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## Introduction to Polypropylene

### ■ INTRODUCTION

Polypropylene (PP) resins are a general class of thermoplastics produced from propylene gas. Propylene gas is derived from the cracking of natural gas feedstocks or petroleum by-products. Under broad ranges of pressures and temperatures, propylene generally polymerizes to form very long polymer chains. However, to make polypropylene resins with controlled configurations of molecules (tacticity) at reasonably acceptable commercial rates, special catalysts are required.

By utilizing techniques such as multiple reactor configurations, polymerizing other gases such as ethylene or butene in conjunction with propylene to form copolymers, using special additives to control crystallinity, etc., different types of PP resins can be produced. The ability to produce so many variations of a basic material permits the manufacturer to tailor PP resins for diverse applications, such as packaging films; clear, rigid food containers; appliance parts; automotive bumper fascia and batteries; medical syringes; etc. Following is a review of the four basic categories of PP resins, how they are produced, and their key properties.

### ■ POLYMERIZATION OF PP RESINS

PP resins are generally produced in large, continuous reactor systems operating in a slurry, "bulk" or gas phase mode. In all cases, the resultant PP products are pelletized on compounding extruders where additives such as antioxidants, processing aids, etc. are incorporated.

A slurry reactor is usually a large diameter pipe in the form of a loop that is filled with a non-reactive diluent such as isobutane. Propylene and catalyst are fed into the reactor. As the PP is produced, it forms into small "crumbs" which are insoluble in the diluent and circulate as a slurry. A portion of this slurry is continuously removed and the PP crumbs are separated, dried and conveyed to the extrusion area.

A "bulk" system operates in a similar fashion except liquefied propylene is used as the diluent for the slurry. The use of propylene is advantageous because there is no need to separate any unreacted propylene from the diluent.

In the gas phase process, no liquid is used and the reaction takes place in a fluidized or mechanically agitated bed of polypropylene powder. All liquid separation and treating steps are essentially eliminated in this process.

### ■ POLYPROPYLENE HOMOPOLYMERS

Only propylene is used in the reaction producing PP homopolymers and usually they are made on a single reactor system. PP homopolymers exhibit high stiffness, high temperature resistance and excellent chemical resistance. End products usually have a hard surface that resists scratching and staining.

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PP homopolymers are available in a wide range of melt flow rates and are used to produce, for example, oriented film, thermoformed deli containers, appliance parts, caps and closures, monofilaments, non-woven cloth and carpet fibers. PP homopolymers do not have good impact strength at low temperatures, so homopolymers are not generally suitable for applications exposed to temperatures below normal refrigeration.

### ■ RANDOM COPOLYMERS

One way to improve the impact strength of PP at low temperatures is to add a second component, ethylene, in the reactor step. The resulting PP product is called a "random copolymer." The addition of the second component reduces the crystallinity of the PP to some extent and provides two benefits: marginal impact improvement at lower temperatures and clarity.

The amount of ethylene added is usually two-to-four percent. In the resulting polymer, the ethylene molecules are randomly inserted along the polypropylene chain. These polymer chains are more flexible so their flexural modulus (stiffness) is reduced but impact resistance improves slightly at room temperature and below. Such PP random copolymer products are used in applications such as "see-through" freezer storage containers, syrup and household chemical bottles, VCR cases, tackle box components and storage boxes. If special additives called "clarifiers" are also added, the sizes of the crystallite areas

in the polymer are reduced and clarity, gloss and stiffness are enhanced. Clarified random copolymers are commonly used for food storage containers and bottles. Although not as stiff as homopolymers, random copolymers can still be used for "hot fill" applications.

### ■ IMPACT COPOLYMERS

PP impact copolymers provide the highest level of impact strength, especially at sub-ambient conditions. These materials are manufactured in a two-reactor system, operating in series. In the first reactor, PP homopolymer is produced. Instead of transferring this product to extrusion compounding, it is conveyed to a second reactor which also contains a high concentration of ethylene. The ethylene, in conjunction with the residual propylene left over from the first reactor, copolymerizes to form an ethylene-propylene rubber (EPR). The resultant product has two distinct phases: a continuous, rigid homopolymer matrix and a finely dispersed phase of EPR particles. This rubber phase absorbs and disperses the energy of any impact load to prevent part failure while overall stiffness is maintained by the rigid homopolymer matrix.

Although impact modification can be (and has been) done by mechanically mixing rubber into a PP homopolymer, it is not possible to achieve either the level of dispersion or a small enough rubber particle size (about five microns) to obtain the

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maximum rubber efficiency that can be achieved by in-reactor synthesis. By carefully adjusting the amount and composition of the EPR, a wide range of impact/stiffness combinations can be produced. Impact copolymers are used in diverse applications including medical waste bags, automotive batteries and heavy duty tool and tackle boxes. Impact copolymers are also used as the base materials for producing filled and reinforced compounds for many automotive structural applications. Because these materials are composed of two distinct phases, impact copolymers tend to be translucent to opaque.

### ■ OLEFINIC THERMOPLASTIC ELASTOMERS

These products, often referred to as TPOs, are a relatively new PP development. Historically, the highest rubber content that could be incorporated into an impact copolymer in the second reactor was about 20-25%. With the advent of new catalyst and process technologies, these capabilities have widened considerably and some products have been developed with rubber content of 50% or more. Such high rubber

levels result in products with excellent impact strength even at temperatures as low as -30°C. Although some amount of stiffness is lost, these materials can still be used in material handling crates, highway dividers, etc. However, the largest application for TPOs is filled and reinforced compounds which are replacing many of the more expensive engineering thermoplastics in automotive and appliance applications, such as paintable bumper fascia and interior panels.

### ■ SUMMARY

PP resins are one of the more versatile families of thermoplastics. By tailoring the process or the composition, a supplier can produce products ranging from semi-rigid, extremely tough, elastomeric types to very rigid grades that can withstand severe environments, such as autoclave sterilization at high temperatures. In between are grades suitable for films, filaments, automotive battery cases and rigid packaging with exceptional optical properties, all sharing the same characteristics of easy processing, durability and chemical resistance.

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