Color, functional and multi-attribute solutions for polyester fibers

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Over the past 20 years, polyester (polyethylene terephthalate) has emerged as a leading polymer for fibers, film and packaging. Recent publications [1, 2] put the 2002 production of polyester fiber at 20.9 million tons, slightly more than cotton during the same period. The container resin production during 2002 was about 9 million tons. The combined forecast for 2010 is estimated to top 50 million tons. Some of the applications for polyester include:

- textile products such as apparel, automotive, home furnishings and bedding products etc.
- nonwoven products such as filters, medical and protective fabrics
- technical fibers such as tire cord, awnings, tents and sewing threads
- packaging applications including bottles for soft drink, water and juice etc.
- polyester film - imaging, magnetics and other industrial specialties.

In keeping with the explosion of the use of polyester resin in various applications, Americhem, Inc., is constantly developing new masterbatches for PET that enhance the properties and value of the products in which they are incorporated. Properties that today's fibers and packaging materials demand. Examples of such products include fibers with anti-microbial properties, fibers that withstand the harsh effects of UV so that articles made from such fibers last longer, fibers that absorb odor or fibers and textiles that offer moisture management properties and packaging materials that offer UV protection and acetaldehyde reduction. Here, solution dyeing techniques for coloring polyester and the use of the concept for producing value added fibers will be described. Recent developments in functional and multi-attribute masterbatches for fibers as well as masterbatches for packaging are discussed. Americhem has been serving the synthetic fibers industry with color and additive masterbatches for solution dyeing (mass dyeing) for the past 18 years.

Coloring of polyester fibers

Polyester fibers, because of their structure and well-developed order during spinning, absorb little dye in conventional dye systems. Hence traditional polyester fibers are predominantly dyed using disperse dyes. Cationic dyeable polyester fibers, with modified structure offer enhanced dyeability. Solution dyeing (also referred to as mass dyeing or spin dyeing or dope dyeing) offers a way of coloring polyester fibers and is independent of its chemistry.

- Solution dyeing

Solution dyeing can be defined as a process for coloring polyester (and other synthetic yarns) in which the colorant is added to the polymer melt, before it is extruded through a spinneret in to individual fibers. As a result, the colorant is permanently locked into the fiber and the fiber is colored throughout. Solution dyeing offers following advantages:

- better color fastness to light (UV), bleaching agents and ozone
- very good migration stability under adverse conditions
- tight lot to lot color uniformity
- environmentally friendly manufacturing process (energy efficient, since fiber spinning and coloring is done in the same step; does not use water - conventional dyeing on the other hand uses water extensively; effluent treatment may be necessary, since part of the disperse dye is left behind in the dye bath - only about 85% or so becomes part of fiber)
- high yields with low scrap
- wide range of colors can be produced
- customized products can be easily designed for value added fibers.

On the limitations inventory, control can be an issue, since the decision to produce colored yarn is done at the early phase of the production process. Development of small lot capability and speedy color matching are helpful in overcoming this concern.

- Product design for solution dyeing

Proper masterbatch design is an important aspect of solution dyeing. Poorly designed masterbatches can lead to spinning problems. There are a number of critical factors which can affect spin performance of solution dyed polyester that can be controlled by means of proper product design. Two of the important parameters of color masterbatch design are:

- product specification or end application in which the product is used
- spin performance - the term spin performance relates to factors such as spin breaks, draw warps, yield rates, filter pack life, and deposit build up on spinneret and godets.

Proper colorant selection is the first critical step in masterbatch design. Since the masterbatch is added to the polymer melt prior to spinning, the colorant must withstand the high processing temperature without color variation. Thermal stability of the pigment is important for both color control and specification control. Color concentration also has an effect on the color stability. Depending on the end application, weathering and other fastness requirements play an important role in masterbatch design.

The choice of carrier resin also plays an important role in product performance. This is especially critical when producing lower denier fibers. Incompatibility of masterbatch carrier resin with host polymer leads to problems such as

- bridging problems at the throat of the extruder and polymer build up in the feed section
- differences in recrystallization temperature can affect bulking conditions in air-jet texturing.

Very good dispersion of colorant in the polymer matrix and proper melt viscosity of the masterbatch are an absolute necessity, without it, the spin pack is immediately blocked or restricted. Poor pigment dispersion also results in breakage of fiber, especially in the drawing process, which results in draw warps around the godets. Americhem has developed a test that correlates laboratory filtration analysis with the length of time that the filter packs will last.

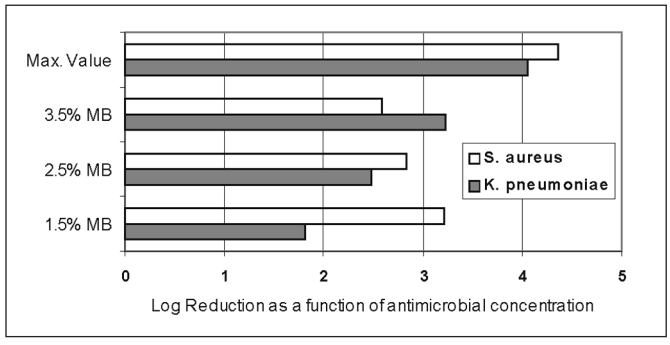

Fig. 1 Antimicrobial efficiency of polyester fiber as a function of concentration of antimicrobial masterbatch

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Black polyester yarn has been traditionally produced using the solution dyed process. The demand for solution dyed colors is steadily increasing especially in automotive and specialty fabrics/textiles where higher performance offered by solution dyeing is preferred. One of the key advantages that solution dyeing offers is that customized products can be easily designed for producing value-added fibers. For example customized colors (fluorescent, metallics), functional fibers and more importantly multi-attribute products can be produced.
Lastly, there are many colorants, which give the expected color, but only properly designed masterbatches give both color and performance. Communication in regards to which product values are critical is very important to assure proper product design.

Functional masterbatches

Functional masterbatches deliver functional attributes without compromising the processing properties. Typical functions offered include
- antimicrobial
- weathering/UV protection
- customized optical whitening effects
- flame retardants.

In addition to these, Americhem is developing several novel masterbatches that offer unique functional attributes to fibers such as odor adsorption, moisture management and low abrasion/friction properties.

Antimicrobial masterbatches

Antimicrobial masterbatches based on silver chemistry are designed to stand up to high processing temperatures at which polyester fibers are produced. Being non-migratory in nature, the concentrate becomes part of the synthetic fiber, thereby offering protection throughout the life of the product. A unique compounding process, specifically developed for this application offers excellent dispersion and makes possible higher loading of the antimicrobial additive in the polymer matrix. At the recommended use rate of 1.5-4% the products offer very good spin performance and high yields. Fibers and articles containing Americhem's antimicrobial masterbatches display very good efficiency against gram positive (Staphylococcus aureus) and gram negative (Klebsiella pneumonia) bacteria as shown in Fig. 1.

Light stabilizer masterbatches

Polyester fibers are increasingly used in exterior applications, such as automotive fabrics, awnings and flexible signs etc. These applications require that the fiber be stabilized against degradation by ultraviolet light. Light stabilizers, depending on the chemical class (UVA, HALS) either absorb the harmful ultraviolet radiation or counteract the photo-degradation of synthetic fibers by UV and oxygen and help retain color and mechanical properties. Using a customized approach and extensive weathering expertise, Americhem has developed masterbatches, which stand up to tough weathering requirements. Fig. 2 shows the transmission spectrum of polyester containing UV additive compared with neat polyester. Polyester containing UV additive shows absorption of light to 380 nm, which extends the useful life of the fiber/fabric. Data on tenacity of fiber as a function of extended UV exposure is being developed.

Flame retardant masterbatches

Flame retardant masterbatches based on phosphorous chemistry are designed to offer flexibility in producing niche fiber products. At the present time, the use rate of such masterbatches is rather high (in excess of 10%) and requires additional handling solutions for large volume runs.

Smart masterbatches

Active research is underway to develop novel masterbatches that can impart unique functional and performance properties to polyester fibers.
For example, imagine a polyester fiber containing activated carbon that absorbs odor and offers moisture management, and can be processed and handled similar to traditional textile or industrial fiber! Americhem, in co-operation with Traptek is working on developing such a masterbatch, based on activated carbon. Activated carbon, well known for its outstanding adsorptive properties is used in a variety of applications such as treatment of drinking water, decolorization of sugar, pharmaceutical production and automotive filters.
A range of other novel property and performance enhancing additive masterbatches are being explored at Americhem research and development laboratories.

Multiattribute masterbatches

Multiattribute masterbatches combine color and functional properties or offer more than one functionality in a single masterbatch, thereby providing a custom product that is easy to handle and highly effective. The concept can be used to design a wide range of products. Some examples of multi-attribute products include
- color and UV
- color and antimicrobial
- delustrant and optical brighteners.

Fig. 3 shows the reflectance spectrum of delustured polyester fiber containing optical brightener compared to a typical delustured fiber. Customized optical

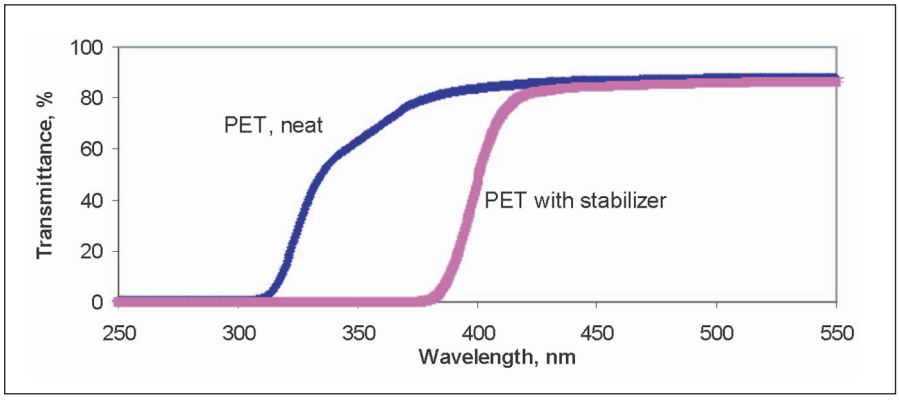

Fig. 2 Transmission spectrum of polyester film containing 0.5% of light stabilizer compared with polyester film containing no additive

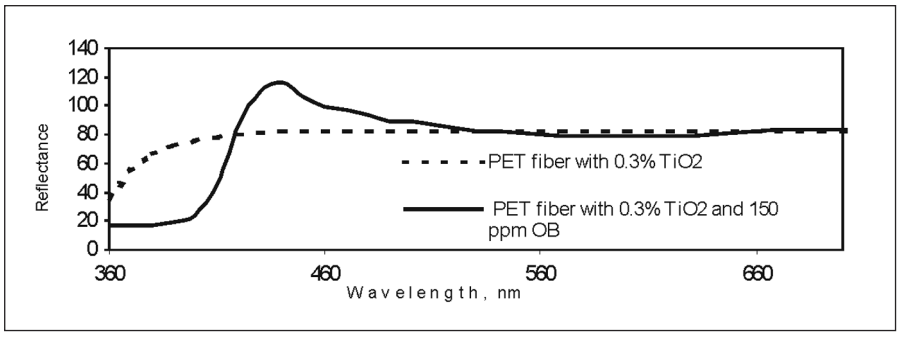

Fig. 3 Reflectance curve of polyester fiber showing optical whitening effect

whitening masterbatches impart cool, bluish white appearance to polyester fibers. Customization in regards to brightness, tone and use rate can be done to suit specific needs

Solid color solutions for PET packaging

Polyester bottles and packaging materials are colored using masterbatches comprising various carrier systems ranging from liquid to low melting wax to solid resin. Americhem color and additive masterbatches based on polyester carrier resin with melting point of greater than 220 °C offer several advantages over other systems as shown in the table.

Advantages of solid masterbatches over liquid and wax systems

Advantage	Eliminates
decrease plasticizing time by 5-7%	injection-molder screw slippage & recovery times caused by lubrication of liquid and wax carriers
solids color change can be 50% faster compared to liquid	longer purge times typically observed with liquid colors
no lost time from shutting line down to clean	residue build-up on screw resulting in machine lost time
no bridging	bridging caused by low melt resins adhering to PET pellets
no volatiles during recycling	recycled reclaim problems caused by volatiles
cleaner to use and easier house keeping	general housekeeping problems of liquids

Summary

In conclusion, the solution dyeing approach to coloring polyester fibers and its advantages in terms of performance such as weathering, migration as well as a environmentally friendly manufacturing processes are described here. Furthermore functional, multi-attribute products are described and novel smart masterbatch concepts are introduced. Multiattribute masterbatches offer an effective means to produce value added products with color and functionality or multifunctional fibers.

References

[1] Chemical Fibers International 53 (2003) 216
[2] International Fiber Journal 18 (2003)