VICTREX® PEEK FILM TECHNOLOGY

Thermoforming APTIV® Film

About this guide

This version of the thermoforming guide is provided to our customers as a quick reference tool for the thermoforming process. The following notes may be applied to any of the commonly used forming techniques. There are no exact rules that can be given for thermoforming APTIV film. Many variables such as part design, process equipment and film thickness will influence the process.

It is assumed for this guide amorphous APTIV film is being used as the starting material for the thermoforming process. It is normally expected that the final thermoformed part will be crystalline in nature to obtain the best properties of PEEK in the final application. The forming temperature is just above the Tg of PEEK.

Introduction to VICTREX® PEEK Polymer

VICTREX® PEEK polymer is a high-temperature, semi-crystalline thermoplastic which provides a unique combination of properties to Engineers, Designers & OEM's.

Thin films of PEEK can be made amorphous due to the method of manufacturing the film. This amorphous film is optically clear in nature with a light brown colour and can be thermoformed at temperatures of 140-160 °C (284-320 °F) using common forming techniques such as vacuum forming, drape forming, air slip forming and plug assist forming.

Amorphous APTIV film is typically available in thickness from 6 μm to 250 μm (0.25 to 10 mils).

PEEK polymer has a glass transition temperature (T_g) of 143 °C (289 °F) and a crystalline melting point (Tm) of 343 °C (649 °F). Amorphous APTIV film can be annealed by heating it to temperatures above its T_g to induce crystallinity, thus enhancing both heat stability and chemical resistance. This changes the optically clear light brown amorphous film, to a light tan colour & optically opaque as the semi-crystalline film.

The lowest energy state of PEEK polymer is in the semi-crystalline form & PEEK will always try to reach that lowest energy semi-crystalline state if the molecules are sufficiently thermally mobile to re-order themselves. This happens at temperatures above the Tg of 143 °C. Once above the glass transition temp of 143 °C, amorphous PEEK will rapidly begin to revert into the crystalline state in the order of 2-20 seconds and the crystallisation process can have completed in as little as 10-30 seconds depending upon the temperature. This crystallising behaviour of amorphous PEEK above Tg is considered exceptional amongst most of the polymers commercially available today and may be unfamiliar to some of the processors trying to thermoform PEEK parts.

Process Control

The most important factor when using **ANY** of the forming methods for APTIV film is the accurate control of the both the mould temperature and the temperature of the polymer. Many processors rely primarily upon time as the key process parameter, but as the forming temperature of PEEK is critical, it is possible that this control method may not yield sufficient consistency in the process and the resulting parts. We highly recommend that the mould tools have a thermocouple capability to measure the temperature of the process, and that timers are used for each stage of the forming process.

Time is still an important factor where the APTIV film is changing from an amorphous material to a crystalline material during the shaping process. The combination of **temperature and time** must both be controlled in this type of process to achieve consistent results.

Heating and Forming the APTIV® Film

Amorphous APTIV film will gradually lose modulus as it is heated and will begin to soften more significantly at temperatures above 143 °C (289 °F). However it will also quickly start to crystallise at temperatures above its Tg at 143 °C. If crystallisation is allowed to take place, then the film will become too rigid to easily thermoform at temperatures around 140-160 °C (284-320°F). Heating times should be started as short as possible and only increased gradually until the shaping process becomes difficult indicating that crystallization has occurred. It is important to note that when the film crystallises, it becomes opaque.

The film forming temperature should be reached as rapidly as possible to minimise the cycle time and also reduce the possibility of film crystallisation. If the thermoforming machine is not fitted with a pyrometer to monitor sheet temperature, then the optimum forming point of APTIV film is easily observed visually. As heat is applied to an amorphous film, a relaxation in the film is first seen as the temperature reaches Tg 143 °C (289 °F); this is shortly followed by the whole area of the film becoming taut. As soon as the film is taut, forming must take place; further heating will only cause the film to crystallise.

The thickness of the film has an important effect on the heating rate, and therefore the crystallisation rate. When using thinner films of less than 50 microns, temperatures of 150°C or slightly lower are recommended so that crystallisation doesn't occur before stretching. We would recommend that for the thin films, processors start with a forming temperature of 140C & gradually increase temps from there to accurately determine their optimum heating temperature. For films above 50 microns then the 160°C forming temperature is probably more appropriate with crystallisation not occurring as fast.
This thickness effect can be seen in the table below.

Film Thickness	Pre-heat time	Forming temp
Microns	***Seconds***	***Deg C***
6 - 25	2 - 10	150
30 - 75	5 - 15	160
100 - 250	10 - 30	170

A period of time needs to be built in the process once the material has been correctly shaped with the mould temperature above Tg (holding stage). This will allow the crystallinity of the APTIV film to fully develop. If the part is removed before complete crystallisation has taken place them any subsequent heating above Tg may cause final stage of crystallisation to occur which will affect the part accuracy & dimensions. Optimum temperatures for crystallisation will depend upon required cycle times and the shape to be formed, but will be in the range of 160-220 °C (320-428 °F). There is no advantage in heating the tool to temperatures in excess of 220 °C (428 °F) - this will not increase crystallisation rates (see fig 2).

It is important that the polymer is below or very close to Tg (143 °C) for the mould removal process to prevent any further deformation of the part. APTIV film may easily be ejected from the forming tool using an air blast. When forming APTIV film, followed by crystallisation on the tool, cooling of the tool to 130 °C (266 °F) may be required to increase the rigidity of the film for mould release.

Post Forming Annealing

It should be noted that if the part has not sufficiently crystallised during the forming process, dimensional changes in the part may occur upon this subsequent heating. This post process annealing step should be conducted as part of the process development for the parts to determine that the part has reached satisfactory dimensional stability. If the part is to be subjected to operating temperatures at the same level or above the maximum process temperature during the forming process, we recommend that processors conduct this as a quality check for functionality of the part design.

If the part is seen to change dimensions during such a post forming annealing, then the process should be modified to increase the crystallinity of the parts during the process. This can be achieved by either a longer holding time after forming, or going to a higher temperature during the holding stage. This can also be checked by conducting a crystallinity measurement by DSC on the part after forming and after an annealing process. Significant increases in the levels of crystallinity due to a post forming annealing step would indicate a potential issue with the process not achieving full crystallinity in the part.

About Victrex

Victrex plc is the leading manufacturer of high performance materials, including VICTREX® PEEK polymer, VICOTE® Coatings and APTIV® film. These materials are used in a variety of markets and offer an exceptional combination of properties to help processors and end users reach new levels of cost savings, quality, and performance.

The company is headquartered in the UK. Invibio®, Victrex's biomaterials business, provides access to specialized products and services for medical device manufacturers. Victrex Japan, Inc. is a wholly-owned subsidiary of Victrex plc. For more information visit http://www.victrex.com

For more information about Victrex APTIV® films made from VICTREX® PEEK polymer, go to www.aptivfilms.com

Manufactured in the U.K. under a Quality System approved to ISO 9001 by Victrex plc
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