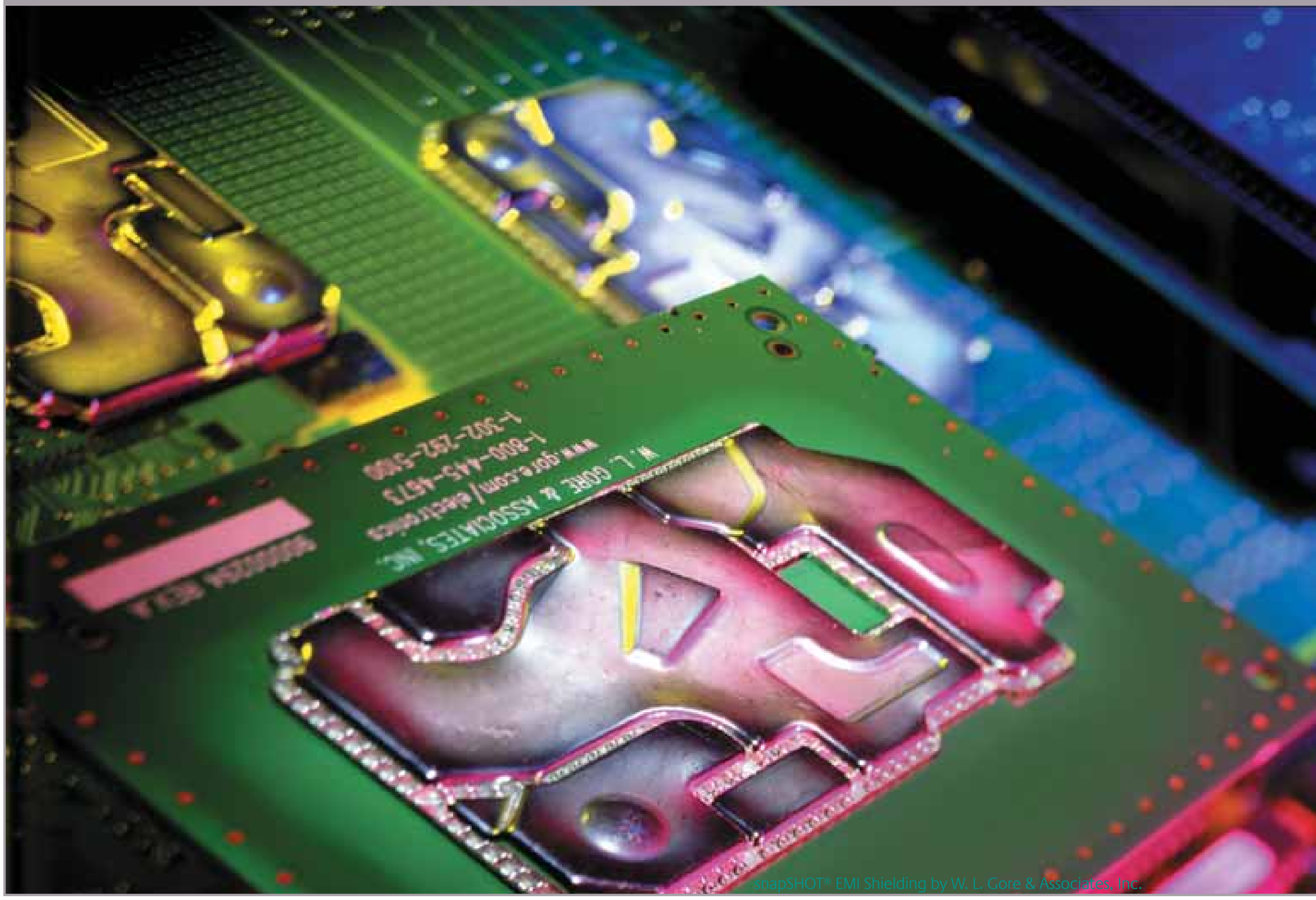
SABIC
Innovative
Plastics™

Ultem* film



snapSHOT® EMI Shielding by W. L. Gore & Associates, Inc.

Turn up the heat.

Ultem film has what it takes.

Sharing our futures

Introduction

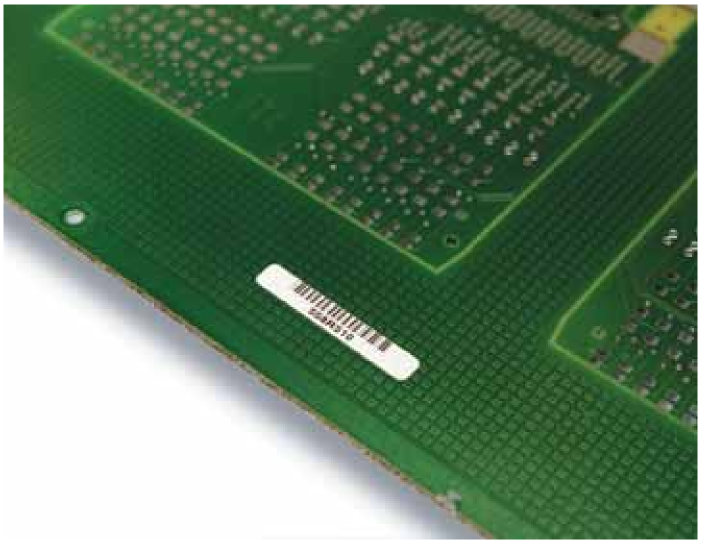
Ultem* high performance films are created from SABIC Innovative Plastics Ultem resin technology. Ultem polyetherimide resin, PEI, is an amorphous high performance polymer, which is characterized by excellent thermal properties, good chemical resistance, and exceptional dimensional stability.

The combination of high temperature resistance, excellent dielectric properties and low moisture absorption, may make Ultem film an excellent candidate for a broad range of electronics applications.

All of the Ultem film products are un-oriented films; the properties of the film are obtained from the resin utilized, not from secondary operations. The Ultem films utilize three different Ultem resin technologies to offer a range of performance attributes.

Key properties of the Ultem films

- High heat resistance exhibiting a glass transition temperature (Tg) from 217°C to 245°C (Tg)
- Low moisture absorption (up to 1.2% maximum absorption)
- Good dielectric strength compared to polyimide films
- Low dielectric constant (up to 3.0 @ 10 GHz) and dissipation factor over a wide range of temperatures and frequencies
- Flame retardant to meet VTM0 performance requirements
- Good resistance to a broad range of chemicals, such as fully halogenated hydrocarbons, alcohols and aqueous solutions
- Heat sealable, capability to seal to itself and a variety of other materials
- High metal adhesion, with sputtered copper and heat fused copper



Bar code label utilizing Ultem 1000B film by Polyonics Inc., Westmoreland, NH, USA. polyonics.com

High performance and superior product properties may make Ultem* film suitable for a variety of high-quality applications, like electronics insulation, high temperature labeling, EMI shielding, speaker cones and conductive ink substrates. SABIC Innovative Plastics, Specialty Film & Sheet is working on a number of future applications, which are continually being validated for Ultem high performance films.

Bar code labels utilizing Ultem 1000B film by Polyonics Inc., Westmoreland, NH, USA. polyonics.com

2.1 Identification labels

Ultem* film can be used as part of a labeling system for many different applications. Typical application requirements, like high temperature resistance, restrict usage of lower performing products.

Ultem 1000B film is currently used in top side labeling applications. Ultem film may provide high heat resistance to labeling applications which can be exposed to temperatures as high as 235°C for a short time. Also, Ultem XH6050B film may be a potential fit for bottom side labeling applications, where the temperature requirements could reach 265°C.

The main characteristics which may make Ultem film a suitable candidate for labeling applications are

- High temperature resistance with glass transition temperature (Tg) from 217°C to 245°C, materials can perform above Tg

- Films are UL VTM0–compliant

- Compatibility with acrylic base pressure-sensitive adhesives

- Wide web widths for improved coating productivity

2.2 Electrical insulation

Electrical insulation applications require a product with high dielectric strength at thin gauges to prevent the potential for an electrical short. Ultem film may provide design flexibility by offering an alternative material choice to competitive polyimide films.

An example of an electrical insulation application for Ultem film is lithium ion battery insulation. Laminate materials are also under development to meet class H electrical insulation requirements for motor and transformer applications.

The main characteristics which may make Ultem film a suitable candidate for electrical insulation applications are

- High dielectric strength, tight space requirements, i.e., any portable electronic device

- Puncture and tear resistance

- Ability to die cut

- Compatible with acrylic-based pressure-sensitive adhesives

2.3 Speaker cones

Ultem* films are currently used in various speaker cone applications utilizing the excellent sound dampening properties and high adhesion to copper wire–wound voice coils. The thermoforming characteristics of Ultem film is one of the key features for speaker cone applications. Recommended thermoforming conditions are located in section 5.5.

The main characteristics which may make Ultem film a suitable candidate for speaker cone applications are
- High glass transition temperature (Tg) from 217°C to 245°C
- Excellent sound dampening properties
- Low moisture absorption
- UL VTM0–compliant
- Compatibility with latex acrylic adhesives
- Wide web widths for improved coating productivity
- Thermoformable

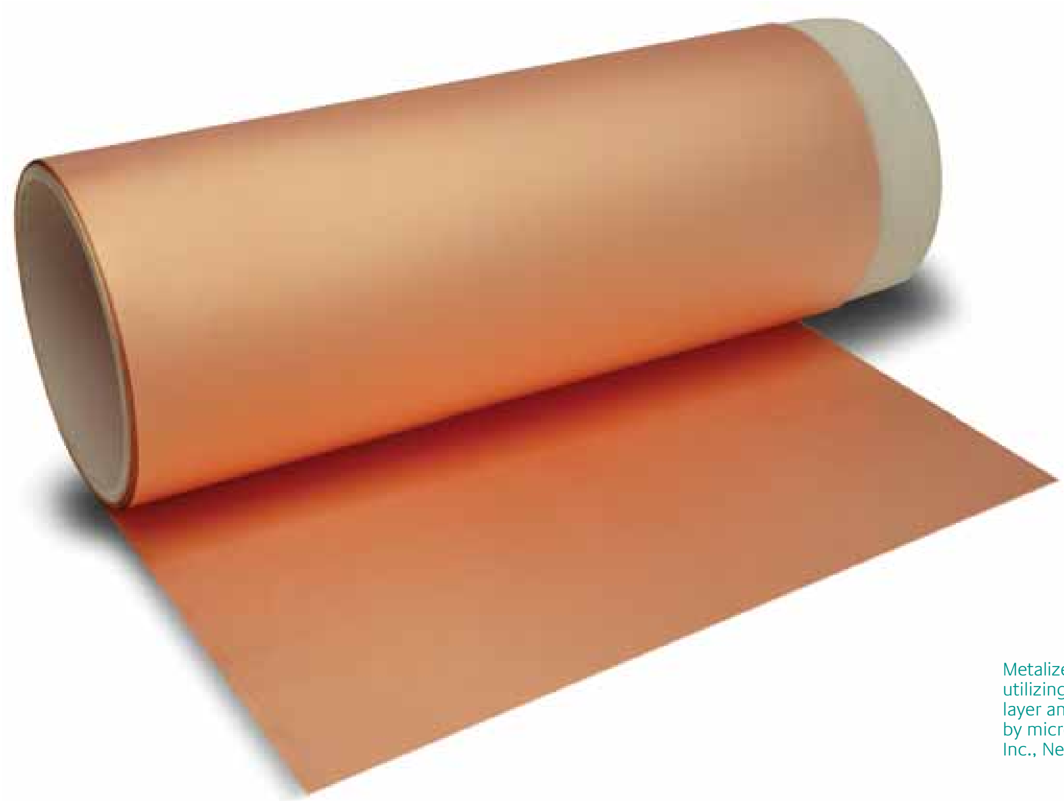
2.4 Pressure sensitive tapes

Tapes are another example of an application where Ultem film may have a performance fit. Currently, Ultem films have been converted into pressure-sensitive tapes, using acrylic-based adhesives. An example of applications for the tape is in electrical insulation for liquid crystal display back light modules and cable modems. Corona treatment of the film may be necessary to ensure proper adhesive anchorage to the film. Validations are underway to evaluate the performance of silicone-based pressure-sensitive tapes, as well.

The main characteristics which may make Ultem film a suitable candidate for pressure-sensitive tape applications are:
- Temperature resistance
- UL VTM0–compliant
- Compatibility with acrylic-based pressure-sensitive adhesives
- Dielectric strength
- Tear strength

3. Product selection

The Ultem* film product family has been recently expanded to include a high temperature film, with a Tg of 245°C. In addition, all Ultem films maintain a VTM0 listing on a range of gauge offerings. Yellow cards can be obtained from the UL Web site, ul.com, File Number E103380. All Ultem films are available in their natural color, which is a slight amber color. Ultem 1000B film is also offered in a black color.



Metalized Ultem 1000B film utilizing sputter-coated tie layer and electroplated copper by microMetal Technologies, Inc., Newburyport, MA, USA.

3. Product selection

3.1 Product selection

3.1.1 Ultem* 1000B film

Commercially available in 50 *µm* to 700 *µm* gauge thickness

- Heat sealable to a variety of materials, including PI and LCPs
- Improved dimensional stability versus polyester films at temperatures > 150°C
- Low dielectric constant and loss factor
- Very high sputtered metal adhesion strength
- Compliance with UL listing. VTM0 listed from 50 µm to 100 µm
- Isotropic property profile

3.1.2 Ultem 5000B film

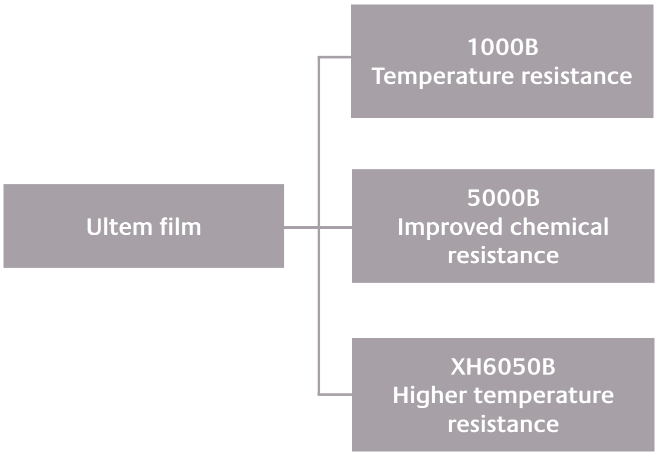
Commercially available in 50 *µm* to 700 *µm* gauge thickness

- Higher temperature resistance versus Ultem 1000B film
- Improved solvent resistance versus Ultem 1000B film
- Heat sealable to a variety of materials, including PI and LCPs
- Low dielectric constant and loss factor
- Very high sputtered metal adhesion strength
- Compliance with UL listing. VTM0 listed from 50 *µm* to 100 *µm*
- Isotropic property profile

3.1.3 Ultem XH6050B film

Commercially available in 50 *µm* to 700 *µm* gauge thickness

- Low dielectric constant and loss factor
- Heat sealable to a variety of materials, including PI and LCPs
- Isotropic property profile
- Highest temperature performance of the Ultem film series, 245 °C Tg
- Compliance with UL listing, VTM0 @ 50 *µm*, V0 from 75 *µm* to 250 *µm*

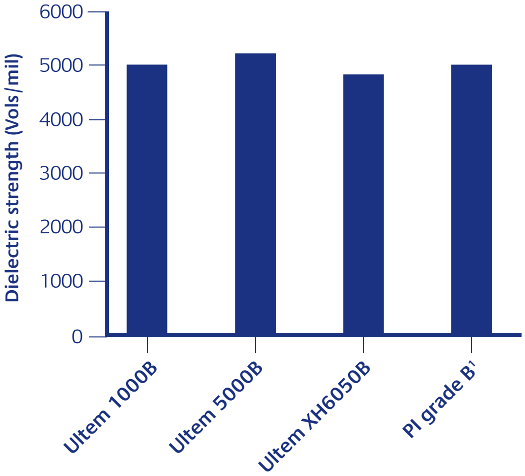


4.1 Electrical properties

Dielectric strength

Ultem* film technology offers exceptional dielectric strength, a key requirement in many electrical insulation applications. Ultem films are comparable benchmark polyimide materials, offering a dielectric strength of approximately 5,000 Volts/mil when tested at a thickness of 2 mil or 50 microns.

ASTM D – 149 µm thickness
Dielectric strength of Ultem films compared to other materials



Flexible heater fabricated using Ultem 1000B film by Thermion Systems International, Inc., Stratford, CT, USA.
thermion.com

4.1 Electrical properties

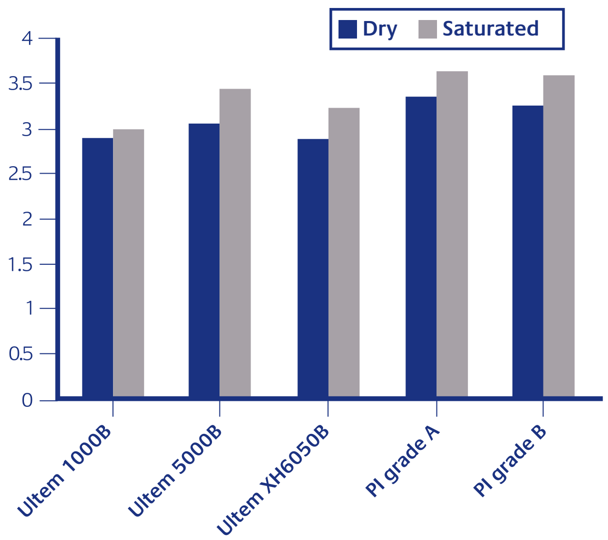
Dielectric constant and dissipation factor

Another attribute of Ultem* film is the low dielectric constant and dissipation factor. Although low or high absolute values of the dielectric constant may be desirable depending on the application, it is more important that the values remain stable.

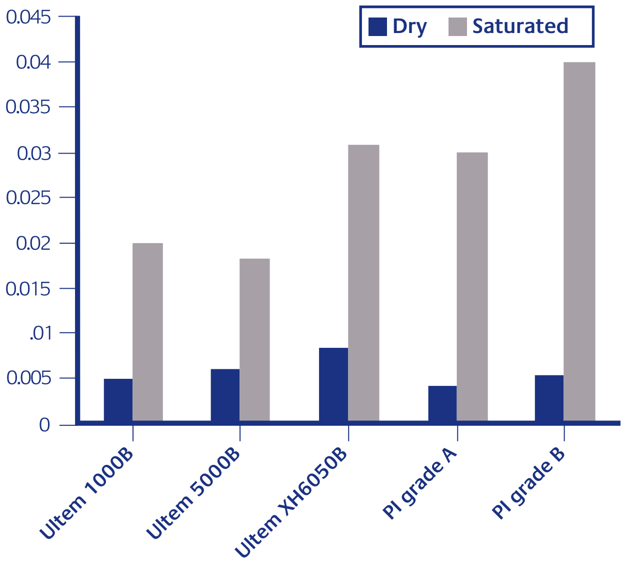
The dielectric constant and dissipation factor for Ultem films were measured at The GE Global Research Center. The films were tested and compared to commercially available industry standard benchmark materials.

Dielectric performance was measured on films that were fully saturated with moisture and completely dried. Testing was performed at high frequency, and versus standard testing at 1 MHz.

Dielectric constant at 10 GHz



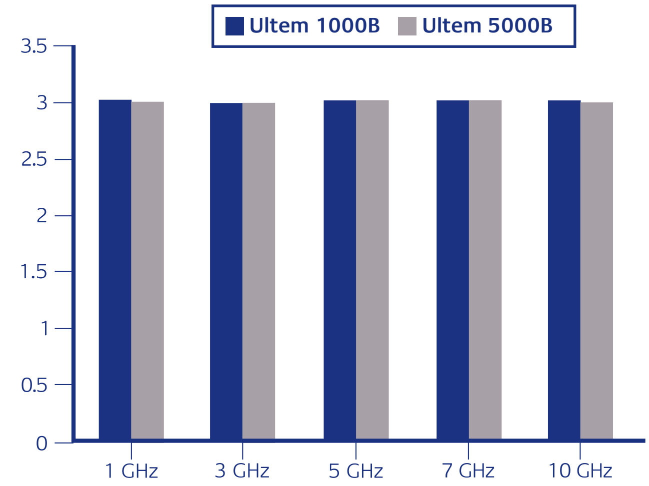
Dissipation factor at 10 GHz



In addition to the attribute of low dielectric constant, Ultem* films demonstrate a very stable dielectric constant when tested at various frequencies. The dissipation factor shows some sensitivity to frequency, however, the results of testing still show very good performance values. The data provided on dielectric constant versus frequency and dissipation factor versus frequency was supplied by Rogers Corporation.

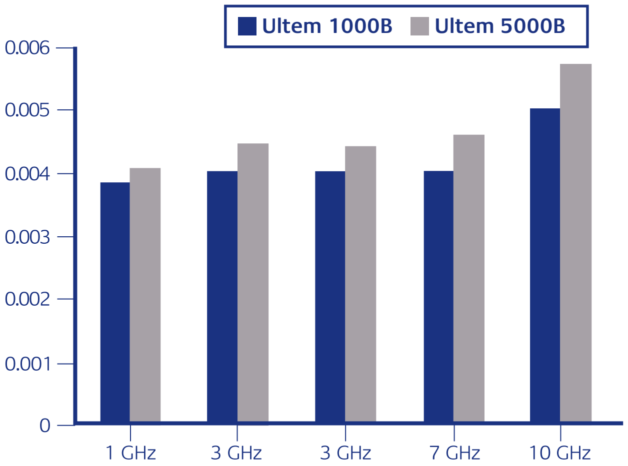
The combination of low dielectric properties and stable dielectric properties may make Ultem film an ideal candidate for high frequency electronic applications.

Dielectric constant versus frequency



*Data provided by Rogers Corporations, Rogers, CT

Dissipation factor versus frequency



*Data provided by Rogers Corporations, Rogers, CT

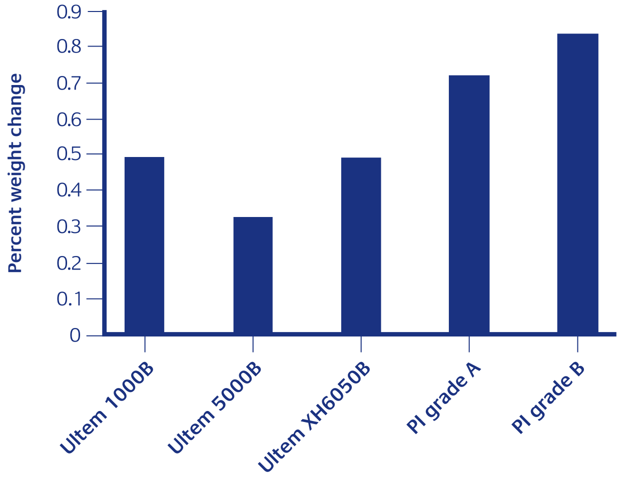
4.2 Moisture properties

Moisture absorption can be a critical factor in the performance of many electronics applications. It affects the electrical performance, namely the dielectric constant and dissipation factor, as well as potentially affecting the process yield of secondary metalization. Ultem* film moisture performance was measured and compared to benchmark polyimide materials. Ultem films demonstrated better moisture performance at both conducted test methods.

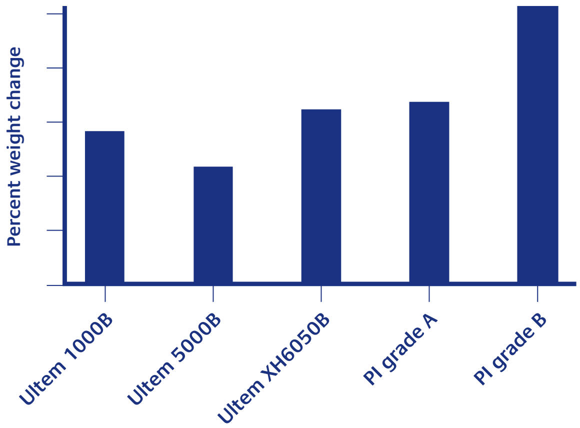
The amount of moisture that the material can absorb will also have an impact on the dimensional stability of the application.This measure of dimensional stability is often referred to as the coefficient of hydroscopic expansion (CHE).

CHE measurements are very similar to measuring the coefficient of thermal expansion for materials (CTE), except the percentage of relative humidity is varied, instead of the temperature. Expansion of the films is measured over humidity at room temperature. The performance of Ultem films is shown compared to a benchmark polyimide film.

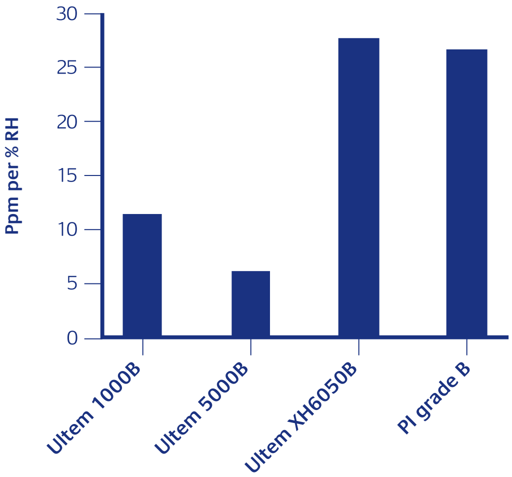
Moisture absorption
ASTM D-570, 24-hour 50% RH



Moisture absorption
ASTM D-570, 24-hour water immersion



Coefficient of humidity expansion
Ultem 1000B and 5000B films show a distinct advantage over the benchmark polyimide film



4.3 Mechanical properties

Modulus

Another outstanding property of Ultem* film is its high modulus compared to most amorphous thermoplastic films. The modulus of the films was measured and compared to commercially available, commonly used products. As the data suggests, Ultem film offers very similar tensile modulus compared to standard polyimide films.

Unlike crystalline materials, which demonstrate a rapid decrease in modulus due to the relatively low glass transition temperature, the amorphous nature of Ultem film offers the additional benefit of gradual reduction in modulus as temperature increases.

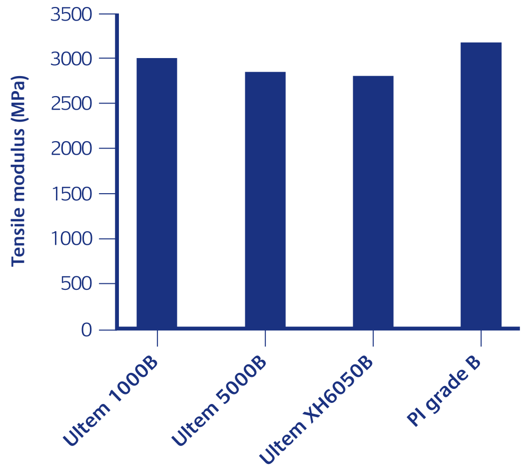
Tear strength

Tear performance of thin films is often critical to any secondary process that is performed on the film substrates. The tear strength performance is very dependent on the thickness of the film and how the film was converted. If dull trimming blades are used, it could cause a reduction in the tear strength of the film materials.

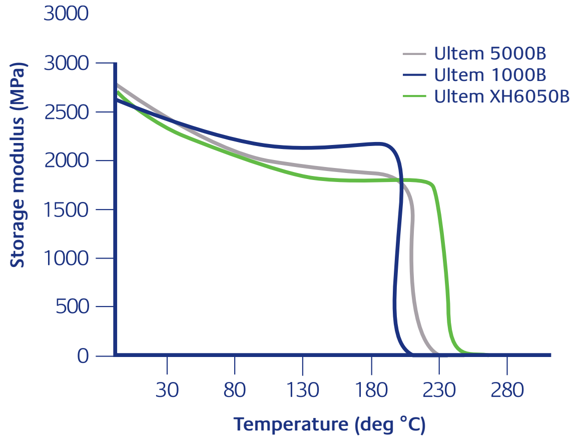
Tear initiation measures the force required to start a tear in the film. Tear propagation measures the amount of force required to propagate a tear after it has been started in the film. Ultem films' tear propagation and tear initiation strengths were measured and compared to commercially available benchmark materials.

The data shows that Ultem films are similar in performance to the benchmark polyimide materials. Additionally, Ultem films show consistent performance in the machine direction and transverse direction of the extrusion process.

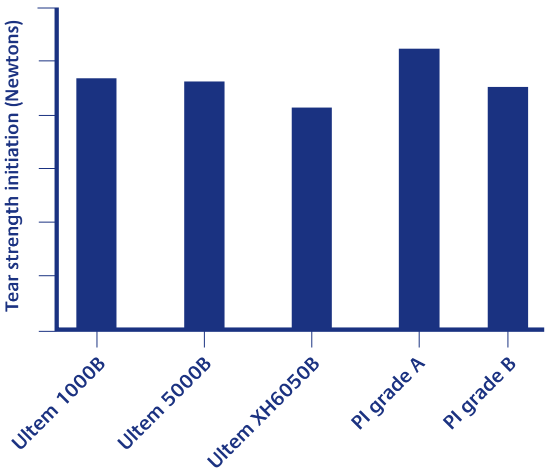
Tensile modulus — ISO R527
Measure at 50 microns



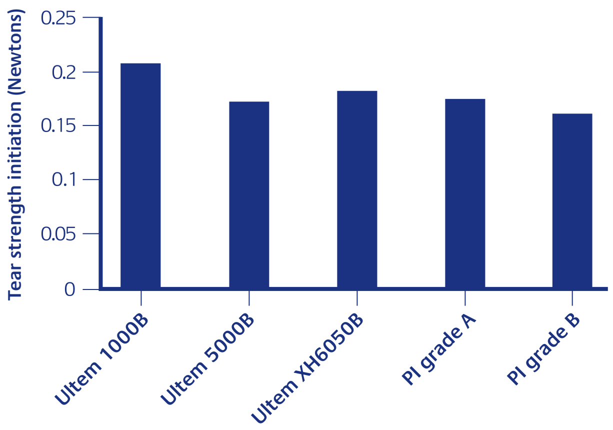
Flexural modulus versus temperature



Tear strength initiation — 50 microns
IPC TM-650 2.4.16



Tear strength propagation — 50 microns
IPC TM-650 2.4.16



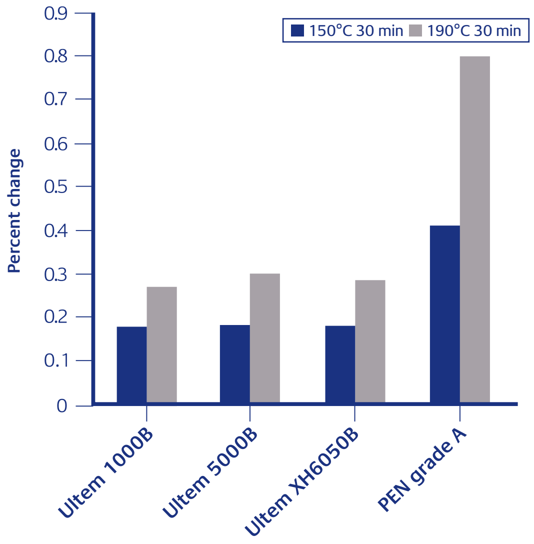
4.4 Thermal properties

Shrinkage or dimensional stability of high performance films can be critical to the performance of the end use application. The shrinkage of Ultem* films has been characterized by using the IPC TM–650 2.2.4 method A test on a bare film.

The shrinkage in the Ultem film materials is caused primarily by the manufacturing method employed to make the film. A small amount of stress in the film is relieved when the films are exposed to elevated temperatures.

If lower shrinkage is desirable, the films can be heat stabilized to remove the shrinkage in the film up to the stabilization temperature. This has been demonstrated by experiments conducted by the SABIC Innovative Plastics technology team. However, heat stabilized Ultem films are not currently commercially offered by SABIC Innovative Plastics.

Dimensional stability
IPC TM–650 2.2.4 method A
50 micron films



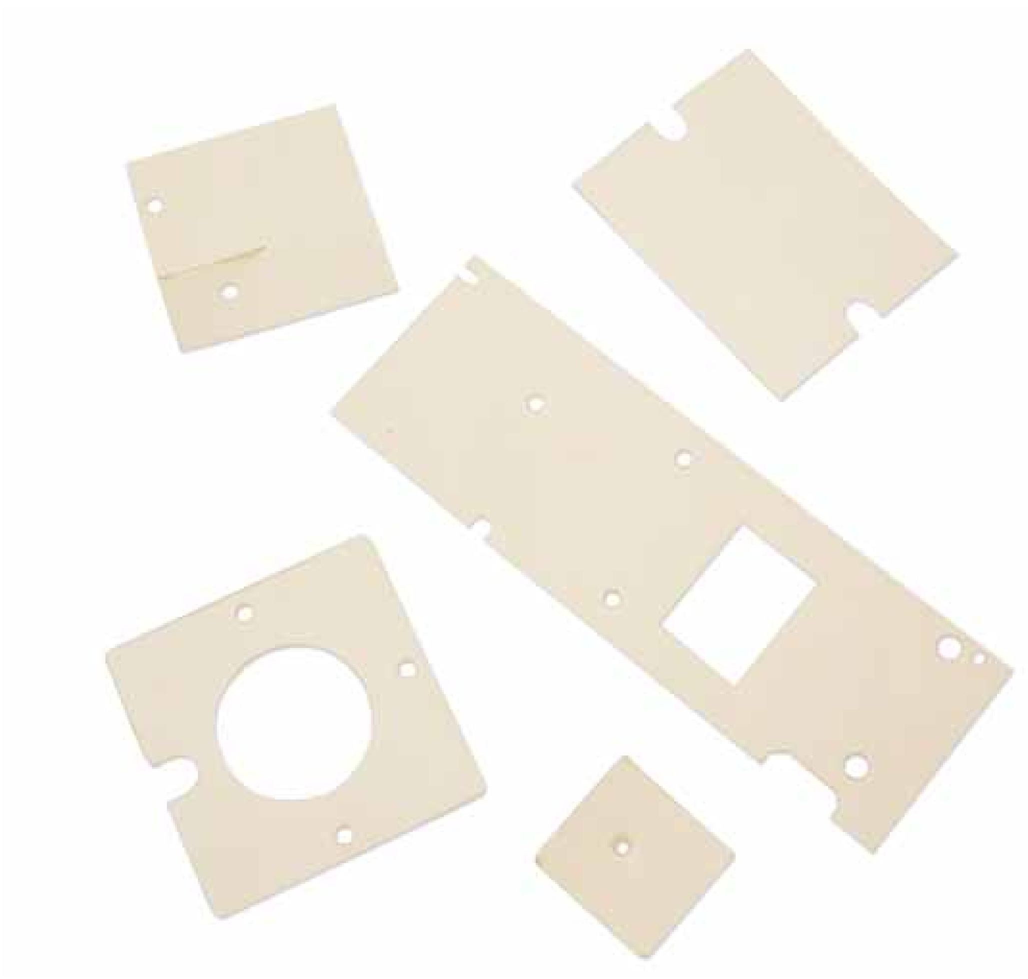
4.5 Product property summary

Ultem film product properties

Property	Units	Ultem 1000B	Ultem 5000B	Ultem XH6050B	Test method
Tensile modulus	MPa	3014	2857	2851	ISO R527
Tensile strength (yld)	MPa	101	86	91	ISO R527
Tensile strain (yld)	%	6.4	7.4	8.1	ISO R527
Tensile strength (brk)	MPa	90	90	89	ISO R527
Tensile strain (brk)	%	22	45	9.5	ISO R527
Tear strength initiation	N	18	18	16	IPC TM-650
Tear strength propagation	N	0.21	0.17	0.18	IPC TM-650
Dimensional stability	%	0.16	0.17	0.18	IPC TM-650
Dielectric constant (1 MHz)	—	3.2	3.3	3.3	IPC TM-650
Dissipation factor (1 MHz)	—	0.005	0.006	0.005	IPC TM-650
Volume resistivity	M Ω-cm	$2.1x10^7$	$2.5x10^8$	$6.4x10^8$	IPC TM-650
Surface resistivity	M	$6.4x10^5$	$2.1x10^5$	$7.9x10^4$	IPC TM-650
CTE (-100 – 200˚C)	ppm/˚C	47	48	46	IPC TM-650
Water absorption (immersion)	%	1.4	1.2	1.6	ASTM D-570
CTE (0 to 100% RH)	ppm/%RH	11	6.4	26	SABIC test
UL flame performance	VTM0	50–100µm	50–100µm	50–250µm	UL 94
Dielectric strength (oil)	Volts/mil	5,000	5,300	4,700	ASTM D149
Glass transition temperature	˚C	217	225	245	DMA

All data generated on 50 µm film, not for specification purposes

Most applications that use Ultem* film require some degree of processing to enhance the functionality of the film. Often they are coated with adhesives, pigmented cover coats or laminated with another material.



Die cut electrical insulation laminate structure, using aramid paper and Ultem 5000B Film – aramid paper. Produced by Dr. D. Mueller, GmbH, Ahlhorn, Germany. mueller-ahlhorn.com

5.1 Heat sealing and thermal lamination

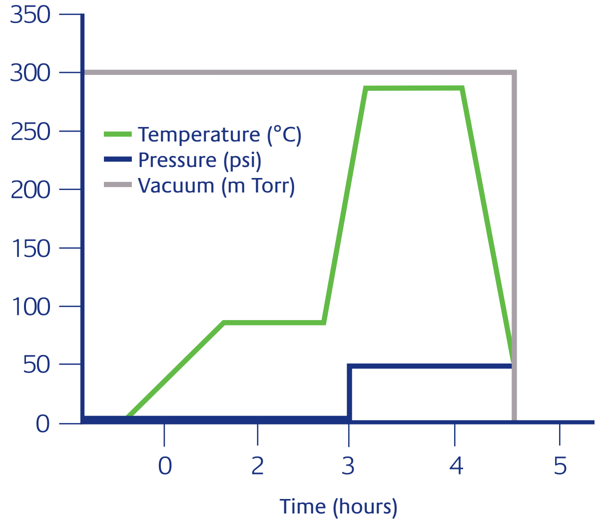
Because of its unique thermoplastics nature, Ultem* film is compatible with heat sealing. The heat sealing process can eliminate the adhesive layers that would normally be required to bond two materials together.

According to tests conducted by the SABIC Innovative Plastics technology department, Ultem film shows adhesive property to a variety of materials, including itself or other Ultem films, polyimide films, and LCP films. Ultem film also demonstrates good adhesion strength to copper foils. However, because of the CTE mismatch between copper and Ultem film, the potential use of this method is limited. The curling effect is elimated at thicker gauges of film, making Ultem film a potential candidate for circuit board laminates.

Lamination conditions vary according to the selected grade of Ultem film. Ultem film must be laminated at least 40 to 45°C over the glass transition temperature of the film. Lamination pressures of 50 to 100 pounds per square inch are needed to achive the required bond strength. Lamination time can vary, depending on the thickness of the film.

These conditions have been used to bond Ultem film to copper and to circuitized polyimide film without adhesives. The GE Global Research Center demonstrated the capability to encapsulate 35-µm-high traces by allowing the Ultem film to “flow” around the traces.

Ultem lamination cycle
Film lamination conditions



5.2 Metalization

Ultem* film can be metalized utilizing a number of traditional processes such as direct metal sputtering, electro-deposition, electroless deposition, direct lamination (fusion bond) and lamination utilizing adhesives.

Utilizing a metal sputtering process, The GE Global Research Center has demonstrated very high metal adhesion strength with Ultem 1000B and 5000B when compared to other materials. A design of experiments was conducted on Ultem films to examine the effects of process conditions on metal adhesion strength. The results showed that the metal adhesion results for Ultem films are not as sensitive to certain conditions.

5.3 Adhesives

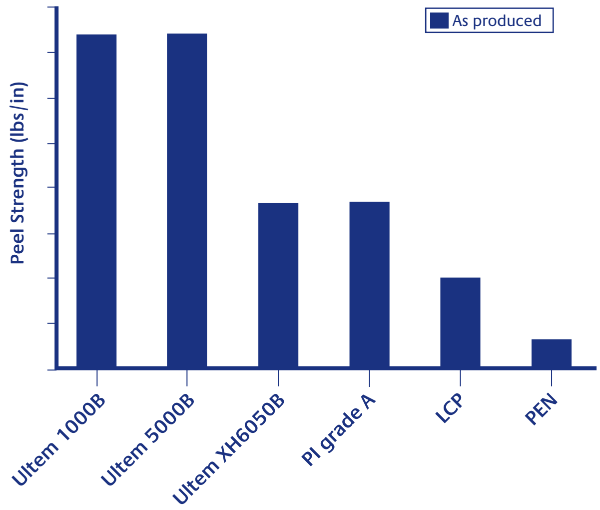
Ultem PEI film can be bonded together or to dissimilar materials, using a variety of commercially available adhesives.

There are several selection criteria used to choose adhesive. These include the method of application, mechanical properties, and temperature and environment requirements. Ultem film is currently used in high temperature applications where acrylic-based pressure-sensitive adhesives are utilized. Pre-treatment of the film to promote adhesion, such as corona treatment, may be necessary to achieve acceptable adhesive anchorage to the film. The surface energy of Ultem film has been measured to be approximately 35 to 40 dynes, depending on grade and the side of the film measured.

The most important criteria used to choose the right adhesive system is the effect of the solvent on the Ultem film. The use of methylene chloride and MEK-based solvent systems should be generally avoided.

A list of recommended adhesive systems for all Ultem films is currently under development.

Sputtered metal adhesion
IPC TM–650



5.4 Laser and mechanical drilling

Many times, it is a common assembly process for electronic applications that vias need to be created in the film substrate. Ultem* film can be successfully drilled by using either mechanical punching or laser-drilling technology.

Mechanical drilling studies have shown that Ultem film can be drilled with common process conditions.

Ultem film can also be successfully laser drilled. However, the standard process conditions that are used for polyimide films will cause reflow of the material. A lower power setting has to be used in order to avoid the reflow. Processing parameters for the Ultem film by using an ESI laser system are included in the following table.

Original polyimide conditions (trepan mode)

hole size	bite size	velocity	rep. rate	reps.	settle time	power	eff spot	mode	inner dia.	rev.
33	1	20	20	3	2	0.2	13	trepan	NA	NA
45	1	20	20	3	2	0.2	13	trepan	NA	NA

Optimized Ultem conditions (spiral mode)

hole size	bite size	velocity	rep. rate	reps.	settle time	power	eff spot	mode	inner dia.	rev.
45	1	20	20	2	2	0.2	13	spiral	25	10
33	1	20	20	2	2	0.2	13	spiral	20	10

5.5 Thermoforming conditions

Thermoforming is a process used to produce complex three-dimensional plastic parts from flat thermoplastic film or sheet. This process requires heating the plastic film to its softening temperature and drawing the soft material over a mold, using vacuum or air pressure. When the part has assumed the shape of the mold, it is allowed to cool. The use of heated positive air allows for much higher pressures, making sharper detail possible.
Unlike polyimide film, Ultem* film may be thermoformed in a variety of shapes because of the thermoplastic nature of the film. Applications such as speaker cones require the film to be formed into a specific shape.

Recommended thermoforming temperatures for Ultem film are between 260 and 290°C. The required forming temperature will be dependent on the grade of film selected to meet the application requirements. Typically the film temperature must be elevated greater than 40°C above the glass transition temperature (Tg) of the material. Tool temperatures are suggested to be between 150 and 170°C.

Ultem film should also be dried, prior to thermoforming, to reduce the possibility of moisture bubbling during processing. The film should be dried 2 to 4 hours between 150 and 160°C. After the film is dried, it will be useable for 2 to 4 hours (depending on relative humidity) before it will need to be re-dried.

5.6 Via integrity testing

Adhesiveless flexible circuits have been fabricated on Ultem film to test the performance and reliability of Via Interconnects. Via Interconnect processing was tested using a via string pattern, which incorporated adhesiveless Ultem film lamination processing with laser via drilling. Subsequent metal deposition and subtractive pattern transfer resulted in the test circuit design that was evaluated. The process of lamination, drill and metal can be repeated for multi-layer circuit fabrication.

Each Ultem film test circuit contained over 1000 vias. Circuits were tested in a thermal cycle from -40 to 125°C for 1,000 hours. Testing of approximately 120,000 vias showed no change in contact resistance.

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