PERP Program – New Report Alert

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Nexant's *ChemSystems* Process Evaluation/Research Planning program has published a new report, ***Amorphous High Temperature ETPs (03/04S12)***.

Background

High temperature amorphous engineering thermoplastics cover three product families, namely:

- Polysulfone (PSU)
- Polyethersulfone (PES)
- Polyetherimide (PEI)

These polymers are characterized by high transparency and the remarkably high in-service temperatures permitted by high glass transition temperatures in the 187ºC to 230ºC range. The first of these polymers to be commercialized was UDEL® polysulfone developed in the 1960s by Union Carbide. VICTREX PES® polyethersulfone was commercialized by ICI in the 1970s, with GE Plastics bringing its ULTEM® polyetherimide materials to the market in the early 1980s.

Polysulfone almost approaches polycarbonate in terms of clarity and color. Due to their amorphous nature, the products can be used in applications almost up to their glass transition temperatures, with polyethersulfone able to withstand temperatures above 200ºC in use. Combined with excellent hydrolysis, chemical, and fire resistance, the materials are being used as metal, glass, and thermoset replacements across the auto, electronics, consumer, aircraft, and medical fields. Compared to other plastic materials these materials have the highest performance amongst amorphous thermoplastics as shown in Figure 1.

Technology

Polysulfone/Polyethersulfone

Since their original commercialization, the synthetic routes to these polymers have not changed to any great extent. The first successfully commercialized product was UDEL® polysulfone developed by Union Carbide. The fundamental repeating unit of the polymer is shown in Figure 2.

Polysulfone synthesis involves the nucleophilic substitution of 4,4′-dichlorodiphenyl sulfone (DCDPS) with 4,4′-(1-methylethylidene)bisphenol (bisphenol A) in a dipolar aprotic solvent such as dimethyl sulfoxide (DMSO), sulfolane, or N-methyl-2-pyrrolidone (NMP).

Figure 1 Plastics Performance Tree

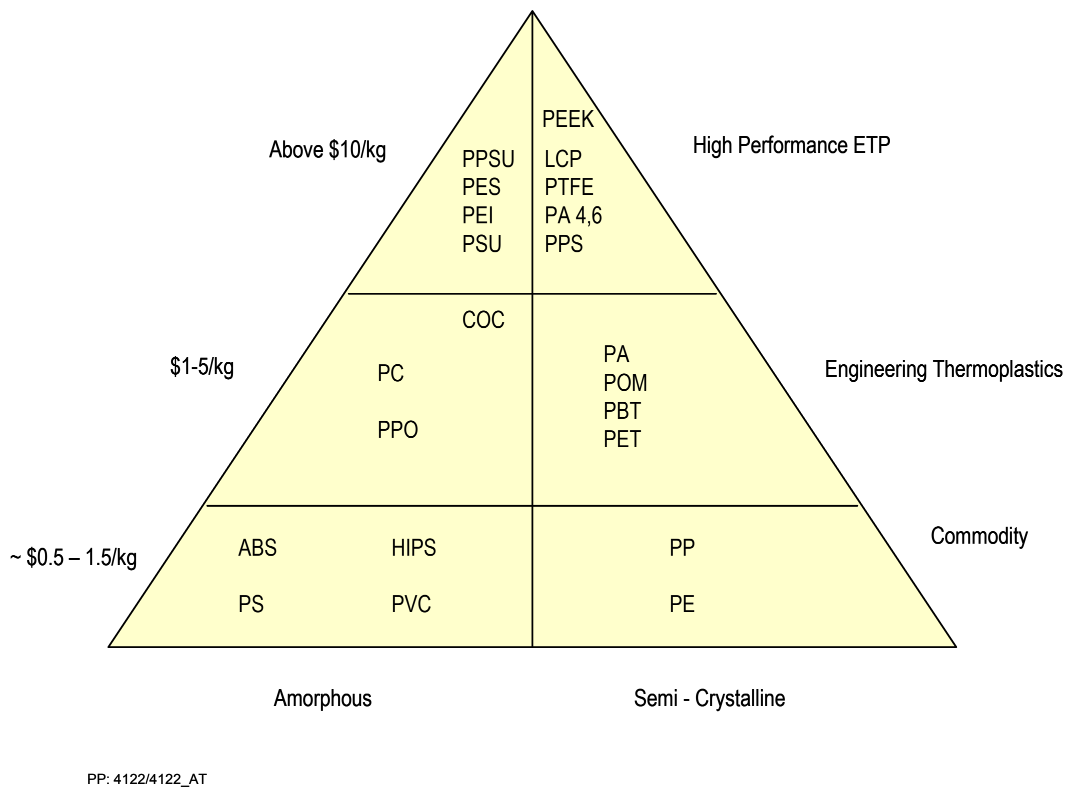
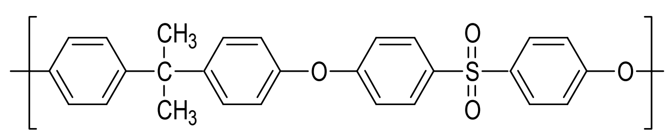
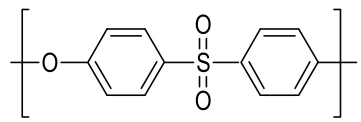


Figure 2 Polysulfone



Polyethersulfone is synthesized in a similar manner to polysulfone but a higher temperature solvent is generally required such as diphenyl sulfone, although both sulfolane and NMP are known to be used also. The monomers in this case are DCDPS and 4,4′-dihydroxydiphenyl sulfone (DHDPS), otherwise known as bisphenol S. ICI introduced the first commercial polyethersulfone polymer (VICTREX PES®) in the 1970s. The repeat structure of polyethersulfone is shown in Figure 3.

Figure 3 Polyethersulfone



The resulting molecule is wholly aromatic, and this increases the thermal properties compared to polysulfone both in terms of the glass transition temperature and also stability close to the glass transition temperature of 223ºC.

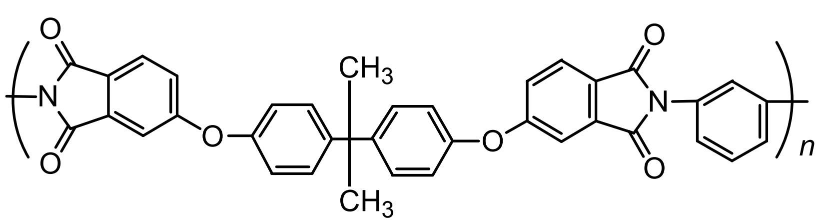
The main difference in the commercial synthesis of the sulfone polymers tends to be the reaction solvent used and whether the facility is dedicated or multipurpose (being able to produce all sulfone polymers in the same batch process). A number of producers are back-integrated into monomer feedstocks.

Polyetherimide

Polyetherimide for melt processable engineering plastics applications is represented by only one commercially available amorphous product – ULTEM® produced by General Electric Plastics (GE Plastics).

Polyetherimides are synthesized by the melt polycondensation of bisphenol A dianhydride with a diamine, usually m-phenylenediamine. The repeat unit for polyetherimide is shown in Figure 4.

Figure 4 Polyetherimide



The Tg is 217ºC, making it comparable to polyethersulfone.

Economics

The high prices of these materials (approximately $10 per kilo) are borne out by their production costs. Cost of production estimates have been developed for PSU, PES and PEI for archetype

10,000 tons per year base resin facilities located on the U.S. Gulf Coast in 2003. The production costs for one of the key monomers, 4,4'-dichlorodiphenyl sulfone (DCPDS) were also developed.

Polysulfone has the lowest total ex-works cost mainly driven by lower raw material costs, as bisphenol A is a comonomer which, due its commodity status, is relatively low cost. Although polyetherimides also use bisphenol A, the rather complex process coupled with the use of other relatively costly raw materials adds to the overall cost. Polyetherimide production also demonstrates higher utility costs by virtue of the additional energy input in various process stages such as monomer recovery.

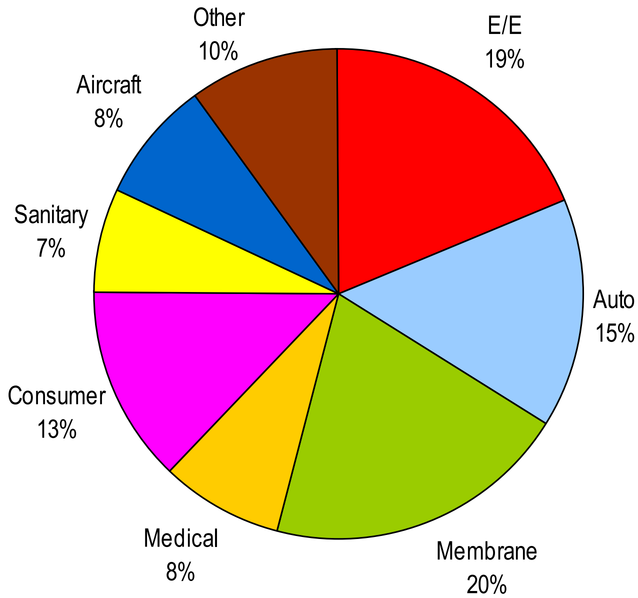
Commercial

All the amorphous high temperature polymers are enjoying strong growth as a result of general market growth for metal or thermoset replacements and also specific end market growth. Unlike more traditional and mature polymers the split of applications can change markedly due to the increase or decrease of usage in particular applications. In general, the products are used across all industry segments as a replacement for metal, thermoset, glass or even ceramics. This replacement is continuing across all segments with particular growth in the auto sector for applications such as headlamp reflectors where BMC is being replaced by polyethersulfone and polyetherimide.

The polysulfones are the lowest priced of the amorphous high temperature polymers with a minimum price in the region of $9/kg ($4/lb) with some applications demanding special grades or PPSU costing more than three times this value. This has resulted in constant substitution threat by lower cost polymers, blends and even recycled material. Hence growth across the sectors is not uniform and dependent on the application and whether at least two key performance properties of these materials are required. Therefore application areas where temperature and transparency or flame retardancy or another specific property are showing the highest growth.

The largest application area is the electronics and membranes fields which, as Figure 5 shows, is each about 20 percent of the total market.

Figure 5 Consumption of Amorphous High Temperature Thermoplastics



Production capacity is dominated by Solvay and GE Plastics. Other smaller producers include BASF, Sumitomo, Gharda, and Changchun Jida. Substantial capacity increases are planned.

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