Sharing The Knowledge
Module 3

Polymer Modification

STK 301

GE Plastics

Module 3

Polymer Modification

- Methods of Modification
- Resin Modification
- Tooling
- Processing

3

Participant's Notes:

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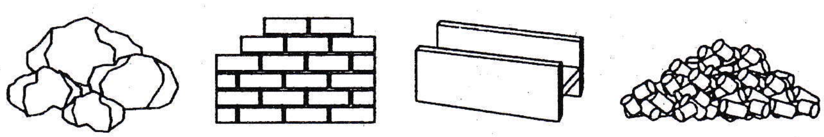
The Development of Materials



Stone Brick Metal Plastics

Materials are selected to meet the specific performance requirements of an application.

3

Participant's Notes:

Introduction

Polymer Modification

Different applications call for different material performance. A car bumper, for example must be able to withstand high impact. A car fuel tank, on the other hand, requires good chemical resistance. Both the product design and the designer's choice of material must satisfy these performance requirements. **STK 301**

Objectives:

At the end of this module, participant should be able to:

- Describe the methods used to modify basic polymers.
- Describe the difference between blends and co-polymers.
- Define impact modification and describe the characteristics of impact modifiers.
- Compare glass and mineral reinforcements.
- Contrast impact modification and glass reinforcement.
- Describe the purpose and effects of additives such as stabilizer systems and flame retardants.
- Identify whether you are working with a material that has glass or mineral reinforcements, and/or impact modifiers. Describe the effect on processing

The Development of Materials

Plastics are the next step in the development of materials.

Through the ages, man has sought materials to meet specific application requirements, such as strength and flexibility, that are cost effective to manufacture. Since the turn of the century, man has chosen plastics because they are formable, lighter in weight, corrosion resistant, and easily mass produced. Then engineering thermoplastics emerged in the 1960's, offering unique, high performance material properties that were previously unavailable. **STK 302**

STK 303

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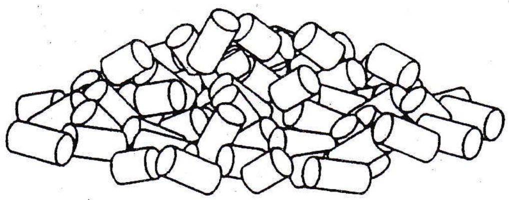
Plastics



Plastics modification expands the use of plastics in application by offering an increased variety of property combinations.

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Polymer Modification

Basic Polymers

Blends **Homopolymers** **Copolymers**

Impact Modification **Rigid Reinforcement** **Additives**

Useful Polymer Material

3

Participant's Notes:

Basic polymers may be modified to change their properties.

Plastics

Today, individual resins can be chosen for a greater variety of specific performance attributes than ever before. Plastics modification expands the use of plastics even more by increasing the variety of performance combinations available to the manufacturer.

STK 303

Basic homopolymers can be blended or modified.

A homopolymer is a polymer formed by the polymerization of a single monomer.

Polymer Modification

This module explains the methods used to modify basic homopolymers in an effort to make them more useful in specific applications. A homopolymer, a polymer that is formed by the polymerization of a single monomer, may or may not provide part designers with just the right combination of properties they need. Modification of basic homopolymers by blending or copolymerization, or by adding impact modifiers, rigid reinforcement, or additives increases options in material selection. Polymer modification lets the designer choose a material that best meets the particular properties the part requires.

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STK 305

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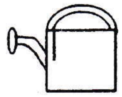
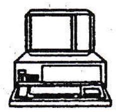
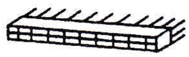
Basic Homopolymers

Polystyrene  Picnic Utensils

Polypropylene  Containers

Polycarbonate  Computer Housings

PBT  Electrical Connectors

Basic homopolymers are available to meet certain performance requirements in a variety of applications.

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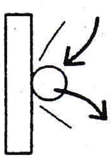
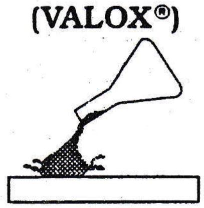
Unique Properties

Polycarbonate
(LEXAN®)



Excellent
Impact Resistance

PBT
(VALOX®)



Excellent
Chemical Resistance

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Participant's Notes:

Homopolymers have specific properties.

Basic Homopolymers

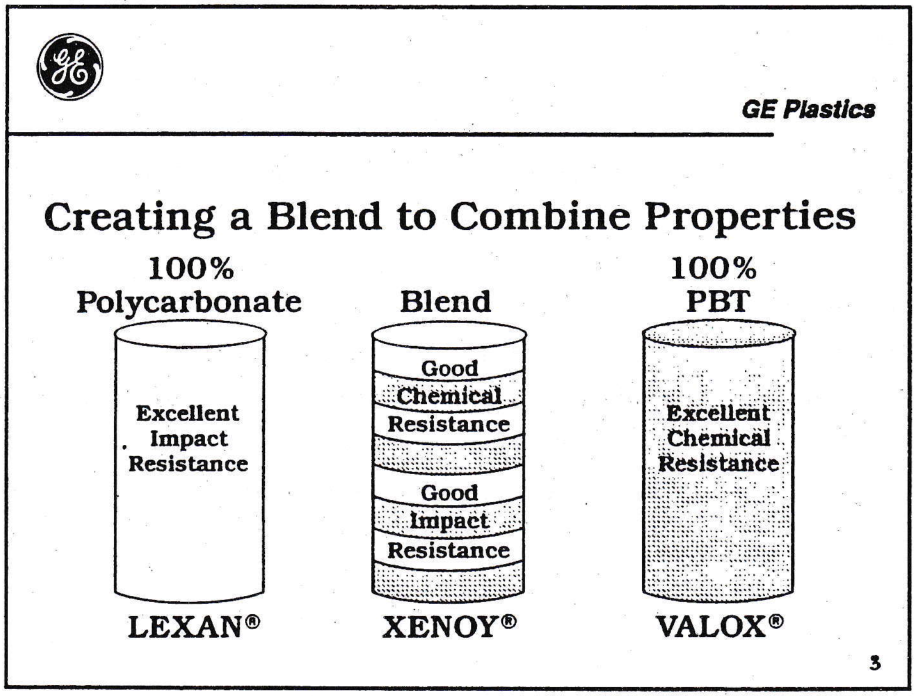
There are many basic homopolymers available to meet specific performance requirements. Commodity thermoplastics such as polystyrene and polypropylene are lower performance homopolymers used to manufacture products such as plastic picnic utensils and watering pails. Engineering thermoplastics such as polycarbonate and PBT are higher performance homopolymers. Polycarbonate, for example, provides excellent stiffness and impact resistance for use in such demanding applications as computer housings. PBT provides excellent electrical, heat resistance, and chemical resistance and is used in such applications as electrical connectors. **STK 305**

Each polymer has a specific property profile.

Unique Properties

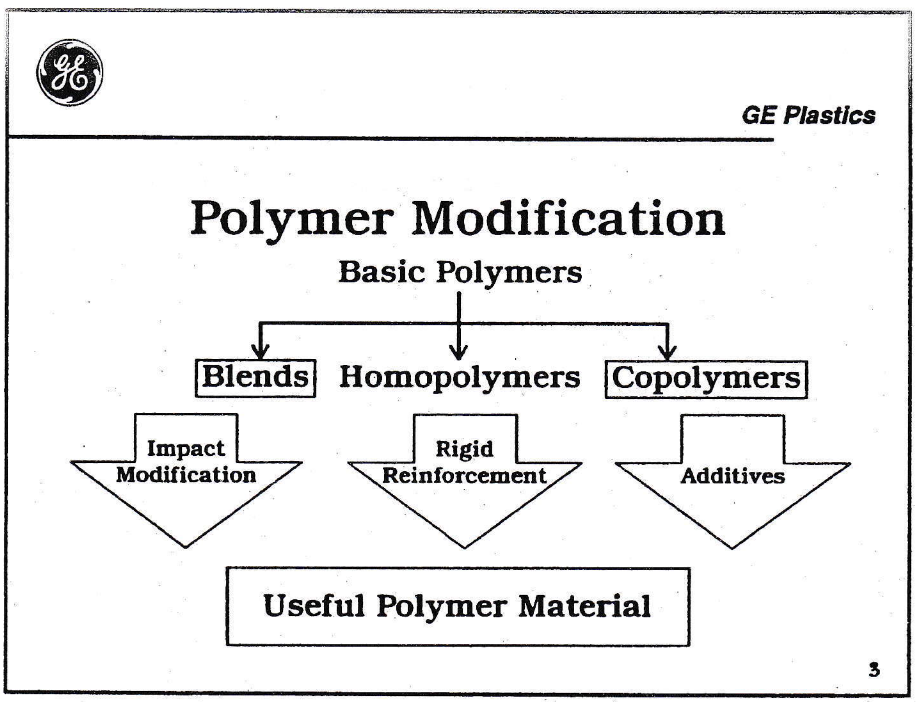
Polycarbonate and PBT are both high performance engineering thermoplastics, yet each provides its own unique properties. Polycarbonate provides excellent impact resistance. PBT provides excellent chemical resistance. **STK 306**

STK 307



Participant's Notes: ______________________________

STK 308



Participant's Notes: ______________________________

Blending is the combining of homopolymers to take advantage of the properties of each.

Creating a Blend to Combine Properties

By combining homopolymers, we can end up with the best properties of each. GE Plastics blended LEXAN® polycarbonate and VALOX® PBT to create a new material, XENOY®. XENOY has neither the excellent impact resistance of LEXAN, nor the excellent chemical resistance of VALOX. But it contains a good portion of each. XENOY has very good impact resistance, much better than VALOX, and very good chemical resistance, much better than LEXAN. By blending, the material supplier has expanded the variety of materials available to better meet the manufacturer's specific performance requirements. **STK 307**

Polymer Modification

One of the first methods of polymer modification is blending. Blending takes two homopolymers and blends them together to make a new resin product. XENOY is an example of a polymer blend. LEXAN and VALOX were physically mixed together to make XENOY, a new resin product.

A homopolymer may be physically combined as blends or chemically combined as copolymers.

Another method of polymer modification is copolymerization. In copolymerization, two homopolymers are copolymerized to make an entirely new polymer - a copolymer. This copolymer then becomes its own resin product.

Blending and copolymerization are two different methods of combining polymers to create new resin products. Blending is the result of a physical combination, while copolymerization is the result of a chemical combination. **STK 308**

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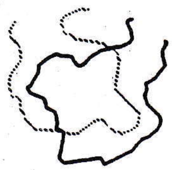
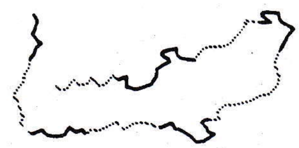
Combining Polymers

Physical Combination	Chemical Combination





Blend
Homopolymers Are Physically Mixed

Copolymer
Homopolymers Are Chemically Linked

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Participant's Notes: ______________________________

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Polymers

Homopolymer	LEXAN® ULTEM® PEEK® VALOX® SUPEC™ VICTREX®
Multiple-phase Blend	XENOY® GTX® NORYL® BAYBLEND® PREVEX®
Single-phase Blend	PPO/PS
Copolymer	LOMOD® SANTOPRENE®

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Participant's Notes: ______________________________

The difference between a physical combination and a chemical combination.

Combining Polymers

When two homopolymers are blended, they are physically mixed together. LEXAN® and VALOX® polymer chains are merely "stirred" together to make XENOY®, a material composed of LEXAN and VALOX polymer chains. When two homopolymers are copolymerized, their polymer chains are chemically combined. Two sets of polymer chains are actually linked together, resulting in an entirely different polymer composed of an entirely different polymer chain.

STK 309

Basic Modification Examples

Differentiation of typical commercial polymers.

Polymers

A material supplier, like GE Plastics, offers an assortment of resin products that includes: homopolymers, like LEXAN®, VALOX®, and ULTEM®; multiple-phase blends like XENOY®, NORYL®, and PREVEX®; single-phase blends like PPO/PS; and copolymers like LOMOD®.

STK 310

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Combining Polymers

Physical Combination → Blending

- Multiple-phase Material
- Single-phase Material

Chemical Combination → Copolymerization

The phase characteristics of the blend depend on the miscibility (solubility) of the parent polymers.

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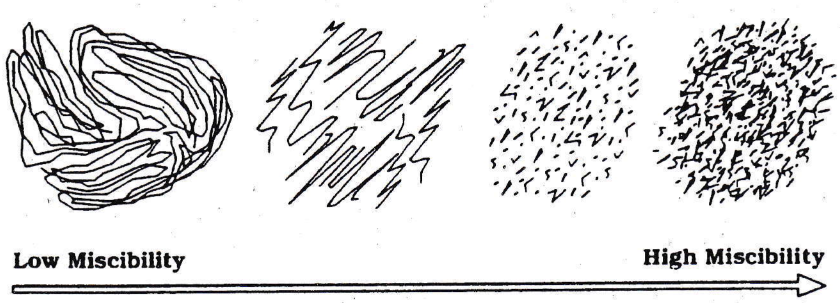
Miscibility (Solubility)



The Tendency or Capacity of the Parent Homopolymers to Dissolve in Each Other with Ease

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Participant's Notes:

Blending

Blending can result in one or more phases.

Combining Polymers

First, let's examine polymer blends. A polymer blend can take one of two forms: multiple-phase, or single-phase. The phase development in the blend depends on the miscibility or solubility of the parent polymers.

STK 311

Miscibility determines the degree of mixing in a blend.

Miscibility (Solubility)

Some materials have a greater capacity to dissolve in each other. Salt, for example, will dissolve in water. The salt and the water will actually break apart into smaller and smaller particles, and eventually particles of salt will dissolve with particles of water creating a single-phase blend. Salt is highly miscible, or soluble, in water. **STK 312**

STK 313

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Multiple-phase Blend

Each of the blended homopolymers maintains a discrete phase in melt and solid states.

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Participant's Notes:

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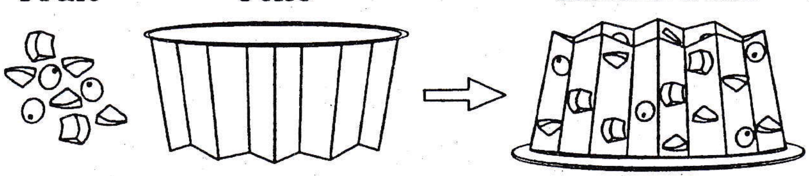
Multiple-phase System

Multiple-phase systems maintain discrete phases similar to jello salad...

Fruit Jello Molded Jello



Two Phases Two Phases

3

Participant's Notes:

Multiple-phase Blend

Low miscibility results in discrete phases.

In this actual photo of a multiple-phase blend, the rubber material is easy to distinguish from the polymer material. This is because the parent homopolymers are not miscible or soluble in each other and each maintains a discrete phase in melt and solid states. Low miscibility results in a multiple-phase system. **STK 313**

Multiple-phase System

Fruit in jello is an example of a two phase system.

In a multiple-phase system, the materials are mixed together yet maintain discrete phases, or distinct areas, in the mixture. The result is a blend that resembles a molded jello salad. The jello and the fruit are insoluble. When mixed, they remain separate in the mixture, creating a two-phase system. **STK 314**

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Single-phase Blend

The blended homopolymers dissolve in each other resulting in a single-phase material.

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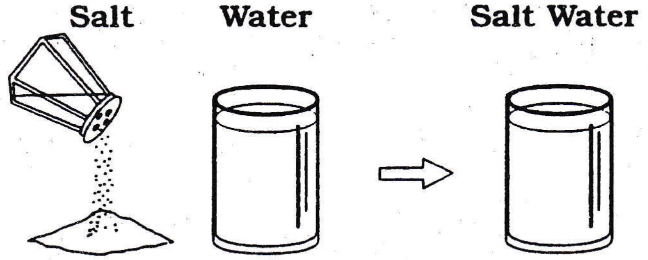
Single-phase System

The blended materials dissolve in each other similar to salt water...



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Participant's Notes:

The blended homopolymers dissolve in each other resulting in a single-phase material.

Single-phase Blend

In a single-phase blend, the two parent homopolymers are soluble in each other and therefore dissolve, resulting in a single-phase system.

STK 315

High solubility results in a single-phase blend.

Single-phase System

In a single-phase system, the materials are mixed together and dissolve, creating a single, continuous phase. Salt and water are soluble. When mixed, they dissolve, creating a single-phase system.

Single-phase polymer systems appear homogeneous when examined under magnification.

STK 316

STK 317

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Combining Polymers

Physical Combination → Blending
- Multiple-phase Material
- Single-phase Material

Chemical Combination → $\boxed{\text{Copolymerization}}$

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Participant's Notes:

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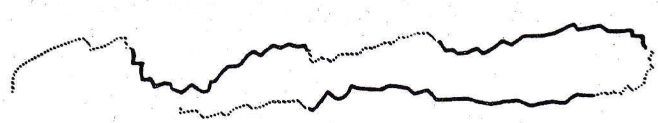
Copolymers



Two homopolymers are chemically reacted to form an entirely new polymer material.

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Participant's Notes:

Copolymerization

Copolymerization differs from blending.

Combining Polymers

Blends are the result of physically mixing the homopolymers, while copolymerization is the result of chemically reacting the parent polymers. STK 317

The copolymer is a chemical combination to form a new polymer chain.

Copolymers

In copolymerization, two polymers are actually copolymerized to form an entirely new polymer material. STK 318

STK 319

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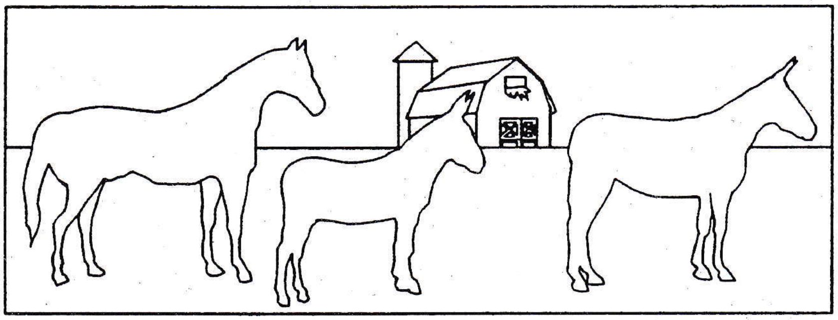
Chemically Combined Copolymers

The homopolymers are copolymerized, a chemical reaction similar to producing a mule...



Horse → Donkey → Mule

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Participant's Notes:

STK 320

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Polymer Modification

Basic Polymers

↓ Blends | ↓ Homopolymers | ↓ Copolymers

Impact Modification | Rigid Reinforcement | Additives

Useful Polymer Material

3

Participant's Notes:

Chemically Combined Copolymers

Unique products can be produced from dissimilar polymers.

Copolymerization can be likened to the mating of a donkey and a horse to produce a mule. The resulting offspring is neither a donkey nor a horse, but another animal entirely. Likewise, the resulting copolymer is something new and different from its parent polymers and it can never be changed back into the parent polymer. Though a blend may be physically separated back into its distinct components, the process of copolymerization can not be reversed. Copolymerization produces a new polymer product. **STK 319**

Polymer Modification

Impact modification and rigid reinforcement are two additional means of modifying polymers.

Homopolymers, blends, and copolymers comprise the basic market basket of polymer materials. These materials make up the foundation of the material supplier's product lines. Within these lines, however, there are still material performance distinctions created by polymer modification. For example, a resin may offer varying degrees of impact resistance created by impact modification, or a resin may offer varying degrees of rigidity created by rigid reinforcement. Impact modification and rigid reinforcement are two means of modifying polymers to improve their usefulness in a variety of applications. **STK 320**

STK 321

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Impact Modification

To increase toughness or impact resistance of a material, an impact modifier is added.

3

Participant's Notes:

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Impact Modifier

The impact modifier generally has a Glass Transition Temperature (T_G) below room temperature, lends its own properties to the polymer and the polymer improved impact resistance.

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Participant's Notes:

Impact Modification

Impact modification is used to enhance impact resistance.

Impact Modification
Impact modification increases the impact resistance or toughness of a polymer. STK 321

A typical impact modifier will have a low glass transition temperature (T_G).

Impact Modifier
An impact modifier is a material such as rubber that has excellent impact resistance. When blended with the polymer, an impact modifier lends its own impact properties to the polymer, giving it improved impact resistance. The impact modifier is usually a material with a glass transition temperature (T_G) that is below room temperature. STK 322

STK 323

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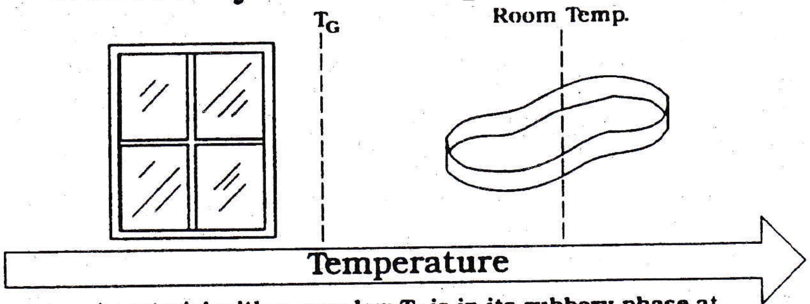
Low T_G Necessary for an Impact Modifier



A material with a very low T_G is in its rubbery phase at room temperature and therefore maintains its impact properties.

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Participant's Notes:

STK 324

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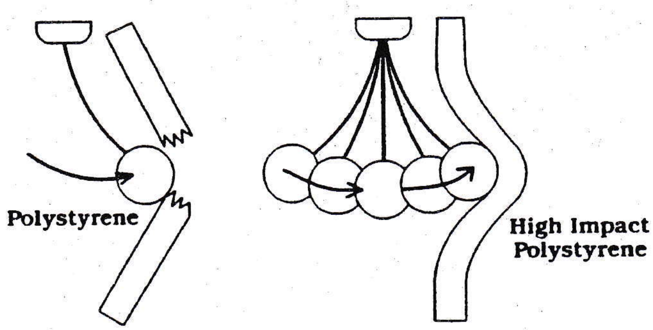
Impact Resistance



The ability of the material to absorb energy before breaking.

3

Participant's Notes:

A good impact modifier works when it is above its T_G.

Low T_G Necessary for an Impact Modifier

The glass transition temperature is the temperature at which a material will turn "rubbery" upon heating and "glassy" upon cooling. Therefore, a material with a low T_G, such as rubber, will remain in its "rubbery" state even at a low temperature. A material in its rubbery state tends to have even greater impact resistance. **STK 323**

Impact resistance implies energy absorption.

Impact Resistance

Impact resistance is a material's ability to absorb energy before breaking. Rubber has excellent impact resistance, while glass does not. If you throw a ball at a piece of rubber, it will bounce back. If that same ball was thrown at a piece of glass, the glass would break. High impact polystyrene (HIPS) contains impact modification which renders it better able to withstand impact and recover than unmodified polystyrene. Still, the polystryrene may be preferable in certain applications requiring stiffness or rigidity. **STK 324**

STK 325

GE Plastics

Rigid Reinforcement

To increase stiffness and strength of a material, a high modulus reinforcement is added.

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Participant's Notes:

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High Modulus Reinforcement

The high modulus reinforcement lends its own properties to the polymer giving it improved stiffness and strength.

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Participant's Notes:

Rigid Reinforcement

Polymer stiffness can be increased by adding a rigid reinforcement.

Rigid Reinforcement

Rigid reinforcement increases the stiffness and strength of a material by blending it with a high modulus reinforcement. **STK 325**

An effective reinforcing agent will have a high modulus.

High Modulus Reinforcement

Modulus refers to the stiffness of a material. Rubber, for example, is a low modulus material. Glass, on the other hand, is a high modulus material. A high modulus reinforcement is a rigid material such as glass, carbon fibers, or minerals that is added to the polymer. Upon blending, a high modulus reinforcement lends its own stiffness to the polymer, giving it improved stiffness and strength. **STK 326**

STK 327

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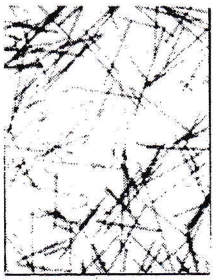
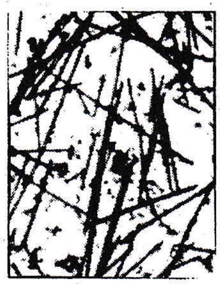
Actual Reinforcements


Glass Fibers


Carbon Fibers


Minerals &
Glass Fibers

High modulus reinforcements increase polymer
stiffness & strength.

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Participant's Notes:

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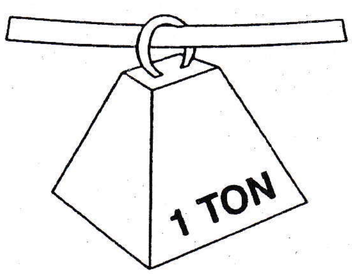
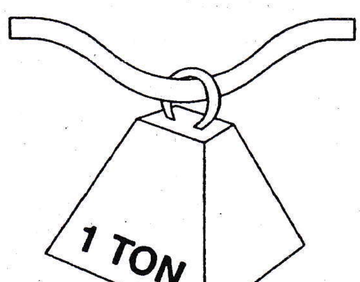
Stiffness (Modulus)



High Modulus Material



Low Modulus Material

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Participant's Notes:

Actual Reinforcements

Some typical high modulus reinforcements.

Here are some actual photos of rigid reinforcement used in polymer materials. Glass and carbon fibers typically have high aspect ratios (their length is much greater than their diameter). Minerals are used for their low aspect ratios. They have similar dimensions in all directions. Each type of reinforcement adds slightly different properties to the final polymer product. **STK 327**

Stiffness (Modulus)

Reinforcement will increase modulus.

The reinforcer increases the stiffness of the material. A higher modulus material is capable of bearing a greater load without deflecting than a low modulus material. By increasing the stiffness of the material, the reinforcer may also increase the material's strength.

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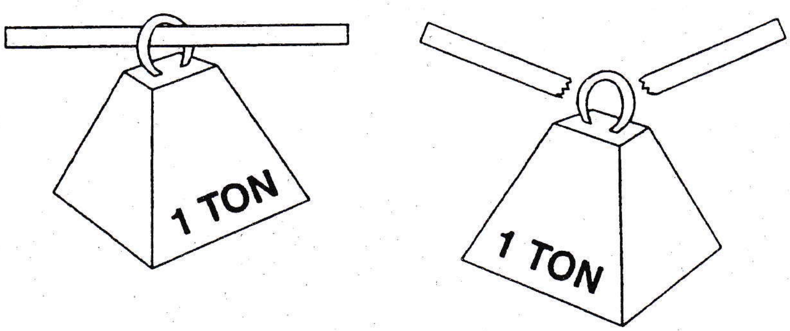
Strength



The ability of the material to carry a very heavy load before breaking.

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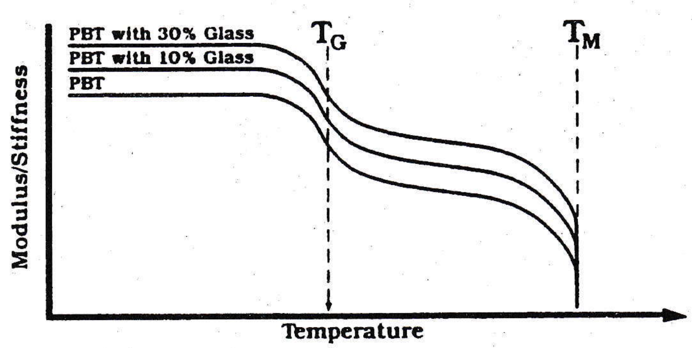
Thermal Transition



Reinforcement raises the modulus of the material, however, the thermal transition curve remains consistent.

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Participant's Notes: ______________________________

Rigid reinforcement may increase strength.

Strength

Strength is the ability of a material to carry a very heavy load before breaking. The rigid reinforcer may also increase the strength of the material. **STK 329**

Thermal Transition

Rigid reinforcement enhances certain polymer properties, but the original polymer remains intact. The basic thermal transitions that the polymer goes through will remain consistent though the material will be slightly stiffer throughout its useable temperature range.

Glass reinforcement does not change the basic temperature transitions T_G and T_M.

Consider the modulus versus temperature curves for a crystalline polymer containing varying amounts of glass reinforcement. The shape of the curve remains the same. The important material transitions - T_G and T_M - also remain the same, regardless of the amount of glass reinforcement. The modulus varies, however, depending on the percentage of glass reinforcement that has been added to the material. The greater the percentage of rigid reinforcement, the higher the material's modulus throughout, as reflected on the graph. **STK 330**

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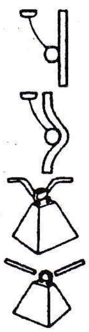
Modification/Reinforcement Comparison

Impact Modification



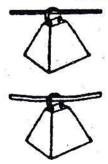
Increased Impact Resistance

Increased Elongation

Decreased Stiffness

Decreased Strength

Glass (High Modulus) Reinforcement



Increased Strength

Decreased Elongation

Decreased Thermal Expansion

Potential Warpage

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Thermal Expansion (CTE)

- Thermal Expansion is the reversible tendency of a plastic to expand in the heat and contract in the cold.
- High modulus reinforcements have low thermal expansion.
- Polymers containing these reinforcements therefore have lower thermal expansion than unreinforced polymers.

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Participant's Notes: ____________________

Modification can enhance selective properties.

Modification/Reinforcement Comparison

Impact modification and rigid reinforcement enhance very different material properties: impact resistance and stiffness/strength. Upon comparison, you can see that by increasing impact, you also increase elongation but must sacrifice some stiffness and strength. By increasing strength, you decrease elongation as well as thermal expansion, and you increase the likelihood of warpage. **STK 331**

The expansion of a polymer is affected by the type of reinforcement.

Thermal Expansion (CTE)

Thermal expansion is the reversible tendency of a plastic to expand in the heat and to contract in the cold. A high modulus reinforcement usually has a very low coefficient of thermal expansion. Since the reinforcer lends its own properties to the material, polymers containing these reinforcements have lower thermal expansion than unreinforced polymers. Consequently, reinforced polymers tend to expand and contract less in the heat and cold than their unreinforced counterparts. **STK 332**

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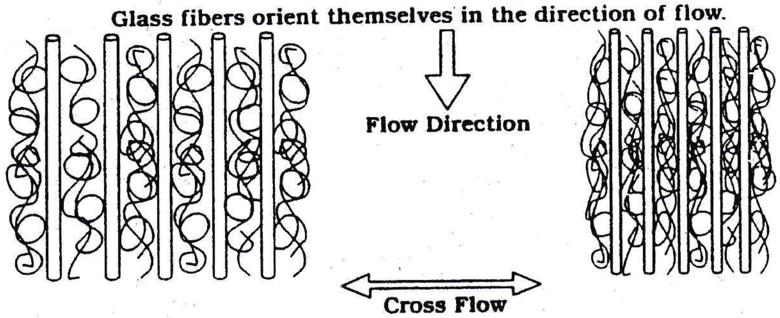
Shrinkage on Cooling

Glass fibers orient themselves in the direction of flow.



Due to the lower thermal expansion of the glass fibers, less shrinkage occurs in the flow direction and larger shrinkage occurs in the cross flow.

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Polymer Modification

Basic Polymers

↓

Blends | Homopolymers | Copolymers

↓ Impact Modification | ↓ Rigid Reinforcement | ↓ Additives

Useful Polymer Material

3

Participant's Notes:

The lower coefficient of thermal expansion (CTE) of the glass fibers limits shrinkage.

Shrinkage on Cooling

The thermal contraction of a reinforced plastic is affected by the presence of a rigid reinforcement. Because the glass fibers expand and contract less than the polymer material, and because these glass fibers tend to orient themselves in the direction of flow, the glass reinforcement will restrict the material's contraction in the direction of flow and cause less shrinkage to occur. Because less shrinkage occurs in one direction than another, it is said to be anisotropic and may cause warpage. **STK 333**

Additives

Additives can be used to tailor polymer properties.

Polymer Modification

Blending and copolymerization create new resin products. Impact modifiers and rigid reinforcements expand the performance capabilities of these products. Additives fine tune a resin. **STK 334**

STK 335

GE Plastics

Additives

Additives Fine Tune a Polymer's Property Performance Profile:

- Stabilizer Systems
- Flame Retardants
- Colorants
- Flow Aids
- Release Agents

3

Participant's Notes:

STK 336

GE Plastics

Stabilizer Systems

Stabilizers are added to the polymer to inhibit degradation caused by:

Oxygen	⟹	Oxidative Stability
Light Energy	⟹	Ultraviolet Stability
Heat Energy	⟹	Thermal Stability
Water	⟹	Hydrolitic Stability

Certain stabilizers protect the polymer during processing and others guard against the affects of weathering.

3

Participant's Notes:

Additives

Additives can improve performance in processing and use.

A variety of additives are available to fine tune a polymer's property performance profile. They can help to improve a polymer's performance during processing, or tailor a polymer's performance capabilities for a specific end use. **STK 335**

Stabilizer Systems

Stabilizers are added to the polymer to inhibit degradation.

A thermal stabilizer can help protect a polymer during processing by preventing degradation caused by overheating. A UV stabilizer protects a polymer from degradation caused by light energy and therefore expands its usefulness by making it suitable for outdoor applications. Stabilizer systems are also available to inhibit degradation caused by oxygen or water to further expand a polymer's usefulness. **STK 336**

STK 337

GE Plastics

Flame Retardants

Flame retardants are added to minimize the chance of a material igniting.

3

Participant's Notes:

STK 338

GE Plastics

Effects of Additives

- Add Performance (Flame Retardants, Flow Aids, & Release Agents)
- Enhance Appearance (Pigments)
- Extend Life (Oxidative, Thermal & UV Stabilization)

Additives May Affect Processing Conditions

3

Participant's Notes:

Flame retardants reduce the potential for burning.

Flame Retardants

A flame retardant is another kind of additive that minimizes the chance of a material igniting from exposure to high temperatures, a spark, or an open flame. Flame retardants are often added to a material as a safety precaution to reduce its burning potential.

STK 337

Additives may warrant special consideration.

Effects of Additives

Additives such as flame retardants, flow aids, and release agents add to the performance of a material. Other additives such as pigments enhance the appearance of a material. Some additives such as oxidative, thermal, and UV stabilizers extend the life of a material. Additives may warrant special consideration during processing. Lower processing temperatures and reduced residence times may be appropriate for materials containing additives. **STK 338**

STK 339

GE Plastics

Plastic Part Production

- Part Design Dictates Performance
- Performance Dictates Material
- Material Dictates Tooling

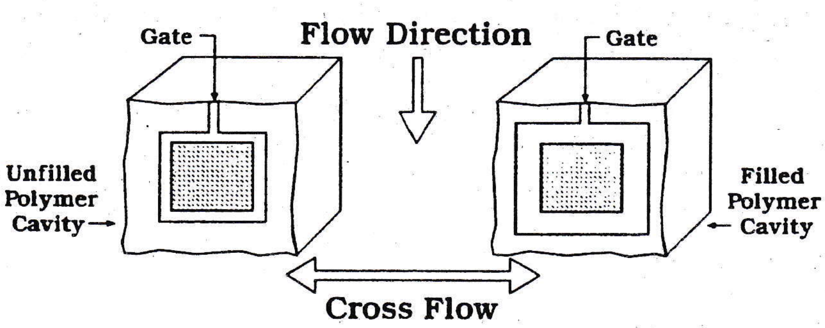
3

Participant's Notes:

STK 340

GE Plastics

Material Dictates Tooling



Tool design must accomodate for anisotropic shrinkage when using filled polymers.

3

Participant's Notes:

Tooling

The material dictates tooling geometry.

Plastic Part Production

The application and design of the part will dictate the performance requirements; the performance requirements and the part design will dictate the material selection; and the material selected will dictate the design of the tool.

STK 339

Filled and unfilled polymers require different tooling geometry.

Material Dictates Tooling

Anisotropic shrinkage is one example of the way a material dictates the design of the tool. Due to anisotropic shrinkage, the tool for a filled material must allow for more shrinkage in the cross flow and less in the flow direction. In order to get the same part dimensions, the tool for the same part using an unfilled material would allow for even shrinkage throughout. Filled and unfilled polymers may require different tool geometry.

STK 340

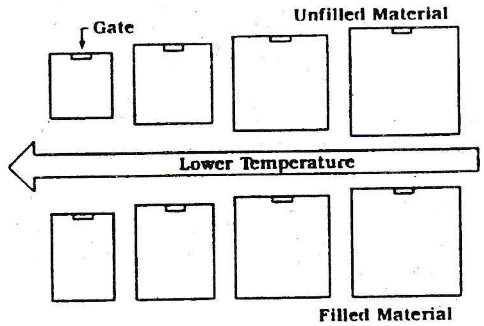
STK 341

GE Plastics

Anisotropic Shrinkage

Isotropic Shrinkage:
The Same in
All Directions

Anisotropic Shrinkage:
NOT the Same in
All Directions



Shrinkage in glass reinforced polymers is anisotropic due to the restriction of shrinkage along the fiber length which tends to be in the direction of flow.

3

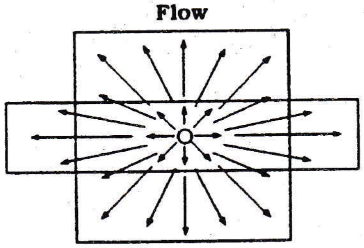
Participant's Notes:

STK 342

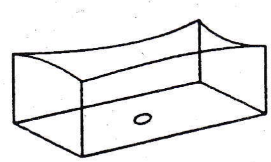
GE Plastics

Shrinkage & Fiber Orientation Cause Warpage

Multidirectional Flow



Uneven Shrinkage - Warpage



Tooling must be modified to control resin flow.

3

Participant's Notes:

Anisotropic shrinkage is different shrinkage in the flow and cross flow.

Anisotropic Shrinkage

Even shrinkage is called isotropic shrinkage - meaning the same in all directions. Glass reinforced materials shrink more in the cross flow and less in the flow direction. This kind of uneven shrinkage is called anisotropic shrinkage - meaning not the same in all directions. Consequently, the tool must be modified to accommodate for anisotropic shrinkage when molding a reinforced polymer.

STK 341

Shrinkage and fiber orientation cause warpage.

Shrinkage and Fiber Orientation Cause Warpage

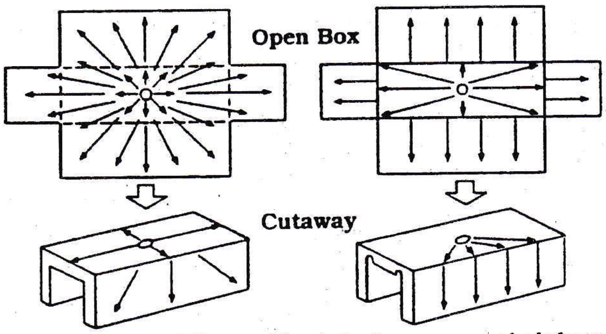
Filled polymers may require different flow designs. Because filled polymers shrink more in the cross flow than in the flow direction, multidirectional flow could cause warpage. The flow entering this five sided box spreads radially to fill the part. Upon cooling the part shrinks unevenly and warps. Therefore the tool for a filled resin should control the flow direction to minimize warpage.

STK 342

STK 343

GE Plastics

Tooling Modification



A unidirectional flow will minimize uneven shrinkage and therefore warpage.

3

Participant's Notes:

STK 344

GE Plastics

Plastic Part Production

- Part Design Dictates Performance
- Performance Dictates Material
- Material Dictates Tooling
- Tooling & Materials Dictate Processing
- Processing Dictates Performance

3

Participant's Notes:

Tooling Modification

The fill pattern can affect and control warp.

A simple tooling modification can be used to encourage a unidirectional flow and minimize uneven shrinkage. In this example, the material enters the cavity and begins to flow radially then hits the flow restrictor and is forced to flow in one direction to fill the sides of the box. The flow restrictor allows the sides to fill more evenly and therefore shrink more evenly, thus minimizing warpage.

Gate location is another important tooling consideration that is greatly influenced by material selection. For example, when using filled materials, end gating is often preferred to encourage unidirectional flow and minimize uneven shrinkage/warpage. **STK 343**

Processing

A direct relationship exists between design, material performance, processing and tooling.

Plastic Part Production

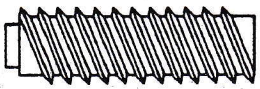
The material and the design dictate tooling. The tooling and the materials dictate processing and the processing dictates performance. Adherence to recommended tooling and processing parameters for the material selected and the design chosen should result in a higher quality, high performance part. Everyone has a stake in making a quality part. **STK 344**

STK 345

GE Plastics

Processing Filled Polymers

Machine Requirements



- Reciprocating Screw Machine
- 20:1 L/D
- 1.5-2.0 Compression Ratio
- Low Shear Screw Design

3

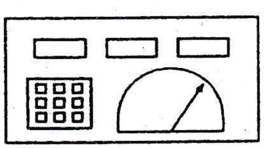
Participant's Notes:

STK 346

GE Plastics

Processing Filled Polymers

Processing Requirements



- Higher Rear Zone Barrel Heats
- Low Back Pressure
- Low Screw Speeds
- Slow Injection Speeds

3

Participant's Notes:

Processing Filled Polymers

Filled polymers have different processing requirements.

Filled materials have different processing requirements than unfilled or reinforced. When processing a filled polymer, it is important to protect the rigid fibers that have been added for material reinforcement. If these fibers are damaged or broken, they will no longer lend the necessary reinforcement to the material, resulting in inferior material performance and substandard parts. Certain equipment, tooling, and processing parameters must be followed to protect these reinforcement fibers during processing.

A reciprocating screw machine equipped with low shear screw design is preferred for molding filled resins. The screw should have an L/D of 20:1 and a compression ratio of no more than 2:1.

STK 345

Processing must be carried out with care.

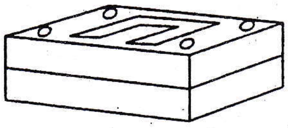
When processing a filled resin, efforts should be made to reduce back pressure and slow injection speed. Barrel temperature can also be raised slightly to help improve the flow of the material without applying additional shear. Gentle processing methods will not only protect the reinforcement fibers in the resin, they will also protect the processing equipment and tooling cavities from excessive wear from these abrasive fibers.

STK 346

STK 347

GE Plastics

Processing Filled Polymers
Larger Flow Channels



- Sprues
- Runners with Radiused Corners
- Gates

3

Participant's Notes: ______

STK 348

GE Plastics

Understanding Polymer Modification

3

Participant's Notes: ______

Tooling recommendations for filled resins.

The tool for a filled resin should have large flow channels, open sprues, runners and gates. STK 347

Summary and Performance Feedback

Understanding Polymer Modification

As you've seen, polymer modification increases the variety of resins available to the manufacturer and expands their usefulness in application. Blending and copolymerization increase the amount of resins available. Impact modification and rigid reinforcement allow for greater selection within the available resin lines by varying the degree of impact resistance and strength in each resin grade. And additives make possible the fine tuning of a resin to meet specific processing and performance requirements. Together, all these methods greatly expand the use of plastics by expanding their usefulness in application. STK 348

STK 349

GE Plastics

Finding a Material to Fit an Application

GE Plastics offers 7 basic homopolymers...
12 different product lines...
and over 700 grades.

How is it possible to get so many property combinations out of seven basic homopolymers?

3

Participant's Notes:

STK 350

GE Plastics

Polymer Modification

- Blend Two or More Homopolymers
- Copolymerize Two or More Homopolymers
- Add an Impact Modifier
- Add a Rigid Reinforcement
- Use Additives

3

Participant's Notes:

STK 351

GE Plastics

Impact AND Stiffness?

Given a polymer with average impact resistance and stiffness, can I alter it to dramatically improve both?

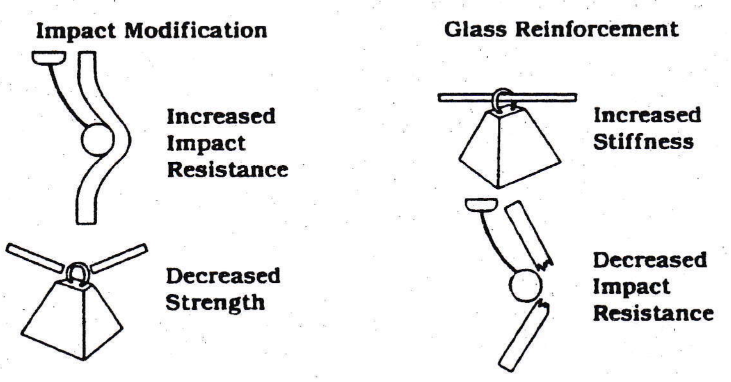
3

Participant's Notes: ____________________

STK 352

GE Plastics

Impact Is Sacrificed for Increased Stiffness and Vice Versa



3

Participant's Notes: ____________________

STK 353

GE Plastics

Isotropic or Anisotropic

Which type of shrinkage is associated with reinforced materials and why?

3

Participant's Notes:

STK 354

GE Plastics

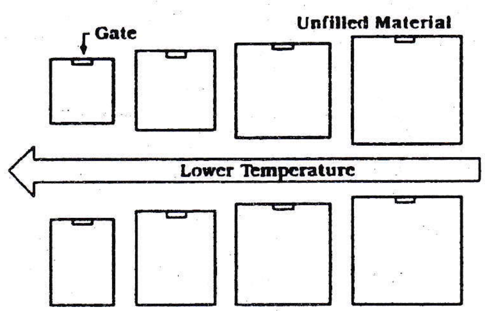
Anisotropic Shrinkage

Isotropic Shrinkage:

The Same in All Directions

Anisotropic Shrinkage:

NOT the Same in All Directions



Shrinkage in glass reinforced polymers is anisotropic due to the restriction of shrinkage along the fiber length which tends to be in the direction of flow.

3

Participant's Notes:

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Module 4

Properties of Polymers

- Mechanical Properties
- Physical Properties
- Electrical Properties
- Thermal Properties
- Structure/Property Relationships

3

Participant's Notes:

Module 3

Performance Feedback

1. Describe the benefits of polymer modification.

2. Describe the methods used to modify basic polymers.

3. What is the difference between a blend and a copolymer?

4. Define impact modification and describe the characteristics of impact modifiers.

5. Compare glass and mineral reinforcements.

6. Compare impact modifications and glass reinforcements.

7. Describe the purpose of additives such as stabilizer systems and flame retardants.

8. Identify whether you are working with a material that has glass or mineral reinforcements and/or impact modifiers.
   Describe the effect on processing.