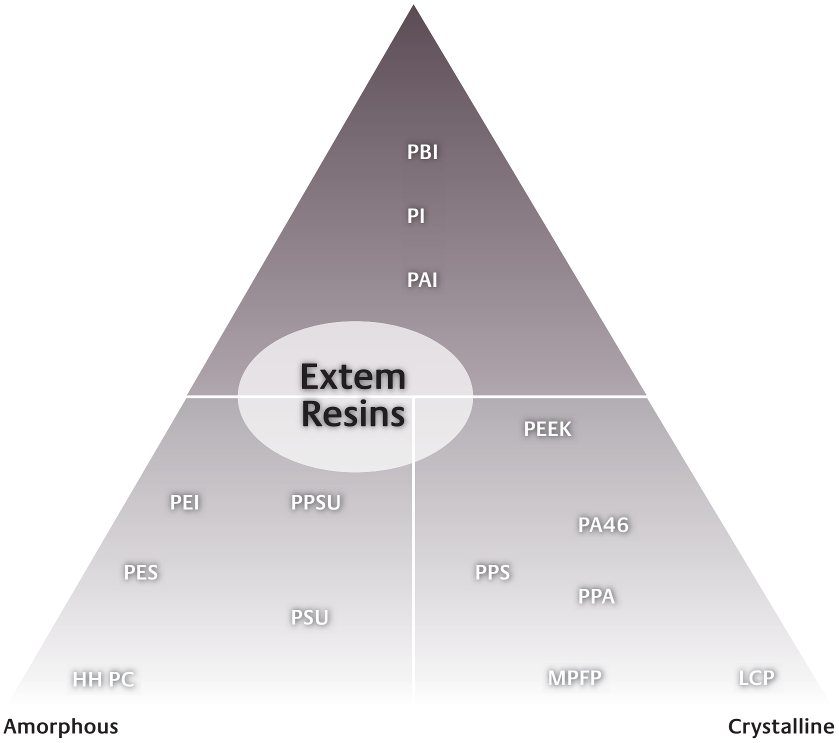
Extem UH resin with LNP effects
Conductive Carbon fiber based compounds • Achieved surface resistivity of E1-E8 ohm/sq • Property profile measurements underway • Cleanliness testing on-going Carbon powder compounds – next
Structural Carbon fiber based compounds • Achieved modulus of 1.0-3.3 Msi (6.9-22.8 GPa) • Property profile measurements underway Glass fiber compounds – next
Lubricated PTFE based compounds • Achieved PTFE incorporation • RT wear factor similar/better than PTFE/PEEK Mixed filler compounds – ongoing

1.5 Victrex® MAX-Series™ blends

Extem UH TPI resin blended with Victrex® PEEK™ resin gives you a tailorable balance of amorphous and semi-crystalline properties. Victrex MAX-Series polymers offer customers enhanced performance over a wide temperature range of 150-275°C (302-527°F).

See Victrex website: www.victrex.com. Victrex Max-Series blends are sold exclusively by Victrex plc.

Victrex MAX-Series polymers made with Extem UH TPI resin
Enhanced performance over wide temperature range – 150-275°C (302-527°F)
Good mechanical performance at elevated temperatures
Good chemical resistance
Low creep at elevated temperatures
Good dimensional stability



1.6 Summary

Over a decade and a half in development, Extem* resins were designed with the processor in mind. They are fully melt-processible on injection molding and extrusion equipment designed for high-performance materials without the need for post-curing imidization steps.

But the performance benefits of these advanced new engineering resins from SABIC Innovative Plastics extend well beyond the mold and offer new levels of performance for several application areas.

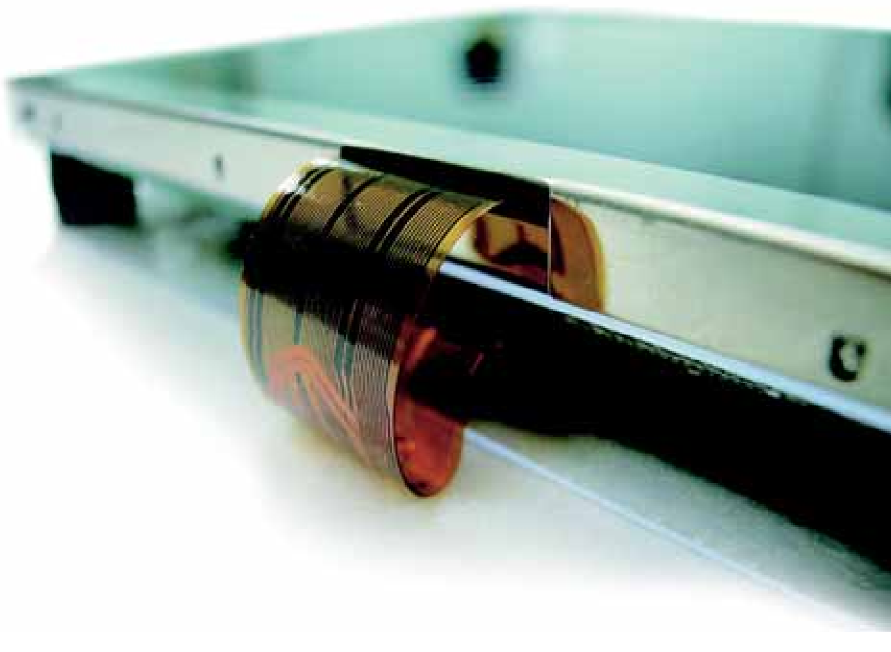
- Extem resin's powerful resistance to heat and chemicals positions it well for components in the down-hole oil and gas industry
- Manufacturers of aerospace and military connectors also can benefit from its as-molded high performance without additional post-cure time or the long cycle times of non-melting and thermoset imidized resins
- Extem resin's potential lead-free solder capability, as well as its combination of strength, stiffness and dimensional stability, make it an excellent candidate for electrical, electronic and semi-conductor markets
- Extem resin also offers opportunities for metal replacement in automotive applications

These advanced materials from SABIC Innovative Plastics meet international standards for recyclability (typically 25%), as demonstrated by multiple-pass regrind studies that indicate over 90% property retention. As always, the amount of regrind utilized will be governed by performance requirements of the application.

Additional features of Extem resins, in general
True thermoplastic melt processibility with ultra-high performance as molded – Processible using standard high-performance resin, high-temperature injection molding equipment and conventional drying – Potential in film and profile extrusion, thermoforming, stock shapes and blow molding applications
Exceptional dimensional stability
High strength, stiffness and creep resistance at elevated temperatures
Inherent flame retardancy
Outstanding flame, smoke and toxicity
High limiting oxygen index

1.7 Export control regulations

Extem resins are commerce controlled under United States export control classification number (ECCN) 1C008 due to its Tg, which is greater than 240°C (464°F). Numerous countries in Europe and Asia do not require an export license, so materials ship just as uncontrolled products. Export licenses can be obtained in a majority of instances. Contact your local SABIC Innovative Plastics representative for more information.

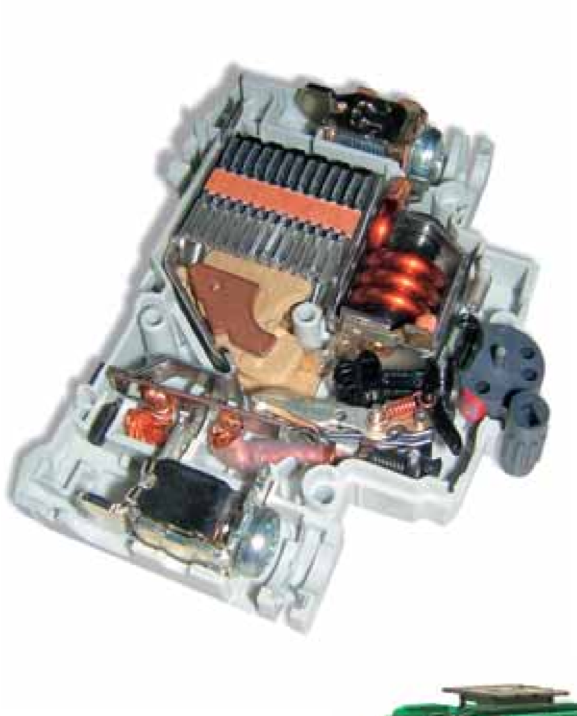


2.1 Electrical and defense

Extem* 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 250°C (482°F)
- Inherent flame retardancy, as well as UL94 V0 and 5VA listings for many grades
- Potential use for plenum space applications. Extem must complete testing to UL2043
- Excellent dimensional stability, with low creep sensitivity and low, uniform coefficient of thermal expansion (CTE)
- Compliance to WEEE/RoHS and various ECO labels
- Higher heat performance for connectors

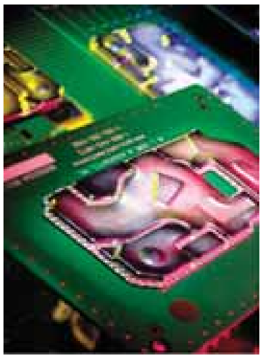


2.2 Telecom and semiconductor

Its unique high-temperature performance and plating capabilities make Extem resin an excellent material choice for telecom applications. Extem 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, telecom internal components, telecom process handling cassettes and fiber optic connectors.

Extem 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 Extem 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 can be obtained with filled Extem 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
- High heat resistance up to 250°C (482°F) allow Extem resins to survive high-temperature telecom processes

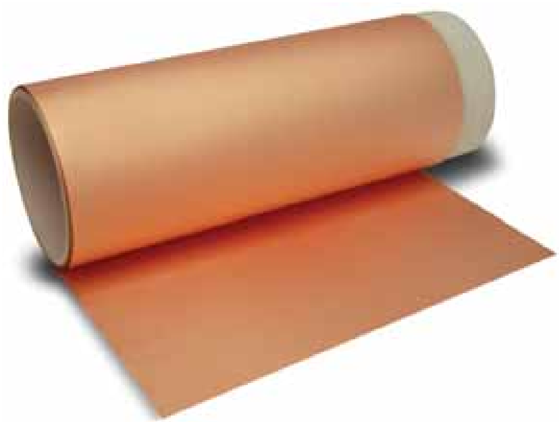


2.3 Extrusion and stock shapes

Extem* resin maintains its outstanding properties when extruded into film, sheet, profiles, rods and slabs. Extem film and sheet will be available in different grades and gauges from SABIC Innovative Plastic's Specialty Film and Sheet business.

Stock shapes (rods and slabs) made from Extem 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.

Extem film can be made by melt extrusion and solvent casting technology, to service the high-end, high-temperature film market. Solvent cast Extem film offers potential for Tg > 280°C (536°F), CTE <25 ppm, adhesiveless lamination to copper foil and the ability to survive lead-free solderable processes, and is targeted at polyimide (PI) resins for flexible printed circuits, electrical insulations and capacitor films.



2.4 LED reflectors

The metallizability, flow and high temperature performance of Extem resins and blends with semicrystalline resin make them outstanding choices for LED reflectors. Extem resins' inherent properties enable thin-walled LED reflectors to survive extreme humidity levels experienced globally with acceptable dimensional changes.

Extem resins for LED reflectors may offer

- Excellent metallizability and adhesion without primer or base coat under long-term, high-heat conditions
- Improved elongation and flow for high-precision parts
- Improved ability to survive reflow process typically 260-270°C (500-520°F), 0-80% relative humidity
- Excellent amorphous dimensional stability
- Unfilled vs. glass-filled PPA and LCP means better surface finish and lower weight
- Recyclability

2.5 Oil and gas

On land. On deck. Sub-sea. Downhole. Extem resins and LNP* Extem-based compounds offer high-performance engineered plastics, custom compounds and polymer shapes. Extem-based resins and blends with PEEK resin can provide corrosion resistance, wear resistance (PV), chemical resistance, creep, dimensional stability, steam resistance and outstanding flame, smoke and toxicity performance.

The excellent balance of properties – especially at elevated temperatures – and chemical resistance make them a potential material for seals, o-rings, drill parts and downhole semiconductor parts.

2.6 Transportation

The excellent balance of flame retardancy, low smoke emission and low smoke toxicity of Extem* 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.

Extem resins can provide superior performance 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, Extem resins can contribute to intermediate products such as thermoplastic composites reinforced with glass, carbon or aramid fibers or fabrics; and potentially to sandwich core materials, like foams and honeycombs.

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

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

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
- Extem UH resin series delivers improved resistance against hydraulic aircraft fluids, such as Skydrol, and other common chemicals such as permethrin (an insecticide)
- Available in limited opaque and transparent colors. New colors can be matched on request
- Ability to manufacture Extem resin-based thermoplastic composites, which may allow increased productivity in component manufacturing over traditional composite materials

2.7 Lighting

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

- Extended application use temperatures as high as 250°C (482°F)
- Excellent molded surface quality, allowing direct metalization 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 Extem XH resin to comply with ECE regulations on beam patterns 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 heat resistance from Extem XH resins may enable high-temperature reflectors for projector lamps and fog lights vs. Ultem* resins and PES with haze onset temperatures up to 250°C (482°F)
- For bulb sockets and brackets, glass-filled materials like Extem XH2315 resin may provide enhanced modulus and strength, plus lower outgassing versus PPA, PPS and LCPs
- Good choice for reflectors with dichroic coating without primer

2.8 Automotive

Extem* 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, Extem resins may offer

- Extended application use temperatures as high as 250°C (482°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

2.9 HVAC and fluid handling

Extem resins can offer a 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. Extem resins are excellent candidates because they may offer

- Extended application use temperatures as high as 250°C (482°F)
- Excellent weld line strength needed to resist high temperatures and dynamic pressures
- Potable water approval currently underway
- Excellent mechanical properties under hot water conditions
- Good hydrolytic stability
- Excellent dimensional stability (low creep sensitivity and low, uniform coefficient of thermal expansion)

2.10 Food service

The design flexibility and outstanding performance qualities of Extem* 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, steam insert pans, gastronorm containers, microwavable bowls, ovenware, cooking utensils and reusable airline casseroles. The good hydrolytic resistance of Extem XH resins makes them a potential material for hot water contact components in coffee and vending machines.

Extem resins for food service applications may offer

- Compliance with FDA, NSF, EFSA, JHOSPA and other national food contact regulations currently under test
- Temperature resistance up to 250°C (482°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
- Good hydrolytic stability
- Excellent processibility, allowing complex designs and low residual stresses
- Practical level of impact resistance, from subzero to 250°C (482°F)
- Cold touch compared to parts made from metal and ceramic
- Available in limited opaque and transparent colors. New colors can be matched on request

2.11 Healthcare

Extem resins are an excellent potential 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.

Extem resins for healthcare applications may offer

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

3.1 Product description

3.1.1 Extem* UH1000 blend series
- General purpose
- Unreinforced
- Various viscosity grades available
- True thermoplastic melt processibility of an amorphous resin
- Extreme ESCR (chemical resistance) to organic solvents such as hydrocarbons, ketones and chlorinated solvents
- Processible via conventional methods such as injection molding and extrusion
- Translucent, dark amber in color
- UL94 V0 and 5VA, outstanding flame, smoke and toxicity performance

3.1.2 Extem UH2000 blend series (under development)
Similar overall performance as Extem UH1000 blend series above, plus...
- Glass fiber reinforced, 10% to 30% fill
- Greater rigidity and strength versus unfilled Extem resins
- Potential for elevated temperature performance with lower filler content compared to PPS, PPA and PEEK resins
- Lower coefficient of thermal expansion over unfilled Extem resins
- Processible via injection molding and extrusion

3.1.3 Extem XH1000 resin series
- General purpose
- Unreinforced
- Lead-free solderable capable, typically at ~260°C (500°F), high relative humidity
- Elevated temperature creep, strength and stiffness performance
- Various viscosity grades available
- Processible via conventional methods such as injection molding and extrusion
- UL94 V0 and 5VA, outstanding flame, smoke and toxicity performance
- Transparent to most visible and near IR wavelengths, dark amber in color
- 50% stronger at 170°C (338°F) than Ultem* resin
- Tensile strength of die cast aluminum at 200°C (392°F), as shown in figure 3.1

3.1.4 Extem XH2000 resin series
Similar overall performance as Extem XH1000 resin series above, plus...
- Glass fiber reinforced, 30% fill commercially available, 10-20% fill under development
- Greater rigidity and strength versus unfilled Extem resins

3.1.5 Extem AUT250 resin
- Developed for high-temperature automotive lighting reflectors and projectors up to 250°C (482°F)
- Unreinforced
- Various viscosity grades available
- Mineral and glass-filled grades can be developed on request
- Excellent molded surface quality, allowing direct metalization without the need for base-coats or primers
- Transparency to near-infrared light, allowing heat dissipation

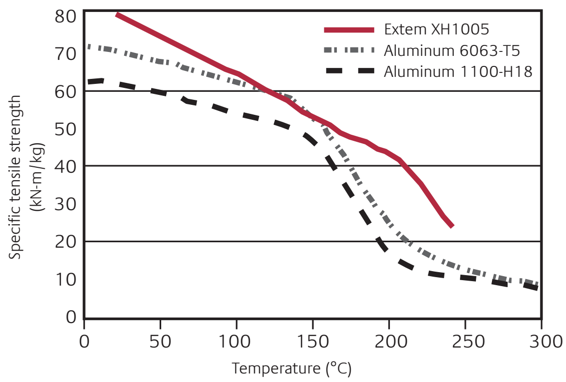


Figure 3.1
Specific strength at elevated temperatures for Extem XH resin vs. cast aluminum.

Note: Specific strength equals tensile strength divided by material density.

3.2 LNP* specialty compounds made with Extem* resins

Compounds under development using Extem UH1000 blends and XH1000 resins with various filler technology and other crystalline resins.

LNP Lubricomp* compounds

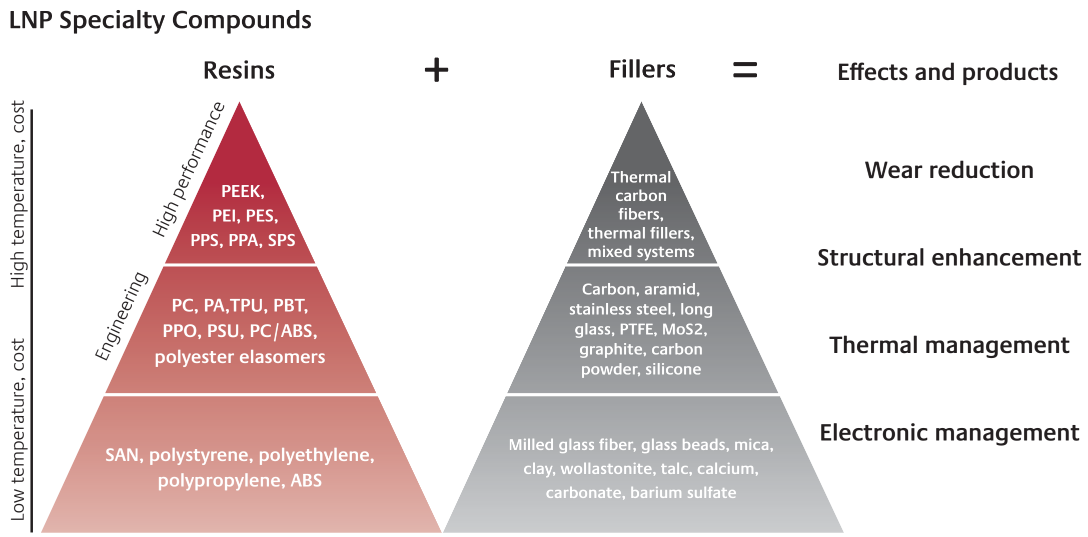
Internally lubricated compounds offer inherent lubrication through the addition of PTFE. Extem-based Lubricomp compounds offer enhanced wear resistance at elevated temperatures. These products may find use in demanding wear applications in the business machines, automotive, medical, appliance and industrial markets.

LNP Stat-Kon* compounds

Electrically conductive compounds may provide economical and reliable solutions against electrostatic buildup and elevated temperature performance. Formulated for ease of processing, these compounds can be injection molded or extruded. These products may find use in applications such as electronic and electrical equipment/instruments, business machines, automotive fuel systems and more.

LNP Thermocomp* compounds

Carbon fiber reinforced compounds offer enhanced mechanical and thermal properties, including exceptional resistance to high temperatures, fatigue, creep, impact and chemicals. These products may find use in electrical/electronic compounds, business machines, consumer goods, appliances, industrial applications and automotive functional components.



LNP specialty compounds effects and products

Wear reduction –
Lubricomp compounds and Lubriloy* compounds
- Elimination of external lubrication
- Wear-related noise reduction
- Enhanced wear-related fatigue endurance

Structural enhancement –
Verton* compounds, Thermocomp compounds and Thermotuf* compounds
- Modulus vs. temperature and time
- Modulus vs. ductility management
- Modulus vs. surface appearance

Thermal management –
Konduit* compounds
- Thermal conductivity
- Temperature vs. dimensional stability (CLTE)
- Temperature vs. electrical conductivity

Electronic management –
Stat-Kon compounds, Stat-Loy* compounds and Faradex* compounds
- Permanent anti-static performance
- Static management – electronic protection
- EMI shielding

Extem* Thermoplastic Polyimide (TPI) resin product tree

Series	Filler type	Flow	HDT @ 66 psi/ 0.45 MPa	Filler content	Grade name
Extem UH blend series	Unfilled	Standard flow	263°C (505°F)		UH1006 (M)
		High flow	260°C (500°F)		UH1016 (M)
	Glass filled	Standard flow	TBD	10-30%	Under development
	Mineral filled				
	Carbon and/or PTFE filled	Standard flow	>250°C (480°F)	0-30%	Under development
Extem XH resin series	Unfilled	Standard flow	250°C (482°F)		AUT250 (M)†
		Standard flow	250°C (482°F)		XH1005 (P)
		High flow	250°C (482°F)		XH1015 (P)
	Glass filled	Standard flow	>250°C (482°F)	10-20%	Under development
		Standard flow	257°C (495°F)	30%	XH2315
	Mineral filled				
	Carbon and/or PTFE filled				

F = Food contact approval under development
M = Optimized mold release for metallized reflectors
P = Powder
† – AUT250 offers haze-onset temperatures up to 250°C (482°F) for lighting reflector/projector applications

Extem resins product nomenclature

Extem XX ABCD ZZ

Platform — Product family — Standard numerical convention — Grade suffix

Platform
- U = Extem UH
- X = Extem XH
- H = Healthcare

Product family
- UH = Ultra performance
- XH = High heat
- HE = Healthcare Extem

Standard numerical convention

A – Filler Type
- 1 = Unfilled
- 2 = Glass fiber
- 3 = Mineral
- 4 = Wear resistant
- 7 = Carbon fiber

B – Filler level

1 = 10%	6 = 5%
2 = 20%	7 = 15%
3 = 30%	8 = 15%
4 = 40%	9 = 35%
5 = 50%	0 = 0%

C – Flow
- 0 = Standard
- 1 = Easy flow
- 4 = Highest flow

D – HDT‡ of final resin/blend

9 ≥ 290°C	4 ~ 240°C
8 ~ 280°C	3 ~ 230°C
7 ~ 270°C	2 ~ 220°C
6 ~ 260°C	0 ≤ 219°C
5 ~ 250°C	

‡ 2nd digit of HDT @ 0.45 MPa (66 psi)

ZZ grade suffix
- HF = High flow
- R = Standard release
- M = Release for metallization
- P = Powder
- V = UL rated

4.1 Thermal properties

Extem* resins' high glass transition temperature (Tg) coupled with its high heat deflection temperature (HDT) contributes to its excellent retention of physical properties at elevated temperatures (see figure 4.1).

Extem resins are inherently thermally stable and offer extended application use temperatures as high as 250°C (482°F) (see figure 4.2). Relative thermal index (RTI) testing is underway according to UL7468.

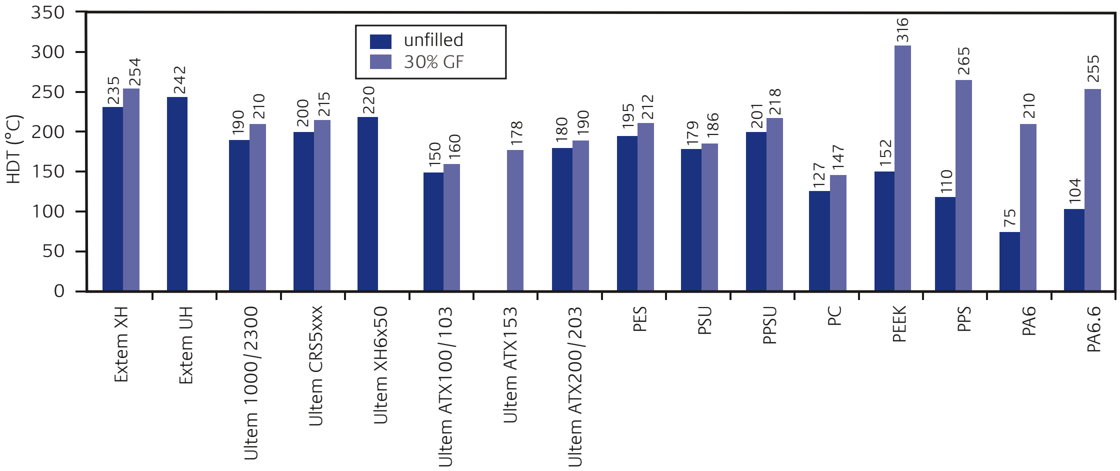


Figure 4.1
Compares the high heat deflection temperature of Extem and Ultem* resins with those of other high performance engineering thermoplastics measured at 1.82 MPa (264 psi).

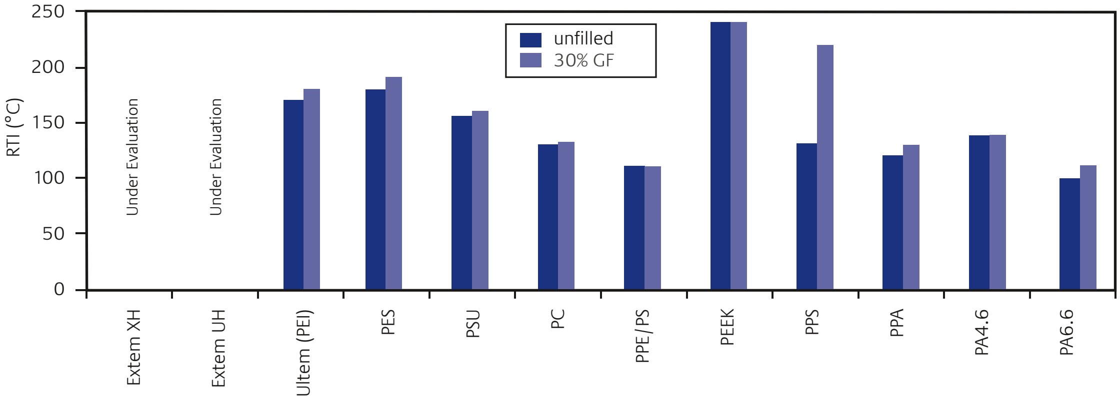


Figure 4.2
RTI properties of high performance engineering thermoplastics.

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 Extem and Ultem resin families, and demonstrates the capability of matching the values of several metals.

Due to their high glass transition temperatures (Tg), Extem and 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.

Table 4.1
Coefficient of linear thermal expansion

Material	CTE flow direction ppm/°C	CTE cross flow direction ppm/°C
Extem UH1006	46	47
Extem XH1005	50	51
Extem XH2315	16	53
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	
Copper/Brass	16-18	
Steel	12-15	
Zinc	27	

4.3 Flammability

Flame resistance

Extem* resins exhibit exceptional flame resistance without the use of additives. Extem UH1006 resin (unfilled) is rated under UL94 V0 at 0.4 mm for all colors, and 5VA at 3.0 mm. Extem XH1005 (unfilled) resin is rated under UL94 V0 at 0.75 mm for all colors.

Glass filled Extem XH2315 is currently being tested. For actual information on all UL-listed grades, see the UL yellow cards. In addition, as shown in figure 4.3, Extem, 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. Extem resin provides enhanced performance vs. Ultem resins (see figure 4.2).

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

OEM spec	Vertical burn FAR 25.853	OSU heat release FAR 25.853	Smoke Ds, 4min ASTM F814/ E662 ABD0031 BSS7238	Toxicity draeger tube ABD0031 BSS7239
Extem UH	a (60s), Pass	0/21† Pass	<50, Pass	Pass
Extem XH	a (60s), Pass	3/41† Pass	<50, Pass	Pass
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

† actual values

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.

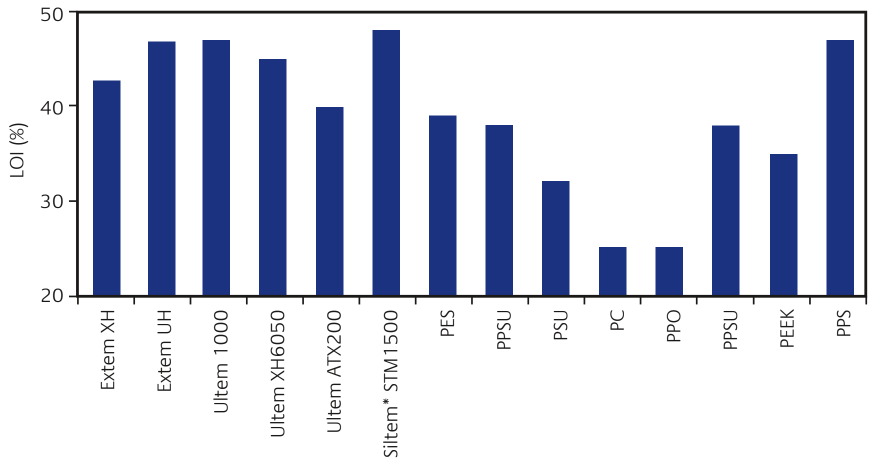


Figure 4.3
Limited oxygen index of various unfilled polymers.

4.4 Mechanical properties

Strength

At room temperature, Extem* resin exhibits strength well beyond that of most engineering thermoplastics, with a tensile stress at yield of 120 MPa (17.4 ksi, ISO R527) Extem UH1006 and 103 MPa (14.9 ksi) Extem XH1005, and a flexural strength at yield of 175 MPa (25.4 ksi, ISO 178) Extem UH 1006 and 168 MPa (24.4 ksi) Extem XH1005. Figure 4.4 demonstrates the higher tensile strength of Extem resins compared to other high performance engineering materials.

The outstanding inherent strength of Extem resin is further enhanced through reinforcement with glass fibers. Even more impressive is the retention of strength at elevated temperatures. At 170°C (338°F), a temperature well beyond the useful range of most other engineering thermoplastics, Extem resin retains approximately 60 MPa (8.7 ksi) tensile strength (ISO R527), as illustrated in figure 4.5.

Modulus

Another outstanding mechanical property of Extem resin is its high modulus. The 3520 MPa (511 ksi) flexural modulus (ISO 178) of Extem UH1006 and 3130 MPa (454 ksi) of Extem XH1005 resins are some of the highest room temperature moduli of any high performance engineering plastic. In load bearing applications where deflection is a primary consideration, unreinforced Extem resin provides structural rigidity approaching that of many glass reinforced resins. Extem resin maintains a high modulus at elevated temperatures, as shown in figures 4.6 and 4.7. For example, at over 200°C (392°F) the modulus of Extem resin is higher than that of most engineering plastics at room temperature.

Thus, Extem 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 Extem 2000 resin series provides additional performance with flexural moduli as high as 10,500 MPa (1,532 ksi, ISO 178) at room temperature.

Ductility

In addition to its unique combination of high strength and modulus, Extem resin exhibits good practical ductility. Its tensile elongation at yield affords the freedom to incorporate snap fit designs for ease of assembly. Since Extem 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.

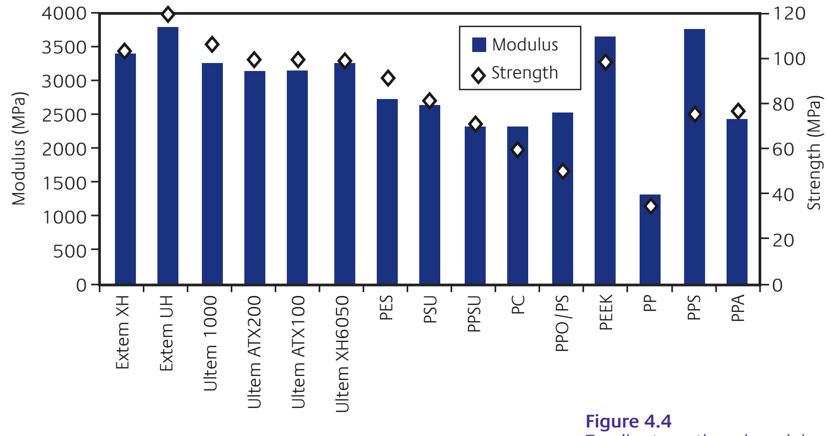


Figure 4.4
Tensile strength and modulus of various materials at 23°C, 5mm/min.

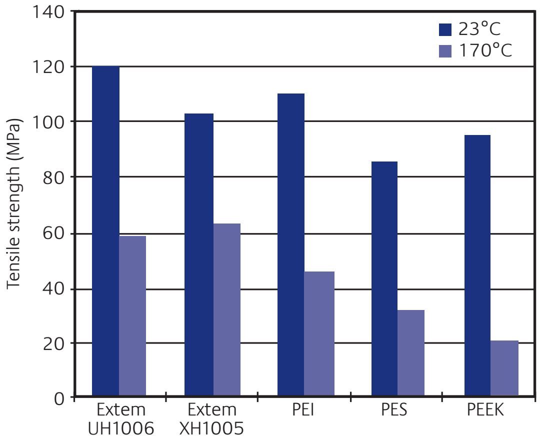


Figure 4.5
Extem resin has excellent strength retention at elevated temperatures in unfilled, thermoplastic materials.

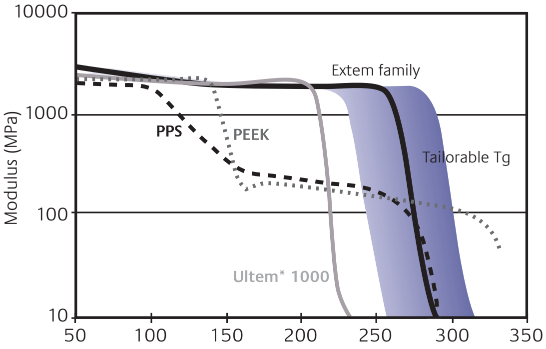


Figure 4.6
Storage modulus of unfilled Extem UH blends versus other unfilled polymers as a function of temperature by DMA.

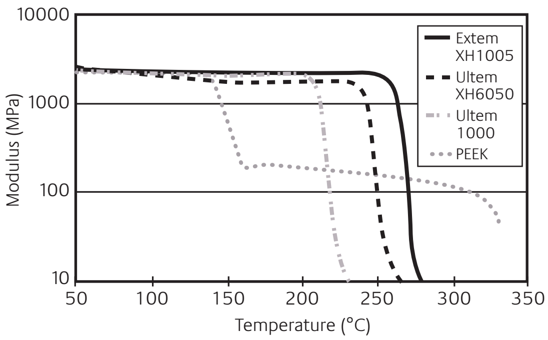


Figure 4.7
Storage modulus of unfilled Extem XH resin versus other unfilled polymers as a function of temperature by DMA.

Fatigue endurance

Fatigue is an important design consideration for parts subjected to cyclical loading or vibration. In such applications, a 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. Extem* resin displays excellent creep resistance even at temperatures and stress levels which would preclude the use of many other thermoplastics (see figure 4.9).

4.5 Electrical properties

Extem 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 Extem resins excellent candidates for highly demanding electrical and electronic applications (see tables 4.3 and 4.4).

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.

Dissipation factor

As shown in Table 4.4, Extem resins exhibit an exceptionally low dissipation factor over a wide range of frequencies, particularly in the kilohertz (10^3 Hz) and megahertz (10^6 Hz) ranges. 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 and constant

An excellent electrical insulator, Extem UH resin exhibits a dielectric strength of 22 kV/mm at 1.5 mm (in air). The effect of thickness on dielectric strength for Extem resin is shown in table 4.3. Table 4.4 shows Extem resins' dielectric constant performance.

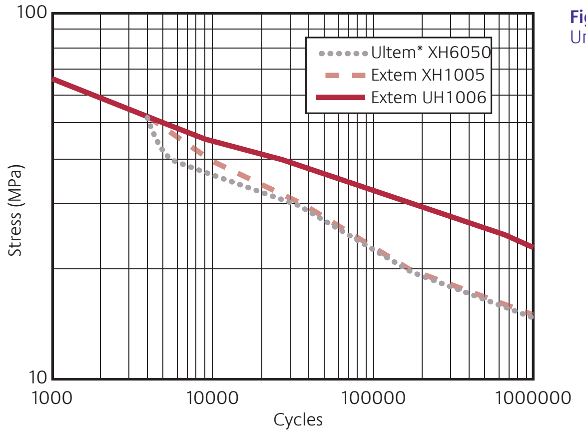


Figure 4.8
Uniaxial fatigue test.

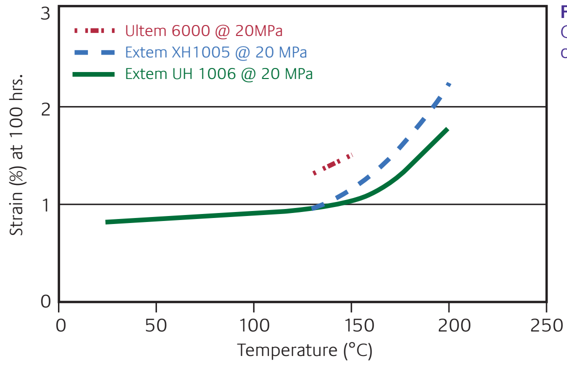


Figure 4.9
Creep strain as function of time of various materials.

Table 4.3
UL summary

Characteristics	Unit	Standard	Extem UH1006	Extem XH1005
Hot-Wire Ignition (HWI)	PLC code @ 0.75mm	UL 746A	1	3
High-Current Arc Ignition (HAI)	PLC code @ 0.75mm	UL 746A	0	2
Comparative Tracking Index (CTI)	PLC Code (Volts)	UL 746A	4	4
High-Voltage Arc Tracking Rate (HVTR)	PLC Code (in mm/min)	UL 746A	3	n
High volt, low current arc resistance	PLC Code (in Sec)	ASTM D495	6	n
Dielectric strength, air, 1.5mm	kV/mm	UL 746A	22	25
Volume resistivity	10^x ohm-cm	ASTM D257	15	16
Glow-Wire Flammability Index (GWFI) 960°C, passes at	mm	UL 746A	0.75	0.75
Glow-Wire Ignition (GWIT) 875°C, passes at	mm	UL 746A	0.75	0.75

n – not tested

Thickness (mm)	Dielectric constant IEC250/ASTM D 150				Dissipation factor IEC 250/ASTM D 150			
	1KHz	100KHz	1MHz	10MHz	1KHz	100KHz	1MHz	10MHz
Extem* UH1006 resin, 1 mm								
Average	3.1783	3.1563	3.1142	3.0976	0.0141	0.0609	0.0774	0.0005
Extem UH1006 resin, 3 mm								
Average	3.5921	3.5552	3.4983	3.4961	0.0141	0.0664	0.0863	0.0005
Extem XH1005 resin, 1 mm								
Average	3.1400	3.1185	3.0590	3.0749	0.0208	0.0547	0.0918	0.0007
Extem XH1005 resin, 3 mm								
Average	3.4724	3.4446	3.3984	3.3866	0.0233	0.0589	0.0983	0.0006

Table 4.4
Extem resin – Dielectric constant and dissipation factor.

Conditioning standard: ASTM measuring condition Dk/Df: 25°C/50% RH

NOTE: Please note that some of the samples were milled and so surface was not very smooth. This could cause added airgap in the Dk/Df measurement which could affect the data. This also shows up as high RSD values for some of the readings. For complete confidence on the data, it might be better to do measurement on molded specimens with smooth surface.

4.6 Environmental resistance

Chemical resistance

Unlike most amorphous resins, Extem* thermoplastic polyimide (TPI) resin demonstrates unusually good resistance to a wide range of chemicals. Table 4.5 lists the performance of Extem 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.

Extem 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 Extem UH 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 and Extem resins.

General solvents

Extem resins are soluble in the following chemicals
Extem XH resin series: n-methylpyarolidone (NMP), dimethylformamide (DMF), 1,2-dimethoxybenzene, phenol, methylene chloride and chloroform
Extem UH resin series: dimethylacetamide (DMAc) and NMP – low room temperature solubility

Agency recognition

Extem resins have and are being tested and comply with various agency regulations and specifications. The Extem resins' heat stability and flammability characteristics make them excellent choices for numerous applications which require Underwriters Laboratory, UL, approval. Several grades of Extem resin are also being tested 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.

Table 4.5
Generic chemical compatibility of Extem and Ultem resin vs. other SABIC Innovative Plastics' resins.

Reagent	Amorphous TPI and PEI		Amorphous materials					Semi-crystalline materials			
	Extem UH resin	Extem XH resin	Ultem resin	Lexan* resin	Cycoloy* resin	Cycolac* resin	Noryl* 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	0/—
Alcohols	+	+	+	+	n	+	+	+	+	+	0/—
Phenols	—	—	—	—	—	—	—	n	—	—	—
Ketones	0	—	—	—	—	—	—	—	0/—	0	++
Amines	n	n	n	n	—	n/—	0/—	n	n	—	—
Esters	++	0/+	0/+	0/—	—	0	+	—	0/—	+	++
Ethers	+	+	+	—	—	0	0	n	+	+	++
Acids											
Acids – inorganic	0/+	0/+	0/+	0/—	0	+	0	0/+	+	0	—
Acids – organic	0/+	0/+	0/+	0	0	—	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	n	—	n	—	—	+	++	+	+	++
Detergents – cleaners	+	+	+	n	0/+	0/+	0/+	+	+	++	0/+
Water – hot (<176ºF (80ºC)	0	+	+	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

4.7 Haze temperature

Haze temperature is the temperature at which the aluminum substrate deforms and causes reflection loss (iridization), in applications such as lighting and automotive reflectors/projectors.

- Haze temperature increased to 250-255°C for Extem* XH and Extem AUT250 resins, as shown in figure 4.10
- Annealing increases minimum haze temperature to 255°C
- Molding optimization required to probe unannealed entitlement

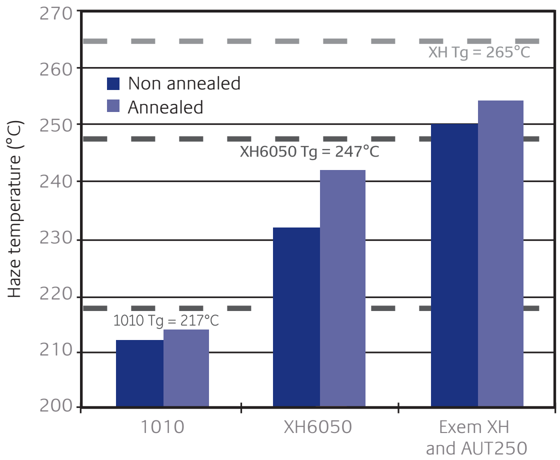


Figure 4.10
Extem resin haze temperature

4.8 Physical properties

Extem XH resin series typically offer 10-20% improved flow over Ultem* resins when processed at melt temperatures 380-410°C (716-770°F) (see figure 4.11). Extem UH resin series is more viscous but injection moldable into relatively thin-walled parts to take advantage of its extreme performance characteristics (see figure 4.11).

Figures 4.12 to 4.17 show Extem resins' capillary rheology and spiral flow performance over a range of melt temperatures and injection pressures.

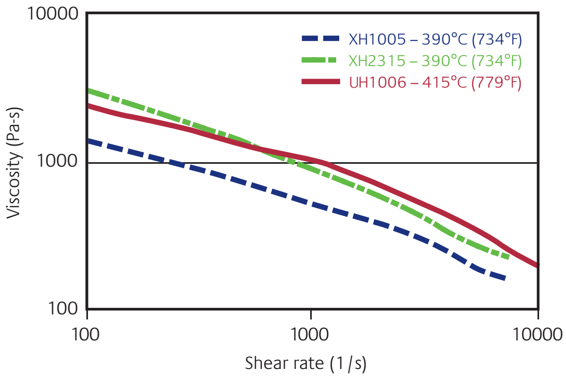


Figure 4.11
Extem resin capillary rheology

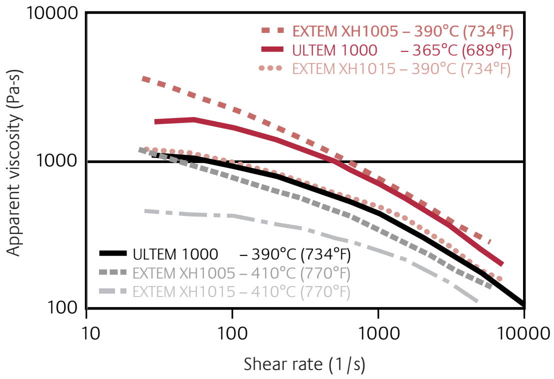


Figure 4.12
Extem resin capillary rheology

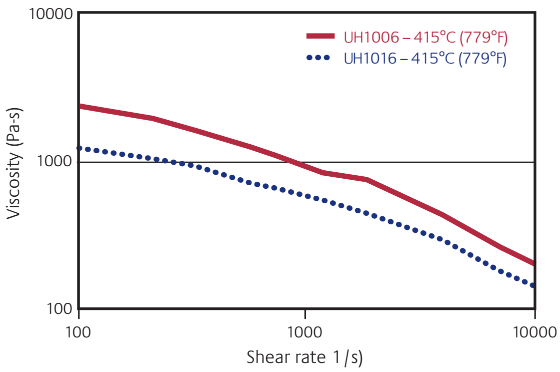


Figure 4.13
Standard and high flow grades

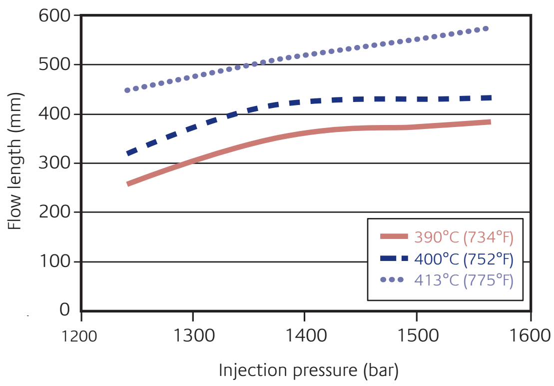


Figure 4.14
Spiral flow analysis of Extem* XH1005 (120 mil/3.0 mm)

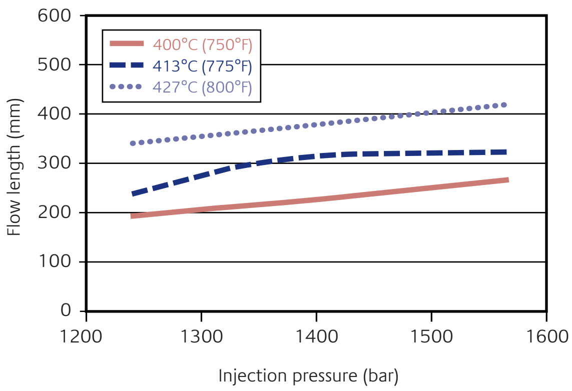


Figure 4.16
Spiral flow analysis of Extem UH1006 (120 mil/3.0 mm)

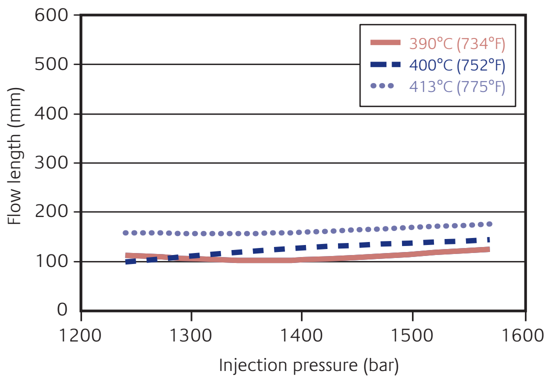


Figure 4.15
Spiral flow analysis of Extem XH1005 (60 mil/1.5 mm)

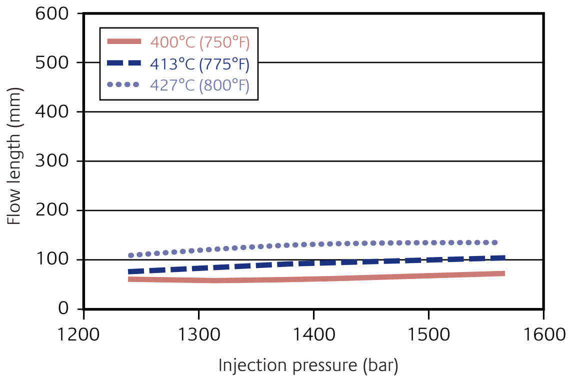


Figure 4.17
Spiral flow analysis of Extem UH1006 (60 mil/1.5 mm)

4.8.1 Water moisture absorption

- All Ultem* and Extem* resin grades absorb water/moisture (see figure 4.18)
- Level depends on time, temperature, pressure and humidity
- Level depends on resin type and filler levels
- Small swelling can occur due to water/moisture uptake
- Proper predrying recommended prior to processing. (Consult datasheet or SABIC Innovative Plastics Technical Support)
- Moisture may affect secondary operations and in some cases predrying is recommended

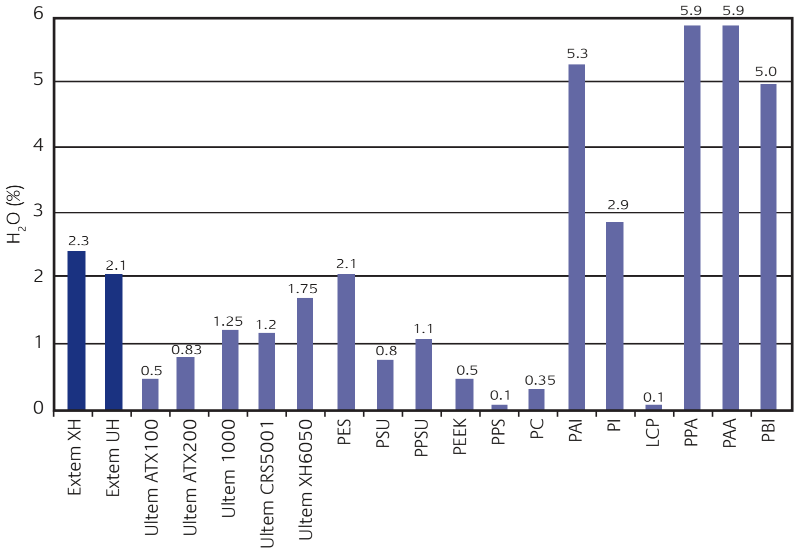


Figure 4.18
Water absorption of various polymers (condition: 23°C, saturation)

4.8.2 Refractive index

		Ultem 1010	Ultem XH6050	Extem XH1005	Extem UH1006
Refractive Index					
	1550 nm	1.6272	1.6289	1.6238	1.6449
	1310 nm	1.6291	1.6308	1.6258	1.6476
	850 nm	1.6395	1.6409	1.6363	1.6612
nC	656.3 nm	1.6536	1.6551	1.6504	1.6787
nd	587.6 nm	1.6633	1.6651	1.6600	1.6902
ne	546.1 nm	1.6715	1.6737	1.6682	1.6997
nF	486.1 nm	1.6887	1.6920	1.6851	1.7192
ng	435.8 nm	1.7113	1.7165	1.7072	1.7439
Abbe		18.9	18.0	19.0	17.0
dn/dt (10^{-5}) 30° - 90°C (86° - 194°F)					
	1550 nm	-10.4	-9.6	—	—
	1310 nm	-9.7	-8.9	—	—
	825 nm	-10.6	-10.8	-9.1	—
	633 nm	-10.5	-10.4	-9.2	-7.7

Table 4.6
Typical refractive index data for Ultem and Extem resins

4.8.3 Light transmission

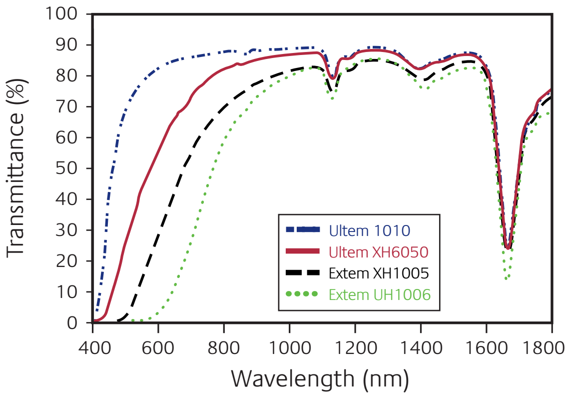
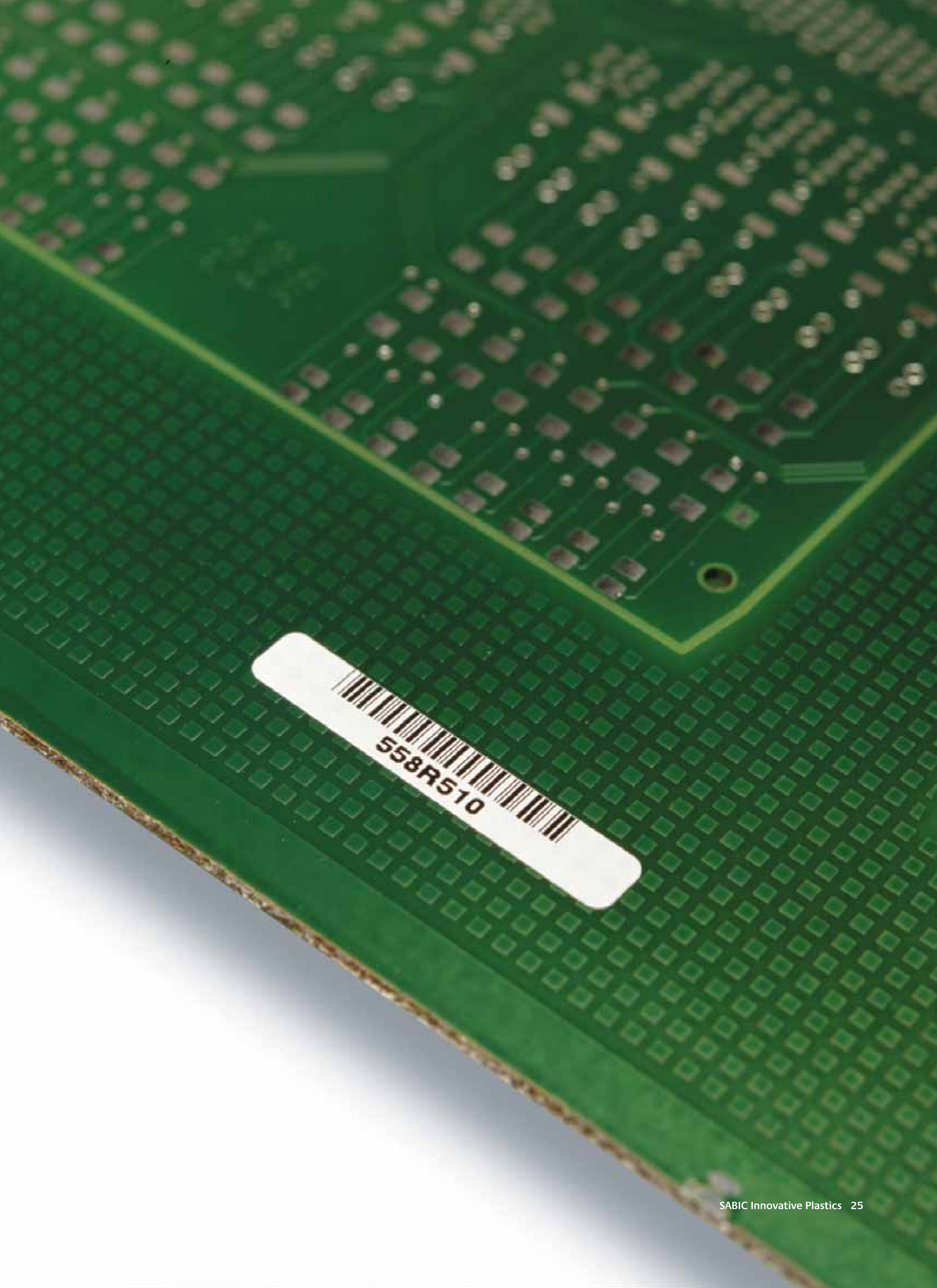


Figure 4.19
Light transmittance @ 3.2mm (0.125 in)


558R510

4.9 Extem* resin properties

Typical properties[1]	Unit	Standard	Ultem* resins (unfilled)		
			1000	CRS5001	XH6050
MECHANICAL					
Tensile stress, yield	MPa (ksi)	ASTM D638	110 (16)	99 (14)	96 (14)
Tensile elongation, yield	%	ASTM D638	7		6
Tensile elongation, break	%	ASTM D638	60	60	25
Tensile modulus	MPa (ksi)	ASTM D639	3600 (519)	2890 (419)	3500 (509)
Flexural modulus	MPa (ksi)	ASTM D790	3500 (509)	3100 (449)	3170 (459)
Flexural strength	MPa (ksi)	ASTM D790	165 (24)	137 (20)	155 (23)
IMPACT					
Izod impact, unnotched, 23°C (73°F)	J/m (ft-lb/in)	ASTM D4812	1335 (25)	2082 (39)	No Break
Izod impact, rev. notched, 23°C (73°F)	J/m (ft-lb/in)	ASTM D256	1174 (22)	1281 (24)	
Izod impact, notched, 23°C (73°F)	J/m (ft-lb/in)	ASTM D256	32 (0.6)	64 (1.2)	69 (1.3)
THERMAL					
Glass transition temp., Tg	°C (°F)	Internal method	217 (423)		247 (477)
CTE, 23°C to 150°C, flow	1/°C	ASTM E831	5.6E-05		5.0E-05
CTE, 23°C to 150°C, xflow	1/°C	ASTM E831	5.4E-05		5.0E-05
Vicat softening temp, rate B/50	°C (°F)	ASTM D1525	218 (426)		242 (467)
HDT, 0.45 MPa, 3.2mm (66 psi, 0.25”), unannealed	°C (°F)	ASTM D648	206 (403)		
HDT, 1.82 MPa, 3.2mm (264 psi, 0.25”), unannealed	°C (°F)	ASTM D648	191 (376)	207 (405)	217 (422)
PHYSICAL					
MFR, 337°C, 6.6 kgf	g/10min	ASTM D1238	9	4	
MFR, 367°C, 6.6 kgf	g/10min	ASTM D1238			12
MFR, 400°C, 6.6 kgf	g/10min	ASTM D1238			
Water abs, equilibrium, 23°C	%	ASTM D570	1.3		1.8
Moisture abs, 24h, 50% RH, 23°C	%	ASTM D570	0.3	0.2	0.6
Density	g/cc	ASTM D792	1.27	1.28	1.31
Mold Shrinkage	%	Internal method	0.5 - 0.7	0.4 - 0.7	0.5 - 0.7
FLAME CHARACTERISTICS					
UL recognized, 94V-0 Flame class Rating	mm (in)	UL94	1.5 (0.059)	1.49 (0.059)	
UL recognized, 5VA Flame class Rating	mm (in)	UL94	3 (0.118)		
Oxygen index (LOI)	%	ASTM D2863	47		45

Extem* XH resins (unfilled)		Extem UH resin (unfilled)	Ultem* resins (30% GF)		Extem XH resin (30% GF)
AUT250[2]	XH1005	UH1006	2300	CRS5301	XH2315
103 (15)	103 (15)	120 (17)	168 (24)	165 (24)	156 (23)
7	7	9			3
10	15	20	3	3	3
3420 (496)	3420 (496)	3800 (550)	9300 (1349)	8960 (1299)	10230 (1483)
3130 (454)	3130 (454)	3520 (511)	8960 (1299)	8960 (1299)	8960 (1299)
168 (24)	168 (24)	175 (25)	227 (33)	234 (34)	206 (30)
1650 (31)	1850 (34)	1950 (37)	427 (8)		1387 (26)
	1444 (27)		491 (9)	555 (10)	320 (6)
43.8 (0.8)	43.8 (0.8)	75 (1.4)	85 (1.6)	112 (2.1)	86 (1.6)
267 (512)	267 (512)	250/305 (482/581)			267 (512)
5.0E-05	5.0E-05	4.6E-05	2.0E-05		1.6E-05
5.1E-05	5.1E-05	4.7E-05			5.3 E-05
260 (500)	260 (500)	257 (495)	227 (442)		267 (512)
250 (482)	250 (482)	263 (505)	212 (414)		257 (495)
235 (455)	235 (455)	242 (464)	210 (410)	221 (430)	254 (489)
			5	2	
10	6				4
		10			
2.4	2.4	2.1	0.9		2.4
0.6	0.6	0.6			0.6
1.31	1.31	1.37	1.51	1.51	1.52
1.0 - 1.2	1.0 - 1.2	0.8 - 1.0	0.2 - 0.4	0.2 - .04	
	0.75 (0.030)	0.4 (0.016)	0.25 (0.010)	1.47 (0.058)	
		3 (0.118)	1.21 (.048)	1.47 (0.058)	
	43	47	50		

(1) Typical properties taken from datasheets available on SABIC Innovative Plastics web site.

(2) Extem AUT250 resin – Similar to Extem XH1015 but designed for automotive lighting applications that typically required ~250°C haze onset temperature and are metallized.

To extract the maximum performance from Extem* 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 Extem 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

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

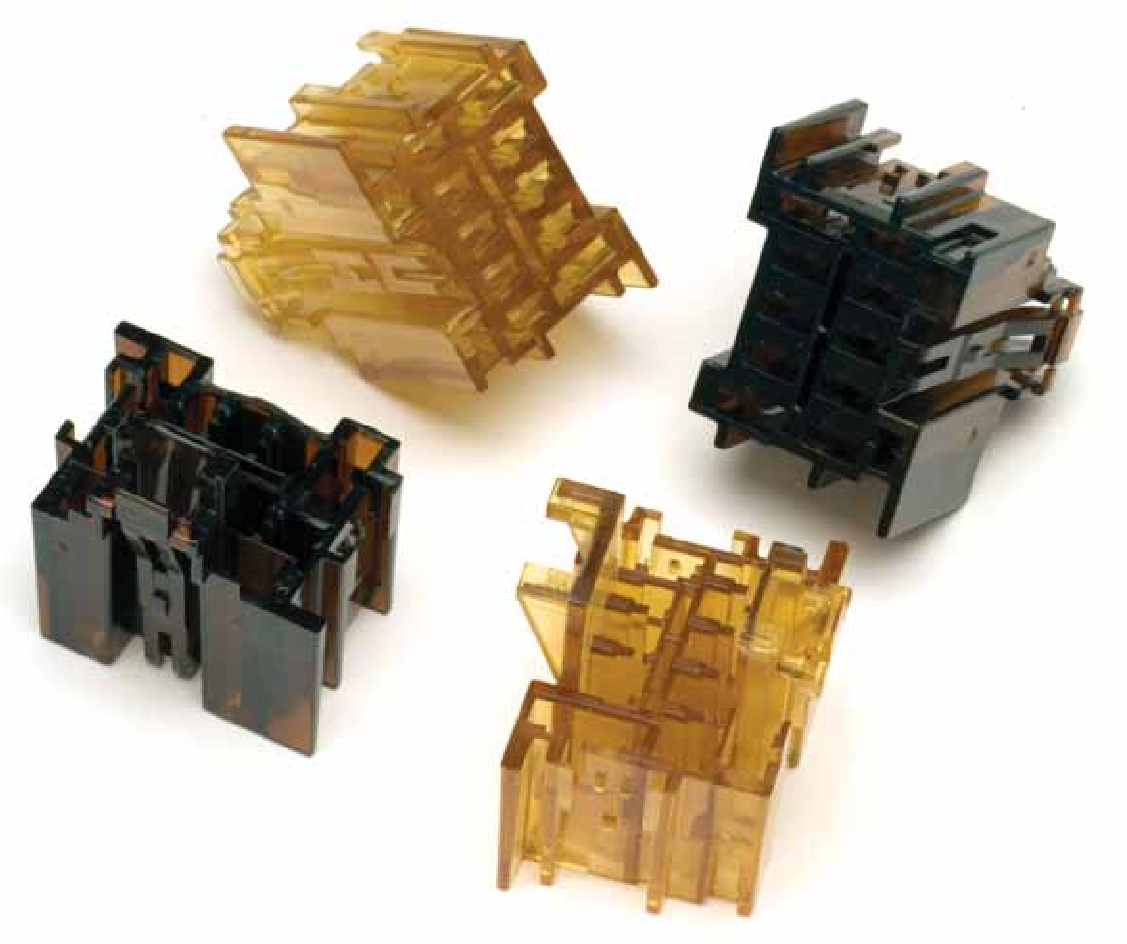
5.1 Color

Extem resins have a dark amber base color. Extem XH resin series is transparent and Extem UH blend series is translucent. Limited opaque and transparent colors can be matched on request.

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.



The excellent processing characteristics and the amorphous nature of Extem* thermoplastic polyimide (TPI) 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.

Extem resins have been successfully molded in parts weighing as little as a few grams to parts weighing as much as several kilograms. Extem resins can also be processed in extrusion applications. Extem UH 1006 resin's "foamy" appearance is due to the die swell effect since it is a blended product. For well dried (<0.02%) resin, the swelling does not adversely affect part performance.

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

Extem resins can be molded on most standard injection molding machines provided the heat capability is sufficient. Although Extem resins are stable at process temperatures, it is recommended to keep residence times minimal by selecting appropriate machine size vs shot size and thoroughly drying the resin to < 0.02% moisture content.

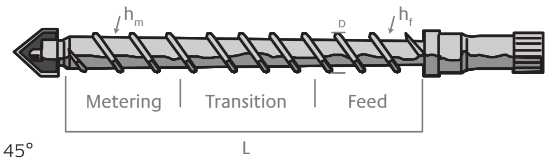
Conventional materials of construction for compatible screws and barrels are generally acceptable for processing Extem resins. The use of bimetallic barrels is suggested. Depending on screw diameter, a compression ratio of about 2.2:1 with a length to diameter ratio of 20-24:1 is preferred (see figure 6.1). A feed zone of 5D, a compression zone of 10D and a metering zone of 5D 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 2.2:1 have been used successfully. Nitrided materials are not recommended for the screw or barrel.

The non-return valve should be of the sliding check ring type. Do not use a ball check valve.

Cold and hot runners are successfully used for molding Extem resin parts. For hot runners 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 430ºC (806ºF) should be possible. Use generous gates, such as fan gates, where possible. Sub-gates have also been successfully used to mold Extem resin. Pin gates may cause shear degradation. It is recommended to make flow studies of the part including hot runner 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.

Screw length	Suggested 20D (1040 mm)	
Screw configuration		**Europe – Typical GP Screw**
– Feeding zone	20-25% (4-5 flights)	~50%
– Transition zone	50-55% (10-11 flights)	~25%
– Metered zone	20-25% (4-5 flights)	~25%
Flight depth feed	7.2-7.8 mm	
Flight depth meter	3.4-3.6 mm	
Compression ratio	2.0-2.3:1	
No flow back valve angle of back ring	45°	



• Do not use a ball check valve
• Nitrided materials are not recommended for screw or barrel

Figures 6.1
Extem resin injection molding screw design

6.1.1 Pre-drying Extem* resins

Extem resins absorb atmospheric moisture which can cause degradation of the polymer during processing. Moisture content higher than 0.02% (200 ppm) 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 Extem resin at temperatures suggested in Table 6.1. Extem resins can reabsorb moisture quickly, ~15-30 minutes exposure to rise to greater than 0.02% (200 ppm). A closed loop, dehumidifying, recirculating hot air dyer with after-cooler is highly recommended.

Table 6.1 Extem resin drying conditions.

Resin family	Drying temp °C/°F	Minimum drying time – hrs
Extem UH resins	175/347	6
Extem XH resins	175/347	6
Ultem* resins	150/300	4

Drying Recommendations

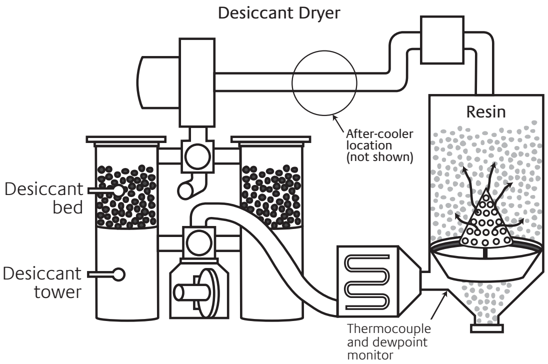
Requirements

- Closed loop, dehumidifying, recirculating hot air hopper. Dryer conveying equipment recommended to minimize moisture exposure (see Illustration 6.1)
- After-cooler highly recommended
- Drying conditions
  350°F (177°C) for 6-8 hours
  Moisture content < 0.02% (200 ppm)
  Air flow : 1 CFM per lb of resin per hour
  Dew point of air: -20°F to -40°F
  (hopper inlet); (-29°C to -40°C)
  Do not dry in excess of 24 hours
  Minimize resin in feed hopper
  Do not rely 100% on dewpoint meter

Potential Processing Issues

- Splay
- Poor impact properties (brittleness)
- Excessive flow

Illustration 6.1 Typical Dryer Setup



Extem XH and UH resin series are robust products when exposed to drying conditions for 48-72 hours. Table 6.2 and 6.3 show little effect on properties when dried at 150-175°C (300-350°F) for extended periods.

Table 6.2 Extem UH resin drying study

ASTM Properties at 23°C (73°F)	Unit	Drying time (hour) at 175°C (347°F)			
		4	8	24	48
Tensile Modulus	MPa	3,840	3,810	3,700	3,800
Tensile Strength	MPa	114	108	109	111
Flexural Modulus	MPa	3,430	3,410	3,430	3,440
Flexural Strength	MPa	162	178	179	177
Izod Impact (Notched)	J/m	61	62	66	58

Table 6.3 Extem XH resin drying study

ASTM Properties at 23°C (73°F)	Unit	Drying time (hour) at 150°C (302°F)			
		6	24	72	% Change @ 72 hrs
MECHANICAL					
Tensile modulus	MPa	3500	3620	3600	2.9%
Tensile stress, yield	MPa	79.6	84.2	81.6	2.5%
Flexural modulus	MPa	3500	3620	3600	2.9%
Flexural strength	MPa	168	163	171	1.8%
IMPACT					
Izod impact, unnotched, 23°C	Ft-lb/in	0.8	0.8	0.8	0.0%
THERMAL					
Glass transition Temp., Tg	°C	268	268	269	0.4%
HDT, 0.45 MPa, 3.2 mm (un-annealed)	°C	251	251	251	0.0%
HDT, 1.82 MPa, 3.2 mm (un-annealed)	°C	236	234	232	-1.7%
PHYSICAL					
MFR, 367°C, 6.6 kgf	g/10mi	5.4	5.2	5.1	-5.8%

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).

Pre-drying Extem resins

SABIC Innovative Plastics worked with several global dryer and moisture analyzer manufacturers to independently characterize Extem resins. To ensure the Extem resin is dried to a moisture content less than 0.02% (200 ppm), use a moisture analyzer which has been calibrated for Extem resins. Sartorius Omnimark and Arizona Instruments are moisture analyzer makers with Extem resins in their data base. Novatec (USA) and Matsui Manufacturing Co., Ltd. (Japan) have conducted extensive drying studies with Extem resins. Figures 6.2 and 6.3 illustrate the drying characteristics of Extem resins.

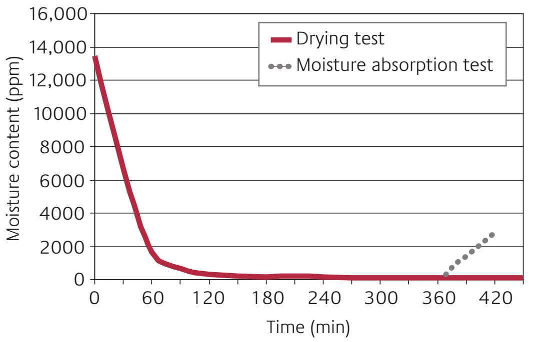


Figure 6.2a
Matsui Mfg. Co., Ltd., Japan drying and moisture absorption test results – Extem* UH1006 resin using DMZ dryer, 175°C (347°F)
- 2 hours to achieve moisture content <0.02%
- <30 minutes maximum exposure before moisture content >0.02% (Conditions: 35°C/95°F, 56% RH, typical Japanese summer)

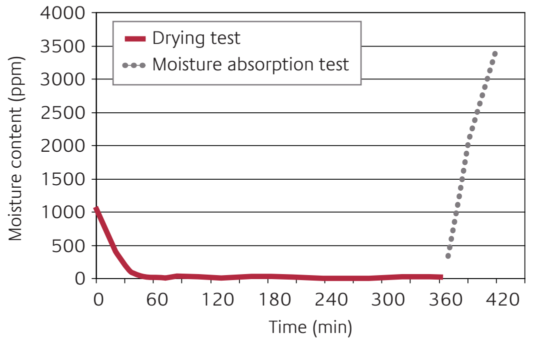


Figure 6.2b
Matsui Mfg. Co., Ltd., Japan drying and moisture absorption test results – Extem XH1005 resin using DMZ dryer, 175°C (347°F)
- <1 hour to achieve moisture content <0.02%
- <30 minutes maximum exposure before moisture content >0.02% (Conditions: 35°C/95°F, 56% RH, typical Japanese summer)

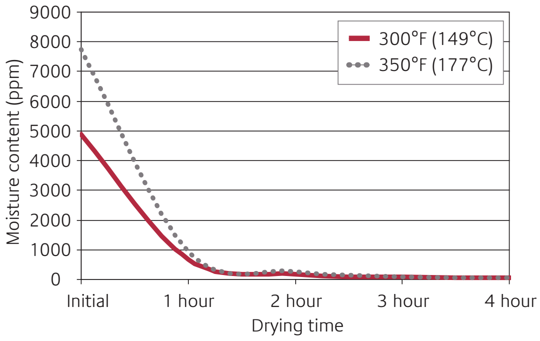


Figure 6.3a
Novatec drying and moisture absorption study – Extem UH1006 resin using NDB-25 dual bed desicant dryer.
- ~3 hours to achieve moisture content <0.02%

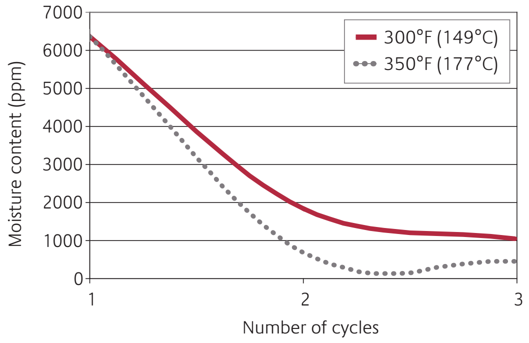


Figure 6.3c
Novatec drying and moisture absorption study – Extem UH1006 resin using VDR-30 vacuum dryer.
- 350°F (177°C), 45 minute cycles needed to achieve <0.02% moisture content

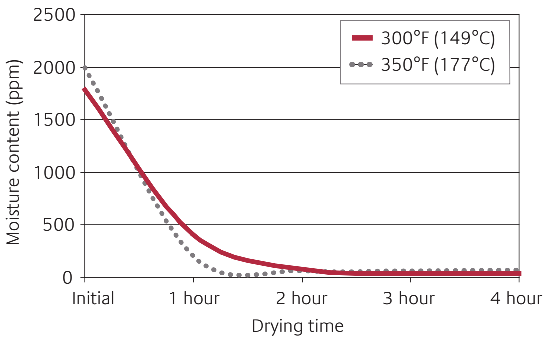


Figure 6.3b
Novatec drying and moisture absorption study – Extem XH1005 resin using NDB-25 dual bed desicant dryer
- ~2 hours to achieve moisture content <0.02%

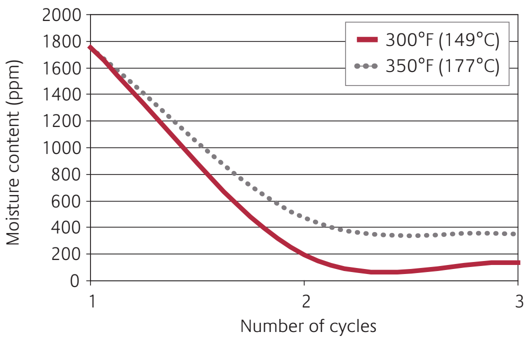
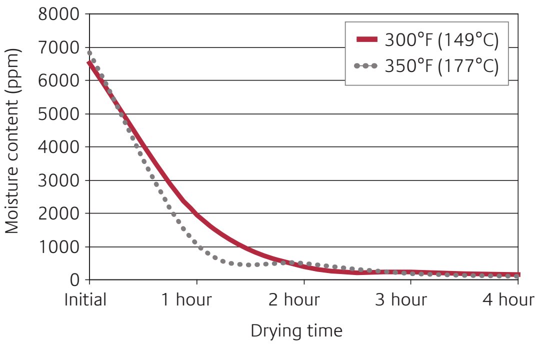
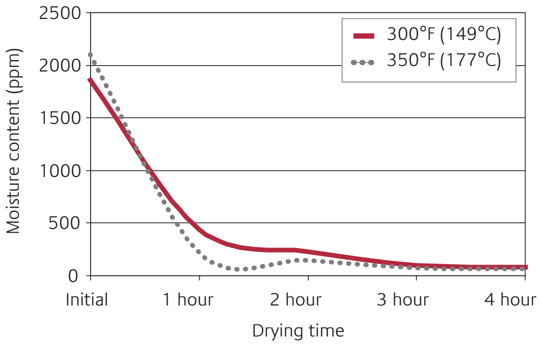


Figure 6.3d
Novatec drying and moisture absorption study – Extem XH1005 resin VDR-30 vacuum dryer.
- 30 minute cycle @ 350°F (177°C) achieves <0.02% moisture content... need ~40+ minute cycle at 300°F (150°C)



Figures 6.3e
Novatec drying and moisture absorption study – Extem* UH1006 resin using N25 compress air dryer.
• ~ 4 hours to achieve moisture content <0.02%



Figures 6.3f
Novatec drying and moisture absorption study – Extem XH1005 resin using N25 compress air dryer.
• ~3 hours to achieve moisture content <0.02%

6.1.2 Molding conditions

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

Extem resins

Process capability

- Minimal equipment investment
- Able to leverage existing mold assets
- Increased productivity via reduced cycle time
- Reduced scrap … fully recyclable
- Process development assistance available via SABIC Innovative Plastics Field Tech Service

Extem UH resin process guidelines

Best practices

- Barrel temperature profile depends on residence time
  – Flat profile for ~2-3 min residence time
  – Ramp profile for longer residence time
- Use 40-70% of barrel capacity per cycle to reduce residence time
- Extem UH resins are amorphous and do not need long cooling times (unlike crystalline resins)
- Use low shear screw to minimize shear (similar to Ultem* resin)
- Higher back pressure may help surface appearance. Minimize decompression/suckback (can cause splay)
- Use slow injection velocity to reduce shear splay – decoupled molding preferred
- Purge with Ultem 1000 or XH6050 resin when possible
- During shut-down, heaters can be banked at 200-225°C (392-437°F) after all the residual resin is run out of the barrel

Critical success factors

- DRYING…must dry to ≤0.02% (200 ppm) moisture. Good dehumidifying dryer is critical (verify dew point; must target -40°C/-40°F). If needed, dry longer than 6 hours and at a higher temperature (200°C/392°F). After-cooler recommended
- FEEDING…minimize exposure of dried resin to humid air to avoid moisture absorption. Cover the feed hopper in case of an open hopper
- RESIDENCE TIME…use a ramp profile for residence times > 2-3 minutes
- INJECTION SPEED…slow speed (e.g., 15-25 mm/sec) is better for part appearance
- GATES…pin-gates (used for crystalline resins) cause shear degradation. Use generous gates when possible

Extem XH resin process guidelines

Best practices

- Ramp-up barrel temperature from rear zone to nozzle. Avoid pin gates
- Use 40-70% of barrel capacity per cycle to reduce residence time
- Use low shear screw design to minimize shear
- Use high heat rated (ceramic) heater bands
- Minimize back pressure and do not use decompression/suckback (causes splay)
- Slow injection speed (e.g., 15-25 mm/sec) is better for part appearance
- Higher injections speeds give higher gloss, but watch for shear induced splay
- Purge using Ultem 1000 resins

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

Extem* 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 plastication when molding reinforced grades.

6.1.4 Purging

Thorough purging is essential when changing to or from Extem resin in machines used for other plastics. Since Extem 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 Extem resin is Ultem* 1000 or XH6050 resins. Drying of the purging material is not required. Begin purging at the processing temperature of Extem 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 Lexan* polycarbonate and HDPE.

Styrenes and acrylic resins should not be used in high-heat purging.

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 Extem resins. When stopping for longer than approximately 30 minutes, lower the temperature to 200°C (400°F).

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. Extem resins demonstrate excellent recyclability and property retention.

Table 6.4
Extem resin processing guidelines

		Extem UH10x6[1] resin	Extem XH10x5[1] resin
Maximum moisture content	%	0.02	0.02
Drying temperature	°C (°F)	175 (347)	175 (347)
Drying time (minimum)	Hrs	6	6
Drying time (cumulative)	Hrs	24	24
Melt temperature	°C (°F)	400-415 (752-779)	380-410 (716-770)
Nozzle temperature	°C (°F)	395-415 (743-779)	375-405 (707-761)
Front – Zone 3 temperature	°C (°F)	395-415 (743-779)	380-410 (716-770)
Middle – Zone 2 temperature	°C (°F)	390-405 (734-761)	370-400 (698-752)
Rear – Zone 1 temperature	°C (°F)	380-390 (716-734)	360-385 (680-725)
Mold temperature	°C (°F)	150-175 (302-347)	150-175 (302-347)
Back pressure	bar	3 - 5	3 - 5
Screw speed	rpm	30 - 70	70 - 100
Shot to cylinder size	%	40 - 70	40 - 70

[1] Extem UH10x6 and XH10x5 resins are available in standard and high flow.

6.2 Extrusion of Extem* resins

6.2.1 Extrusion

Extem resins are used successfully in many extrusion processes for producing film, sheet, stockshapes and profiles. 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. Annealing the part can relieve internal stress and help to achieve maximum performance (see section 7.8).

6.3 Extem and Ultem* resin injection molding troubleshooting tips

Black specks

Small black areas (spots) inside the material, mostly present in transparent Extem/Ultem grades.

- Purge with Extem/Ultem regrind or un-dried Extem/Ultem resin
- Purge periodically after shut-off until cylinder temperature falls below 660°F (350°C); then continue with purging until shutdown is complete
- Bank set temperatures of machine at 350°F (180°C) when not molding Extem @ 400°F (204°C)
- Decrease nozzle temperature
- Check temperature at feed section; low temperatures may cause mechanical degradation
- Check heater bands and control
- Check nozzle tip, check ring assembly, nozzle adapter and end-cap for hang-up areas

Brittleness/cracking

The molded product is failing prematurely either after molding, during testing or during normal usage.

- Dry resin properly (<0.02% moisture content)
- Improve weld line strength (see weld lines)
- Decrease molded in stresses (see stresses)
- Lower melt temperature by
  a. Decrease cylinder temperatures
  b. Decrease screw speed
  c. Decrease back pressure
- Check for voids in the part
- Check for contamination
- Decrease the amount of regrind in feed
- Check part design (sharp corners, wall thickness transitions, bosses, etc.)
- Check tooling (venting, ejection system)
- Investigate for chemical attack

Burn marks

They are usually caused by overheating of the material due to entrapped air (diesel effect): this causes the darkening in color.

- Decrease injection speed
- Decrease booster time
- Decrease injection pressure
- Check venting channels for dirt
- Use programmed injection
- Improve venting of tool
- Alter position of gate and/or increase gate size

Discoloration

The appearance of a non-uniform color distribution in the molding.

- Purge heating cylinder
- Lower melt temperature by
  a. Decreasing cylinder temperature
  b. Decreasing screw speed
  c. Decreasing back pressure
- Lower nozzle temperature
- Shorten overall cycle
- Increase back pressure to improve melt homogeneity
- Check hopper and feed zones for contaminants
- Check for proper cooling of ram and feed zone
- Provide additional vents in mold
- Move mold to a smaller shot size press to reduce barrel residence time
- Check screw design; a high compression ratio screw may cause excessive shear heating

Gloss

- Increase mold temperature
- Increase melt temperature
- Increase injection speed
- Increase injection pressure
- Check surface of the mold for polish
- Clean vents
- Increase venting

Jetting/worming

A serpentine line on the part surface emanating from the gate.

- Decrease injection speed
- Increase melt temperature by
  a. Increasing cylinder temperature
  b. Increasing screw speed (unfilled)
  c. Increasing back pressure (unfilled)
- Increase mold temperature
- Increase gate size
- Decrease gate land length
- Modify gate location or angle: directly into wall or pin
- Avoid gating at thick section

Sink marks

Visible defects resulting from insufficient cooling before removal from the mold. A heavy rib intersecting a thin wall may show up as sink marks: these are very difficult to eliminate by varying processing conditions.

- Increase injection hold time
- Increase injection pressure
- Reduce melt temperature
- Reduce mold temperature
- Decrease injection speed
- Enlarge and/or add vents to mold parting line
- Increase size of sprue and /or runners
- Increase gate size and reduce gate land length
- Relocate gate next to heavy or thicker areas
- Core out heavy wall sections where possible

Splay marks, silver streaks

The result of
  a) Moisture on the pellets which should be removed under recommended drying times and temperatures
  b) Products of degradation due to overheating
  c) Residual non-aqueous volatiles in material

- Dry resin properly; excess moisture may cause splay
- Lower melt temperature by
  a. Decreasing cylinder temperatures
  b. Decreasing screw speed
  c. Decreasing back pressure
- Lower nozzle temperature
- Decrease injection speed
- Shorten or eliminate screw decompression
- Shorten overall cycle
- Increase or decrease mold temperature
- Check for contamination (e.g., water or oil leaking into mold cavity)
- Move mold to a smaller shot size press
- Check for drooling
- Open gates
- Check hot runner system
- Increase nozzle orifice
- Increase sprue and runner size

Sticking in cavity/core

At the end of cycle, the part does not release from the mold but sticks on the core or cavity.

- Decrease injection pressure
- Decrease hold time
- Decrease booster time
- Adjust feed for constant cushion
- Increase mold closed time
- Adjust the cavity/core temperatures to a 20° differential between mold halves
- Decrease cylinder and nozzle temperature
- Check mold for undercuts and /or sufficient draft

Sticking in sprue bushing

At end of cycle, the sprue does not release from the mold but sticks in the sprue bushing.

- Decrease injection pressure
- Increase injection hold time
- Decrease booster time
- Increase mold close time
- Decrease mold temperature at sprue bushing
- Leave nozzle against mold: no pull back
- Raise nozzle temperature
- Check for correct seat between nozzle and sprue
- Check sizes and alignment of holes in nozzle and sprue bushing
- Nozzle orifice should be .030″ smaller in diameter than sprue bushing “O” diameter
- Check polishing of sprue
- Provide more effective sprue puller
- Make sure sprue has enough draft angle for easy release
- If the sprue is stringing, increase or add screw decompression

Streaks

- Decrease melt temperature
- Decrease nozzle temperature
- Decrease back pressure
- Decrease injection speed
- Decrease screw speed
- Decrease cushion size
- Check for contamination
- Increase the cavity venting
- Increase gate size
- Increase nozzle orifice diameter
- Check for material hang-up

Molded in stress

These molded in stresses can result in part brittleness. Usually caused by highly oriented polymer flow.

- Decrease injection speed
- Increase melt temperature
- Increase mold temperature
- Decrease injection pressure
- Increase gate size
- Increase nozzle orifice diameter

Voids

Vacuole hollows in the molding, due to thermal shrinkage that draws material away from the fluid core of a part.

- Decrease injection speed
- Increase holding time
- Reduce melt temperature
- Increase mold temperature
- Check gate size and reduce gate land length
- Increase gate size and reduce gate land length
- Increase nozzle size and/or runner system
- Redesign part to obtain equal wall sections

Warpage, part distortion

A dimensional distortion in the molded part, usually bowing or bending of the part.

- Equalize temperature of both mold halves
- Observe mold for uniform part ejection
- Check handling of parts after ejection from mold
- Increase injection hold time until gate freezes
- Increase mold closed time
- Increase or reduce injection pressure
- Increase or reduce mold temperature
- Set differential mold temperatures to counteract warpage due to part geometry
- Use shrink fixtures and jigs for uniform cooling of the part
- Check gate locations and total number of gates to reduce orientation
- Increase gate dimensions
- Redesign part to equalize wall variation in molded part – thick and thin walls in the same part create differential shrinkage stresses
- Check cooling line layout; unbalanced cooling promotes warpage

Weld lines/knit lines

These lines occur where two melt flow fronts in the mold meet. The streams of plastic should be hot enough to fuse adequately. Weld lines are not just surface marks, but can be points of weakness: notches, stress raisers.

- Increase injection speed
- Increase injection pressure
- Increase injection hold time
- Raise the mold temperature
- Raise melt temperature by increasing cylinder temperatures
- Vent the cavity in the weld area
- Provide an overflow well next to the weld area
- Change gate location to alter flow pattern

6.4 Extem* and Ultem* resin injection molding questions and answers

1. **On what sized press should I mold my Extem/Ultem resin products?**
   The size of the press is dependent on the clamping force and the barrel capacity of the machine. First determine the total projected area of the complete shot – 4 to 6 tons of clamp force should be provided for each square inch of projected area to avoid flashing of the part. However, the total shot weight (all cavities plus runners and sprue) should be 30 to 80% of the machine capacity. Very small shots in a large machine may create unnecessarily long residence times which may result in streaking, discoloration or part embrittlement.

2. **How much regrind can I add to my virgin Extem/Ultem resins?**
   Typically a maximum of 25% is recommended, although larger percentages have been used with minimal losses in physical properties. Because regrind usually absorbs more moisture than virgin resin, extra drying time may be necessary to avoid problems such as splay and part brittleness. Also, grinder screen sizes should be at least 5/16 to 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 also important to keep the ground parts clean to avoid contamination from other materials.

3. **Why are my molded Extem/Ultem resin parts brittle or cracking?**
   Brittle or cracking parts can be caused by a wide variety of sources such as poor drying, abusive molding conditions, weld lines, chemical attack, improper design, and/or tooling problems. However, most Extem/Ultem cracking problems are caused by poor drying and abusive molding conditions. Extem/Ultem resin should be dried as recommended on the Extem and Ultem injection molding page. A closed loop, dehumidifying, recirculating hopper dryer with an after-cooler is suggested for drying Extem/Ultem resins. Also long barrel residence times and excessive melt temperatures may promote brittleness. Keep residence times short and melt temperatures in the recommended range, preferably 716-779°F (380-415°C) for Extem resin; 660-730°F (350-390°C) for Ultem resin.

4. **What mold temperature should I use to mold my Extem/Ultem resin product?**
   For best part performance a mold temperature of 300-350°F (150-175°C) for Extem and 250-350°F (120-175°C) for Ultem are recommended for thin walled parts. However, there is always a trade-off between product performance and cycle time. A higher mold temperature is recommended for a glossy surface and lower molded in stresses resulting in the best part performance.

5. **What is the best purging procedure for Extem/Ultem resin?**
   For Extem, purge with Ultem 1000 or XH6050 resin. If running another resin after Ultem, purge with either high density polyethylene (HDPE) with a melt index of 0.30 to 0.35 g/10 min. or use glass reinforced Lexan* polycarbonate resin. Begin purging at Ultem processing temperatures and reduce barrel temperatures to approximately 500°F (260°C) while continuing to purge.

6. **What type of hot runner system is best for Extem/Ultem resin?**
   Internally heated runnerlesss molding systems are not suggested because of the no-flow areas inherent in these systems, leading to extended residence time and material degradation. Externally heated systems are recommended for molding Extem/Ultem grades. Individually controlled heat zones are strongly suggested. Also, wire insulation must be adequate for processing high temperature resins.

7. **Should glass filled Extem/Ultem resin be processed differently than unfilled Extem/Ultem grades?**
   To maximize part performance, glass reinforced Extem/Ultem grades should be processed at lower screw speeds and relatively low back pressure. This will reduce glass fiber damage during plastication. Also, increase the rear zone temperature to promote improved flow and decrease glass fiber damage.

8. **What chemicals cause stress cracking with Extem/Ultem resin?**
   Chlorinated solvents such as Trichloroethane, 1,1,2 Trichloroethylene, Chloroform, Methylene Chloride, Ethylene Chloride; ketones and aldehydes such as Methyl Ethyl Ketone and Acetone at high stress level; and aromatic hydrocarbons such as Toluene. High stress levels either molded-in stresses or external stresses applied in the application increase the likelihood of an Ultem part cracking while in contact with chemicals. Extem XH resins have chemical resistance similar to Ultem resins. Extem UH resins have enhanced chemical resistance to organic solvents (e.g., hydrocarbons, ketones and chlorinated solvents).

9. **How long after molding can I test my Extem/Ultem resin parts?**
   Extem/Ultem resin parts should be tested at least 24 hours after molding to allow sufficient time for after mold shrinkage and moisture absorption. These parts will also be more representative of the actual performance in the application.

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

7.1 Mechanical assembly

Mechanical assembly techniques are widely used with Extem resin parts. For unreinforced Extem resin grades, the classical rules for amorphous engineering thermoplastics apply. For highly reinforced Extem 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. Extem resins can be welded by using different processes

- Vibration welding
- Ultrasonic welding, at amplitudes above 45 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 Extem resin at melt temperatures

7.3 Adhesives

Parts made from Extem 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.

7.4 Painting

A wide variety of colors and textures can be applied to Extem 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 Extem 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 Extem resin. Generic types are – acrylic, alkyd, epoxy, polyester, polyimide, polyurethane

If the Extem 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 Extem resin. Solvents used in paint formulations may have an adverse effect on the Extem 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.

Extem* 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 Extem to most metals excellent adhesion levels can be obtained.

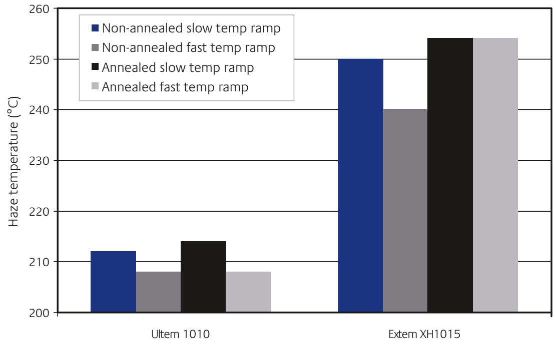


Figure 7.1
Haze temperature results: Illustrates the vacuum metallizability of Extem XH resin series and initial haze temperature results commonly used in automotive lighting applications.

General recommendations for the metalization of Extem 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 metallize 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 Extem resin surface. This provides excellent adhesion and since no basecoating or lacquer primer is needed prior to metallizing the Extem resin surface, a costly step in the process of making reflectors can often be eliminated.

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 affect an electrolytic deposition of metals coming from a dissolved metal salt. Better results are obtained with reinforced Extem resins.

Electroless plating
Extem resin is expected to perform similarly to Ultem* resin.

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
Extem 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

Extem* 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

Extem 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 Extem resin. Rods and slabs of various Extem grades can be obtained globally from various stock shape producers.

7.8 Extem and Ultem* resin annealing

Annealing is the process in which the material is heated close to its glass transition temperature Tg. At the Tg the amorphous molecules become mobile and can therefore relieve internal stresses. It is always best to start with optimal design, then process as optimally as possible to have as low stress as possible before annealing should be considered.

Annealing procedure guidelines:

- Use a programmable circulating air oven to ensure a homogenous temperature in the oven
- Place parts in a cool oven on a meshed grid/plate to allow hot air to reach all sides of the part and ramp up the heat in 50°C/hr to the required temperature
- Anneal at constant temperature for the time given in the table
- Gentle cool down of max 50°C/hr is key to avoid building new stresses again
- These are typical guidelines. Dependent on application, optimization of parameters is recommended

Resin Grade	Tg [°C]	Annealing temp [°C]
Ultem ATX100	174/217	160
Ultem 1285	180	165-170
Ultem ATX200	174/217	165
Ultem 1000/1010	217	200-205
Ultem CRS5xxx	227	210-215
Ultem XH6xxx	247	230-235
Extem XH1005	267	250-255
Extem UH1006	250/305	260-265

Wall thickness (mm)	Annealing time (min)
2	45
3	45
4	60
5	75
>5	+10 min/mm

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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