Recent advances in color and functional masterbatches for man-made fibers

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Solution dyeing offers a convenient way for coloring melt spun fibers such as nylon, polyester and polypropylene. The design of a custom color masterbatch can significantly affect color, performance and cost to color. In light of the excellent colorfastness properties offered by solution dyeing, it is widely used in automotive and outdoor applications, commercial carpeting and other areas where superior colorfastness in desired. It also offers a convenient way to introduce functional properties and preparation of multi-attribute products.

Solution dyeing, also referred to as spun dyeing or dope dyeing, is a process for coloring synthetic fibers in which the colorant (typically pigments), in the form of a masterbatch, is added to the polymer melt before it is extruded into individual fibers. Thus, spinning of the fiber and coloring are accomplished in one step. The solution dyeing process differs from traditional textile dyeing, where the spinning (white yarn) and coloring are carried out in two steps. By virtue of the pigments, solution dyed products are known to offer better colorfastness. However, all solution dyed products do not offer equal colorfastness. Various factors ranging from choice of colorant to the design of a custom color masterbatch impact the performance.

Additionally, since the masterbatch is added prior to the spinning process, its effect on spinning performance and fiber properties is also a consideration in the design of the masterbatch. Depending on the end use application, various performance properties as well as functionalities are desired and need to be factored into the design of the masterbatch. Thus the overall performance, of the masterbatch - color, spin performance, end use properties and cost, is dependent on the design of the custom color masterbatch.

Masterbatches also find application in the manufacture of functional fibers such as antimicrobials, UV protection, flame-retardancy, odor absorption and others. In this article, some case studies showing the effect of masterbatch design on color and properties of solution dyed fibers will be examined. Additionally, comparison between of solution dyed PA and classic dyed PA and functional property masterbatches are presented.

Lecture held at the 44th Man-Made Fibers Congress Dornbirn on September 21-23, 2005 in Dornbirn/Austria

Masterbatches for PET automotive and outdoor fabrics

Solution dyed fabrics are increasingly used in automotive and outdoor applications due to colorfastness requirements. UV stability and extended colorfastness are important considerations when designing masterbatches for these applications. Choices of individual pigments such as phthalocyanine blues and greens, quinacridone and perylene reds, anthraquinone yellows, as well as the design of the custom color, determine the performance of the masterbatch for the intended application.

This is demonstrated in the following case studies. A dark gray automotive fabric color was matched with two different masterbatches (different color combinations). Each masterbatch produced the same color and are identified as Gray 1 and Gray 2. The masterbatches were characterized for color and weathering fastness in semidull PET fiber at 3.5 dpf. Generic formulations and color data are shown in Tables 1 and 2 respectively. The spectral curves are shown in Fig. 1. The color readings and spectral data show both colors to be very close. However, the two colors show considerable difference in weathering and cost to color as shown in Table 1. Gray 2 shows considerable improvement in weathering and at the same time reduces the cost to color by 18%, highlighting the effect of product design.

Similar data for a masterbatch designed for an awning application is shown in Tables 3 and 4 and Fig. 2. A popular burgundy color was chosen for the study. The masterbatches were characterized for color and weathering in PET fiber at 3.1 dpf. As can be seen from the data, Burgendy 2 shows considerable improvement in weathering, which is critical for the application. However, the cost to color had to be compromised.

Masterbatches for solution dyed PA fiber for commercial and residential carpets

Synthetic fibers, in the form of BCF are widely used in carpet manufacture. Among the three major melt spun fibers - PA, PET and PP, PA is clearly the market

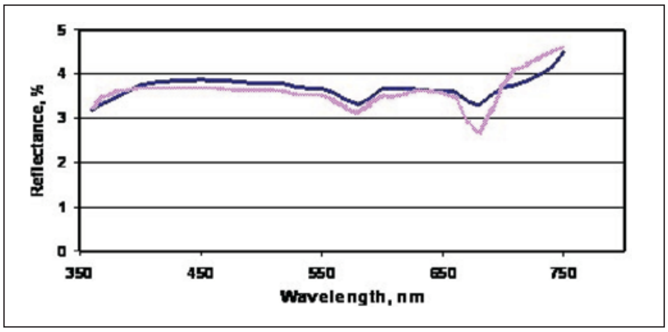

Fig. 1
Spectral curves for PET automotive Gray 1 and Gray 2 color matches

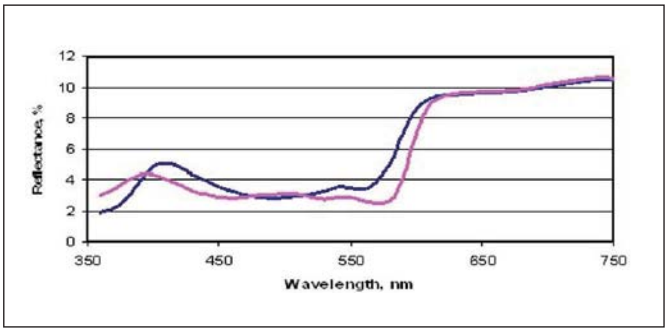

Fig. 2
Spectral curves for PET awning Burgundy1 and Burgundy 2 matches

Table 1 Formulation and performance of dark gray masterbatches

	Dark Gray 1	Dark Gray 2
Formulation		
- Colorant 1	Black	Black
- Colorant 2	Blue	Blue
- Colorant 3	Red 1	Red 1
- Colorant 4	Red 2	Yellow
Weathering and Cost		
- Light fastness, SAE - J 1885; 488 kJ; Gray Scale	3.5	4.5
Cost to color	1	0.82

Table 3 Formulation and performance of Burgundy masterbatches

	Burgundy 1	Burgundy 2
Formulation		
- Colorant 1	Red 1	Red 1
- Colorant 2	Red 2	Yellow
- Colorant 3	Black	Black
- Colorant 4	Violet	Violet
Weathering		
- Light fastness, SAE - J 1885; 488 kJ; Gray Scale	2.5	4.0
Cost to color	1	1.45

Table 2 Color readings for PET fiber made with Gray 1 and Gray 2 masterbatches

	L*	a*	b*	dL*	Da*	Db*	dE*
Gray 1	22.47	- 0.27	- 1.21				
Gray 2	21.93	- 0.17	- 1.22	- 0.53	0.1	- 0.007	0.54
D65 Illuminant							

Table 4 Color readings PET fiber made with Burgundy and Burgundy 2 masterbatches

	L*	a*	b*	dL*	Da*	Db*	dE*
Burgundy 1	25.75	16.98	5.71				
Burgundy 2	23.12	16.29	5.16	-2.44	-0.69	-0.55	2.6
D65 Illuminant							

leader. The stringent requirements for colorfastness to bleach and weathering, especially for commercial carpets have prompted widespread use of solution dyed PA BCF for this application. Further, increased use of glass in commercial buildings and more open residential styles expose carpet to more sunlight (UV) resulting in color fading and possible loss in tenacity of the yarn. Masterbatches for solution dyed PA can be designed to stand up to the tough requirements of commercial carpets. These include, bleach resistance, colorfastness as well as stabilization of the host PA polymer. Proper design of the masterbatch with pre-screened pigments as well as tight color control offers the following advantages to solution dyed PA BCF

- colorfastness to sunlight
- colorfastness to bleach and harsh cleaning chemicals
- good color uniformity and a wide range of colors
- consistent lot-to-lot color.

The following case study demonstrates the outstanding bleach and weathering properties offered using Americhem masterbatch compared with classic dyed PA BCF. In this study two classic dyed carpets (beige and blue) were compared with carpets matched to give similar colors but made from solution dyed PA BCF. Weathering fastness was determined using AATCC test method 16E, while the bleach test was performed by immersing the carpet specimen in 5.25% sodium hypochlorite solution (commercially available 100% bleach solution) for 24 hours. At the end of the test, the carpet swatches were removed from the bleach, washed with a neutralizing solution and rinsed with water. The specimens were allowed to dry for at least 24 hours. The color readings for the treated and untreated specimens were obtained using a spectrometer. Figs. 3 and 4 show the color difference on weathering and bleach treatment of the beige and blue samples respectively.

Fig. 3 clearly shows the superior performance of solution dyed beige PA BCF when exposed to bleach and weathering. The solution dyed sample exhibits a color difference of less than 1 unit compared to 22 units for classic wet dyed BCF on bleach treatment and a color difference of 0.95 compared to 8.9 on weathering. Fig. 4 shows similar data for the blue samples. While the color differences of the blue samples were not as dramatic as the beige color, solution dyed PA BCF clearly demonstrated excellent performance over classic wet dyed PA BCF - a color difference of 3.6 compared to 13.5 on bleach treatment and a color difference of 1.4 compared to 4.2 on weathering.

Fig. 5 shows the photograph of carpet samples of beige colored space dyed and

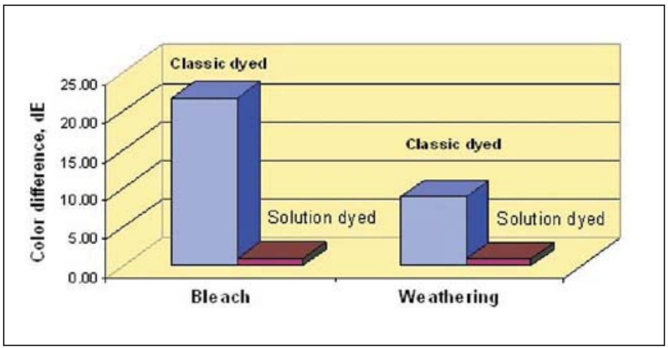

Fig. 3 Effect of bleach and weathering (color difference) on beige colored solution dyed and classic wet dyed PA BCF

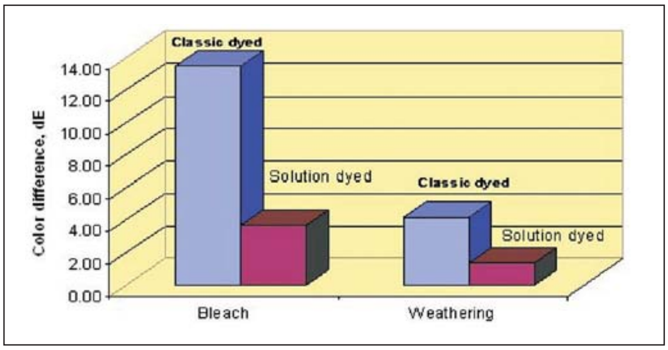

Fig. 4 Effect of bleach and weathering (color difference) on blue colored solution dyed and classic wet dyed PA BCF

Fig. 5 Effect of bleach on solution dyed (top) and space dyed (bottom) PA carpet samples

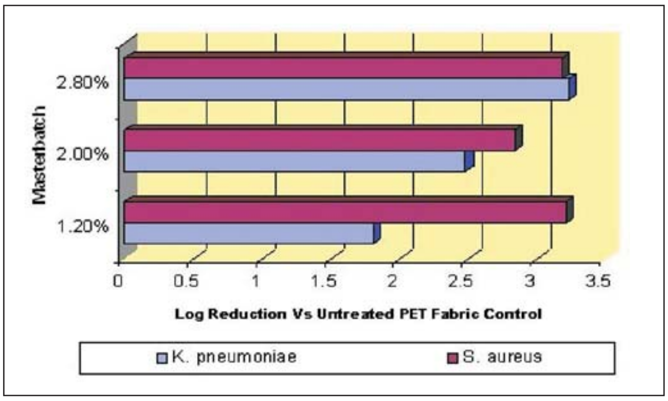

Fig. 6 Efficacy of PET fiber containing silver based antimicrobial as a function of concentration

solution dyed PA carpets after the bleach test. The results clearly show the outstanding bleach fastness of solution dyed PA BCF. The color of the space dyed sample is completely bleached (color difference 41 units), while the solution dyed sample shows hardly any difference (color difference, 1.7 units) .

Antimicrobial masterbatches

Microorganisms are part of our everyday lives. However, some of these organisms pose health concerns and are the source of unpleasant odors. Microorganisms thrive in moist conditions. Textiles such as sportswear and footwear are excellent candidates for bacterial and fungal growth. Antimicrobials are used to control microorganisms and the unpleasant odors and health concerns arising from them. Organic antimicrobial agents have been used to treat yarns and textiles to prohibit the growth of bacteria and enhance the sanitation value of the treated material. However, most organic antimicrobial chemistries exhibit limited thermal stability and are unsuitable for incorporation during melt spinning of synthetic fibers.

Silver based antimicrobials exhibit high thermal stability and are well suited for melt blending in synthetic polymers, especially for high temperature polymers such as PA and PET.

A unique compounding process was developed to disperse silver based antimicrobials, which provides a masterbatch with excellent dispersion. Fibers and articles containing Americhem masterbatch show excellent spin performance and antimicrobial efficiency against gram positive and gram negative bacteria such as Staphylococcus aureus and Klebsiella pneumonia.

Fig. 6 shows the efficacy of antimicrobial masterbatch as a function of concentration in a 3dpf PET fiber. The concentration of antimicrobial agent in the masterbatch was 25%. Similar tests in PA show higher antimicrobial effectiveness at a given concentration compared to PET fiber.

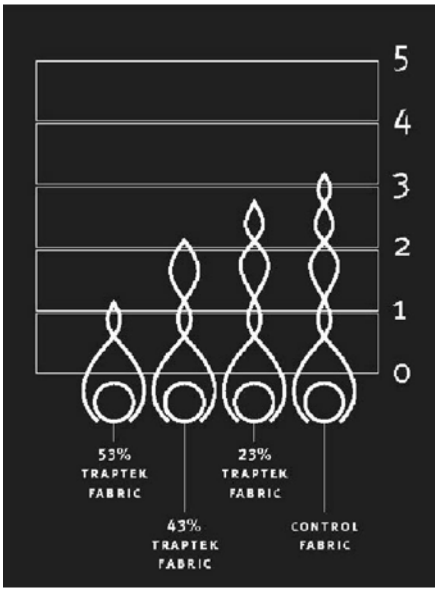

Fig. 7 Odor absorption effectiveness of fabric containing various amounts of fiber containing activated carbon

Masterbatches for producing odor absorbing fibers

Activated carbon is known for its adsorption and absorption properties. Because of its properties, it finds use in a wide range of applications such as purification of water, removal of organic impurities and as a catalyst.

Americhem Inc. (in cooperation with TrapTek) provides an activated carbon masterbatch for use in melt spun synthetic fibers. Fibers containing activated carbon offer odor absorption and moisture management properties to the articles made with such fibers. The key aspect of the technology is the fact that the activated carbon is nearly completely active - despite being encapsulated in the thermoplastic matrix - in the masterbatch and in the fiber. Thus odors originating from the wearer and present in the surrounding environment are attracted to and trapped within the pores of the carbon. The odor molecules are released and the carbon is renewed during the washing and drying of the fibers and garments containing activated carbon. Fig. 7 shows the odor absorption properties of fabric containing various amounts of fiber with activated carbon.