Analysis of Polymer Additives in the Packaging Industry

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Abstract

Polymer additives have had a dramatic effect on packaging materials. Improvements in polymer performance have opened the door for new and innovative ways of production. Numerous additives provide processing and manufacturing performance improvements, others allow materials to have an assortment of enhanced properties.

This paper discusses the developmental history of polymer additives, different categories of polymer additives, their importance to the packaging industry, and types of machinery involved in processing additives. While there are a variety of additives, this paper focuses on those that enhance the processing capabilities and improve functional properties of polymeric materials.

Introduction

Polymer additives are important areas of innovation for packaging materials. An additive is a material that is added to a polymer melt to enhance processability, performance, or appearance. The ability to modify polymers to has allowed the packaging industry to produce better and stronger materials (Murphy, 2001).

Polymeric materials are used in packaging products such as films, molded containers, and cushioning. Packaging materials benefit greatly from inclusion of additives to polymers to enhance processability and performance (Soroka, 2002).

History

The polymer industry has experienced a number of changes throughout the years, starting with the discovery of natural polymers and evolving into the specialized industry that is seen today. Organic polymers such as beeswax and bitumen[1] have been used for centuries, but the materials were unable to be used for general applications because they were too brittle or soft and were not useful with other materials. A few other organic polymers were animal horn or hoof, which could only be molded, and the *Tacchardia lacca* insect, which was used to produce shellac (Williamson, 1994).

The resins exuded from trees were another source of organic polymers. The most popular tree resin was from the rubber tree, however natural rubber is soft and sticky in hot weather and very brittle in cold weather. To solve this problem the rubber was modified with sulfur and heat, which was termed vulcanization. There were many other

[1] Bitumen is obtained through the distillation of crude oil and was first used as a sealant, adhesive and for decorative applications (Williamson, 1994).

mixtures that were created which need modifications or additives to be industrially useful (Williamson, 1994).

The discovery of natural polymers created a need for additives to modify polymer properties so that materials would have improved characteristics to allow for a wider variety of uses. For example, celluloid was considered to be the first semi-synthetic polymer. In order to make it practical for commercial uses, it was improved by adding camphor to reduce brittleness (Williamson, 1994).

Today, natural and synthetic polymers both rely on additives for processing. To create new blends, additives and polymer resins are mixed to produce improved materials. Standard mixtures are produced that can be further customized by adding various additives to create a variety of chosen materials and meet individual processing needs (Ram, 1997). The inclusion of polymer additives allows manufactures to create individualized blends and get a very specialized product to satisfy customer needs. For the packaging industry, this means better materials are available with an increased capacity to create unique blends for products with specific requirements

Additive Types

There are several categories of additives such as stabilizers, processing aids, plasticizers, anti-statics, blowing agents, fillers, coupling agents, antibacterial additives, desiccants, and color changing additives. These additives are vital to the production of the many types of polymers that are on the market today. They help to maximize the performance of the materials and to produce a product that fulfills production needs.

Stabilizers

Antioxidants are a type of stabilizer that can protect a material during processing and extend the material's longevity. They are used to prevent degradation of polymers that can result in loss of strength, flexibility, thermal stability, and color. Antioxidants perform by eliminating oxidation during and after processing when materials are exposed to an energy source (Ram, 1997).

A second category of stabilizers are those that help materials withstand UV light. Ultraviolet radiation damages chemical bonds of polymeric materials; therefore addition of UV stabilizers is critical to produce materials that will provide good performance even when exposed to UV radiation over extended periods. These stabilizers function by absorbing high energy UV radiation and then releasing it at lower energy level that is less harmful to the polymer. For example Titanium dioxide has a high refractive index which enhances long term stability and protects against material discoloration (Murphy, 2001).

A third category of stabilizers prevent thermal breakdown of materials and preserve aesthetic properties (Ram, 1997). These are known as heat stabilizers, which function by eliminating chemical decomposition during processing.

The fourth category of stabilizer is flame retardants, which are formulated to promote extinguishing of a polymer. Many polymers are flammable in their pure form; therefore addition of flame retardants can help protect materials and their contents. Flame retardants function by interfering with the combustion process or creating a new combustion reaction that generates less heat (Callister, 2007). The additive is designed to process easily and have no impact on the other physical properties of the material (Murphy, 2001).

Processing Aids

Polymer processing aids are used to provide higher quality and better output and to shorten cycle times. The two major types of processing aids are nucleating/clarifying agents and lubricants.

Nucleating/clarifying agents

Nucleating/clarifying agents are chemical structures that increase the overall crystallization rate of polymers. They can be used to increase stiffness, hardness, impact properties, tensile strength, and to control the size and distribution of pores (Murphy, 2001). The increased rate of crystallization results in more crystals being produced in the same amount of space; therefore, crystals that tend to be smaller. The smaller, tightly packed crystals reflect less light so they have much higher clarity (Soroka, 2002). Higher crystallization speed also helps a polymer solidify faster when cooling, which can lead to reduced machine cycle time and increased production.

A commercial example of nucleating agents/clarifiers is the Milliad® additive that was created by Milliken Chemical (Spartanburg, SC) for transparent polypropylene packaging. This additive allows for faster processing and improved clarity, gloss, and barrier properties. The ability to provide clarity for polypropylene packaging can be much less expensive than use of a material such as polyethylene terephthalate that is normally used for products in need of high clarity (Murphy, 2001).

Lubricants

Lubricants are used to improve flow and processing properties. There are a variety of types available with varying properties that can greatly improve mixing, extrusion, and calendaring behavior of materials. An internal lubricant is a type of additive that acts by modifying material viscosity. The trend today is to utilize value-added internal lubricants that can also modify other properties. By achieving multiple goals lubricant additives can be more cost effective (Murphy, 2001).

Slip additives are a type of internal lubricant that creates better processability by reducing the internal friction and tackiness of polymers. Slip additives are used to reduce the surface friction of polymers. They are very common in the film industry because the slip additive helps film layers slide over each other which can be very useful in high speed packaging processes (Soroka, 2002).

Anti-blocking additives are another type of internal lubricant that can improve processability during production. Anti-blocking additives prevent film layers from sticking together. There are many types of anti-blocking additives that can provide a diverse offering of formulations. For instance, there are expensive synthetic silica formations that give high clarity. Alternatively, calcium carbonate is used for simple anti-blocking for when clarity is not important. When these two internal lubricants are used in combination, anti-blocking reduces the effectiveness of the slip agent. When these additives are used together this effect must be considered to determine the best formulation for the polymer mixture (Murphy, 2001).

Plasticizers

Plasticizers are additives that increase the plasticity or flexibility of a plastic material. The plasticizers soften the final product, thus increasing movement and durability. Plasticizers work by embedding themselves between the polymer chains and pushing chains further apart. This results in a more flexible plastic, but causes a loss of strength and hardness. Plasticizers are most commonly used with polyvinyl chloride because without assistance it is too rigid to be processed. Plasticizers can be helpful for production, but they are potentially toxic and should not be used for food packaging applications for fear of migration into foods (Wilson, 1995).

Anti-statics

The choice of anti-static is crucial and is determined by a wide range of factors such as polymer type, processing conditions and end application. Anti-static additives allow polymeric materials to disperse static electricity charges. Static charges can attract dust or interfere with production (Soroka, 2002). An additive can be fast acting to reduce dust attraction and can be formulated to give long term effects in demanding applications. Combinations with anti-block and slip products are often used in the film industry to maximize cost effectiveness and high performance (Murphy, 2002).

Blowing Agents

Blowing agents are additives that decompose to form a gas that will expand a polymer's cellular structure. This is used to create foams and expandable materials that are light and provide thermal and/or shock protection. A common example is expanded polystyrene (EPS), which is used heavily in packaging applications. To do this, polystyrene is combined with a blowing agent in a mold and then heated so that the blowing agent is activated and the polystyrene expands (Soroka, 2002). EPS has developed a bad reputation because some foams use chlorofluorocarbons (CFCs) which erode the ozone layer. EPS does not contain CFCs; instead it is created by using pentane gas as a blowing agent (Murphy, 2002).

Fillers

Fillers are added to polymers mainly to reduces cost and improve the properties of the material. Polymers use less expensive fillers to replace some of the volume of more expensive materials. Fillers can improve processing, abrasion resistance, density control, dimensional and thermal stability, and optical effects. Common fillers are wood, silica, glass, clay, and other polymers (Callister, 2007).

Coupling Agents

The primary purpose of coupling agents is to increase interactions between polymer and filler. They create chemical links between molecules to improve bonding. When the coupling agents bond to a polymer they can enhance the adhesion between the two materials (Arie, 1997).

Since coupling agents promote bonding, they can be used to encourage materials that are normally incompatible to bond together. This effect can be very useful for trying to create new polymer blends and for reusing old polymer material.

Antibacterial Additives

Anti-bacterial additives are used to create a resistance to microorganisms so that polymeric materials are protected from bacterial growth. The additives operate by interfering with the metabolism of microorganisms to block enzyme systems. To be effective the additive must be able to migrate to the surface of the material so that it can interact with the microorganisms (Murphy, 2002).

Desiccants

Desiccants can be coextruded in-between layers of resin for moisture control. This process is accomplished by using a co-extrusion head on the molding machine to create a multilayer wall in the package. For example TricorBraun (St. Louis, Missouri) has developed a DryKeep™ blend made with Magnesium Sulfate and HDPE/LDPE to create a blow molded resin. Benefits of having a desiccant in the layers of the packaging are that it can absorb moisture from inside or outside the bottle (Slaga, 2008).

Color changing additives

Color changing additives can be added to polymers to change with their environment such as temperature changes or UV exposure. For example, there are coffee lids that change color when hot so that consumers can identify when the product should be handled with caution. The production process is the same except the plastic is imbedded with thermochromic dye during manufacturing. The color changing technology is safe in food contact situations and is FDA compliant (Color Changing Disposable Coffee Cup Lids, 2007). Polymers can also change color when exposed to UV light. For example, suntan lotion bottles can act as a sensor that changes color in the sun so consumers know when to use the product (Slaga, 2008).

Other additives

There are various other additives that provide a kaleidoscope of additional properties. For example, degradation additives are used to encourage a polymeric material to break down, which means the materials are less harmful to the environment. There are also additives that modify barrier properties by using recent developments in nanotechnology to adjust the gas transmission rate of films. Additionally, there are polymer additives that are used to create aesthetic features to attract consumers. Additives that can make a product more appealing to consumers are color pigments or dyes, gloss controllers, antifogging agents, and optical brighteners (Murphy, 2002).

Equipment

There a few vital pieces of equipment and machinery which are essential for processing additives. Volumetric or gravimetric feeders and blenders are the most important equipment that handles and incorporates additives into polymer blends. Volumetric devices measure volume that passes through a metering disk while gravimetric devices measure and control the weight of additives dispensed over a given time period. Gravimetric types are recommended for cases when two or more additives are being dispensed at either the machine throat or in a blending system. The blending system can be either a dosing or mixing unit, which divides the main component into different streams of material so the streams can combine with additives at the feed inlet to produce a homogenous mixture. Another important piece of equipment is level sensors because they can measure insufficient additive material in order to prevent unnecessary downtime (Total Polymer, 2008).

Conclusion

Many of the additives discussed are used in combinations with each other to optimize performance and create specialized polymer blends. The ability to customize materials allows for more versatile uses of material with a broader range of applications. This is especially important to the packaging industry because it allows developers to create new and innovative ways of designing package protection and decoration.

There are a myriad of combinations that will produce blends of different polymeric materials. The many technological advances that have occurred over the years have revolutionized both the polymer and packaging industries. The ability to modify polymer properties enables new materials to be utilized to improve performance, efficiency, and the protection of packages.

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