Thermoplastic elastomer

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Thermoplastic elastomers (**TPE**), sometimes referred to as **thermoplastic rubbers**, are a class of copolymers or a physical mix of polymers (usually a plastic and a rubber) which consist of materials with both thermoplastic and elastomeric properties. While most elastomers are thermosets, thermoplastics are in contrast relatively easy to use in manufacturing, for example, by injection molding. Thermoplastic elastomers show both advantages typical of rubbery materials and plastic materials. The principal difference between thermoset elastomers and thermoplastic elastomers is the type of crosslinking bond in their structures. In fact, crosslinking is a critical structural factor which contributes to impart high elastic properties. The crosslink in thermoset polymers is a covalent bond created during the vulcanization process. On the other hand the crosslink in thermoplastic elastomer polymers is a weaker dipole or hydrogen bond or takes place in only in one of the phases of the material.

Contents

Types

Thermoplastic polyurethanes

There are six generic classes of TPEs generally considered to exist commercially. They are styrenic block copolymers, polyolefin blends, elastomeric alloys, thermoplastic polyurethanes, thermoplastic copolyester and thermoplastic polyamides. Examples of TPE products that come from block copolymers group are Kraton (Shell chemicals), Pellethane (Dow chemical), Pebax, Arnitel (DSM), Hytrel (Du Pont) and more. While there are three main commercial products of elastomer alloy: Santoprene (Monsanto), Geolast (Monsanto) and Alcryn (Du Pont).

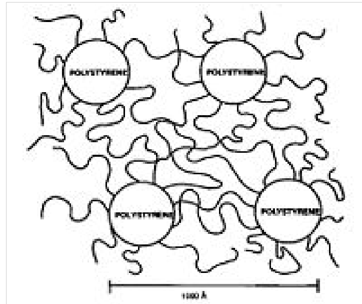
In order to qualify as a thermoplastic elastomer, a material must have these three essential characteristics:

1. The ability to be stretched to moderate elongations and, upon the removal of stress, return to something close to its original shape.

2. Processable as a melt at elevated temperature.

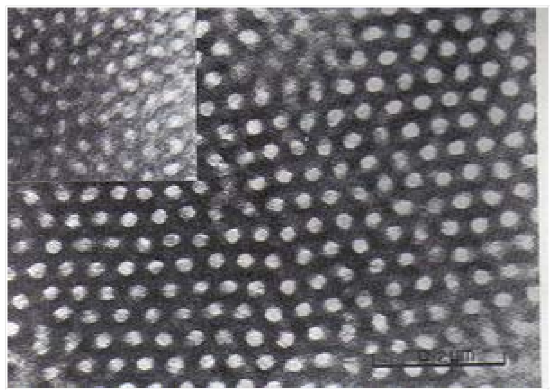
3. Absence of significant creep.

Background

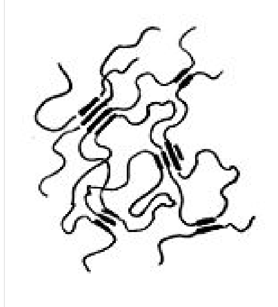


SBS block copolymer schematic microstructure

It was not until the 1950s, when thermoplastic polyurethane polymers became available, that TPE became commercially reality. During the 1960s styrene block copolymer became available, and in the 1970s a wide range of TPEs came on the scene. The worldwide usage of TPEs (680,000 tons/year in 1990) is growing at about 9% per year. The styrene-butadiene materials possess a two-phase microstructure due to incompatibility between the polystyrene and polybutadiene blocks, the former separating into spheres or rods depending on the exact composition. With low polystyrene content, the material is elastomeric with the properties of the polybutadiene predominating. Generally they offer a much wider range of properties than conventional cross-linked rubbers because the composition can be varies to suit customer needs.


SBS block copolymer in TEM

Block copolymers are interesting because they can "microphase separate" to form periodic nanostructures, as in the styrene-butadiene-styrene block copolymer shown at right. The polymer is known as Kraton and is used for shoe soles and adhesives. Owing to the microfine structure, the transmission electron microscope or TEM was needed to examine the structure. The butadiene matrix was stained with osmium tetroxide to provide contrast in the image. The material was made by living polymerization so that the blocks are almost monodisperse, so helping to create a very regular microstructure. The molecular weight of the polystyrene
blocks in the main picture is 102,000; the inset picture has a molecular weight of 91,000, producing slightly smaller domains. The spacing between domains has been confirmed by small-angle X-ray scattering, a technique which gives information about microstructure. Since most polymers are incompatible with one another, forming a block polymer will usually result in phase separation, and the principle has been widely exploited since the introduction of the SBS block polymers, especially where one of the block is highly crystalline. One exception to the rule of incompatibility is the material Noryl, where polystyrene and polyphenylene oxide or PPO forma continuous blend with one another.



Schematic crystalline block copolymer

Other TPE's have crystalline domains where one kind of block co-crystallizes with other block in adjacent chains, such as in copolyester rubbers, achieving the same effect as in the SBS block polymers. Depending on the block length, the domains are generally more stable than the latter owing to the higher crystal melting point. That point determines the processing temperatures needed to shape the material, as well as the ultimate service use temperatures of the product. Such materials include Hytrel, a polyester-polyether copolymer and Pebax, a nylon or polyamide-polyether copolymer.

Advantages of thermoplastic elastomer

TPE materials have the potential to be recyclable
since they can be molded, extruded and reused like plastics, but they have typical elastic properties of rubbers which are not recyclable owing to their thermosetting characteristics. TPE also require little or no compounding, with no need to add reinforcing agents, stabilizers or cure systems. Hence, batch-to-batch variations in weighting and metering components are absent, leading to improved consistency in both raw materials and fabricated articles. TPEs can be easily colored by most types of dyes. Besides that, it consumes less energy and closer and more economical control of product quality is possible.

Disadvantages of thermoplastic elastomer

The disadvantages of TPEs relative to conventional rubber or thermoset are relatively high cost of raw materials, general inability to load TPEs with low cost fillers such as carbon black (therefore preventing TPEs from being used in automobile tyres), poor chemical and heat resistance, high compression set and low thermal stability.

Processing

The two most important manufacturing methods with TPEs are extrusion and injection molding. Compression molding is seldom, if ever, used. Fabrication via injection molding is extremely rapid and highly economical. Both the equipment and methods normally used for the extrusion or injection molding of a conventional thermoplastic are generally suitable for TPEs. TPEs can also be processed by blow molding, thermoforming and heat welding.

Applications

TPE's are used where conventional elastomers cannot provide the range of physical properties needed in the product. Thus copolyester TPE's are used in snowmobile
tracks where stiffness and abrasion resistance is at a premium. They are also widely used for catheters where nylon block copolymers
offer a range of softness ideal for patients. Styrene block copolymers are used in shoe soles for their ease of processing, and widely as adhesives. TPE is commonly used to make suspension bushings for automotive performance applications because of its greater resistance to deformation when compared to regular rubber bushings.

References

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- S.A. Baeurle, A. Hotta and A.A. Gusev, 'A new semi-phenomenological approach to predict the stress relaxation behavior of thermoplastic elastomers', *Polymer* 46, 4344-4354 (2005) [1] (http://dx.doi.org/10.1016/j.polymer.2004.07.034)
- S.A. Baeurle, T. Usami and A.A. Gusev, 'A new multiscale modeling approach for the prediction of mechanical properties of polymer-based nanomaterials', *Polymer* 47, 8604-8617 (2006) [2] (http://dx.doi.org/10.1016/j.polymer.2006.10.017)
- S.A. Baeurle, A. Hotta and A.A. Gusev, 'On the glassy state of multi-phase and pure polymer materials', *Polymer* 47, 6243-6253 (2006) [3] (http://dx.doi.org/10.1016/j.polymer.2006.05.076)

See also

- Copolymer
- Cross-linking

External links

- Thermoplastic Elastomers (http://www.pslc.ws/mactest/tpe.htm)
- Thermoplastic Elastomer FAQ (http://www.glscorporation.com/resources_faqs.php)
- Thermoplastic Elastomer Overmolding Guide (http://www.glscorporation.com/resources_om_guide.php)
- Thermoplastic Elastomer Injection Molding Guide (http://www.glscorporation.com/resources_im.php)
- Stress Relaxation of Thermoplastic Elastomers (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TXW-4D1R2NV-1&_user=616165&_coverDate=(
- Interphases of Thermoplastic Elastomers (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TXW-4M9H3TS-1&_user=616165&_coverDate=1
- Glassy State in Thermoplastic Elastomers (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TXW-4KBVVHK-1&_user=616165&_coverDate=
- Thermoplastic Elastomer Journal by Mustafa Caykoylu (http://www.pageranknet.com/mechanical-engineer/mechanical-engineer-archives/18-Thermoplastic-Elastomerers.htm
- Distance learning course in polymers (http://www3.open.ac.uk/courses/bin/p12.dll?C01T838)
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