Additive Solutions for Manmade Fibers and Nonwoven Materials

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Additives play an important role in the manufacture and use of manmade fibers including textiles, nonwovens and geotextiles. Different additives fulfill various needs ranging from process enhancement to imparting specific end use properties. The need for specialized functional additives such as antimicrobials, flame-retardants, (ultraviolet) UV stabilizers, antistatics, tracers and others is on the rise owing to the use of manmade fibers in a wide range of applications. This article discusses various functional additives as well as solution dyeing as a green coloring technology.

Weathering performance is critical in many fiber and nonwoven applications such as commercial carpets, awning/outdoor fabrics, synthetic turf and geotextiles. The effects of weathering are a combination of chemical and physical effects that occur when textile materials are exposed to outdoor conditions. Polymeric materials used to make synthetic fibers are susceptible to heat and sunlight and require stabilization during processing and long-term use. UV radiation has a profound effect on service life of textile materials. Further, depending on the chemistry of the polymer, moisture and oxygen play a role in weathering. The degradation of fibers and textile materials is manifested by changes in mechanical and physical properties as well as yellowing of the polymer.

Depending on the chemistry of the polymer, hindered amine light stabilizers (HALS) or UV absorbers can be used to protect the textiles from the damaging effects of UV radiation. UV absorbers, as the name implies, absorb the damaging UV radiation and dissipate the energy at lower wavelengths. HALS, on the other hand, act as free radical scavengers and hydroperoxide decomposers to quench the damaging effects of UV radiation.

Most fibers used in textiles and carpets are very thin, ranging in thickness from about 2 denier per filament (dpf) to 20 dpf (10 µm to about 45 µm) and do not provide sufficient absorption depth, which puts an additional challenge on selection of UV absorbers. Often, combination systems are required for optimum performance.

Pigments, especially carbon black, have been known to provide protection against UV radiation, and the proper choice of titanium dioxide is needed for effective stabilization. Organic and inorganic pigments provide varying degrees of protection against weathering. Figure 1 shows the stabilizing effect of two UV systems on 4 dpf polyester fiber, and Figure 2 shows the efficacy of two UV stabilization packages on 4 dpf (~14 µm) natural polyester as a function of UV exposure.
Figure 3: Vertical burn test results of polyester fiber containing 7.5% masterbatch compared with neat polyester and polyester fiber made using an inherently FR polyester chip.

shows the effect of two UV packages in synthetic turf green formulation.

Flame retardant (FR) textiles such as upholstery fabrics, bedding and carpets find application in hotels, apartments and transportation. The use of halogenated compounds is synonymous with flame retardancy. In combination with antimony trioxide, they have been the mainstay of FR plastics as inexpensive and effective flame-retardants. However, owing to regulatory and environmental footprint considerations, they are currently out of favor.

Mineral flame-retardants are typically not an option for textiles and nonwovens owing to the large amount of additive needed. The synthetic fiber industry, led by polyester, has long adopted phosphorous as the preferred FR chemistry. Phosphorous and nitrogen chemistries are commonly used as FR additives for manmade fibers including nylon and polypropylene.

Phosphorous containing co-monomers and oligomers are employed in the manufacture of FR polyester containing a defined amount of phosphorous. The phosphorous thus becomes an integral part of the polymer and offers durability coupled with excellent flame retardancy. Such a product is typically supplied as a resin and is spun as a neat polymer.

With the demand for tuned performance coupled with increased demand for recycled fiber, the industry is looking for a masterbatch approach, to produce yarns with varying amounts of phosphorous.

Over the past few years, Americhem has been working to develop a masterbatch solution to impart FR properties to polyester fiber. Metal phosphinates and, more recently, polyphosphinates are employed to impart FR properties to polyester fibers and textiles.

Americhem offers several standard and customized products with tuned performance-based phosphorous chemistry that offer inherent, durable and eco-friendly flame retardancy to polyethylene terephthalate (PET) and polytrimethylene terephthalate (PTT).

At a use rate of 5-8%, depending on the fabric construction, one can achieve M1 classification as per NF P 92-307 (2004) and pass several other industry standards. Shown in Figure 3 are vertical burn tests on specimens containing 7.5% Americhem masterbatch compared with specimens made with neat PET industry standard PET FR chip.

Technologies based on nitrogen and nitrogen/phosphorous chemistries have been developed for imparting FR properties to polyamide (PA) 6, PA 6,6 and polypropylene (PP) fibers. However, unlike polyester, the technology for PA and PP fibers is not that well advanced. Newer formulations are being developed to address the growing need in the market.

Microbes are all around us. Some are beneficial and others can cause problems. The growth of microbes on textile materials leads to foul odors, discoloration and, in some cases, loss of textile properties. The nutrients in sweat, body warmth, moisture and dark atmosphere are ideal conditions for bacterial growth.

There has been an increasing demand for textiles and nonwovens with antimicrobial properties in a wide range of applications. In addition to medical and healthcare applications,
there is a drive by today's consumer to embrace the "fresh and well-being" aspect in textiles; as a result, antimicrobial textiles are routinely used in performance apparel, undergarments, hosiery and home textiles. Textiles containing antimicrobial additives must be effective against a broad range of microbes and be effective after multiples washes. While a range of antimicrobial solutions are available, silver-based antimicrobials are the most suited for use with manmade fibers. Leading textile fibers such as polyester and PA are melt spun at temperatures in the range of 270-295°C. This requires that the antimicrobial additive be stable at these temperatures during compounding and spinning stages. Silver-based antimicrobials can be successfully incorporated into synthetic fibers by addition during the spinning process, owing to their high thermal stability. Further, the additive becomes an integral part of the textile fiber, enhancing durability. Table 1 shows the efficacy of Americhem antimicrobial masterbatch in PET at 3% use rate. Antistatic fibers and nonwoven structures are widely used in many applications such as carpets and textiles, cleanroom fabrics and medical textiles. Antistatic agents reduce the electrostatic propensity of fibers. Antistatic agents can be broadly classified as migrating and permanent antistats (inherently dissipative polymers and those based on conductive fillers). Migrating antistats are typically used in nonwovens and short-term applications. Such chemistries work by attracting water, creating a conductive pathway that dissipates the charge buildup. Typical surface resistivities attained are in the $10^{11}$ to $10^{12}$ Ω/sq. Antistatic fibers used in textiles and carpets, on the other hand, require lower resistivities and demand permanent antistatic properties. These are typically based on conductive particles such as carbon black or antimony-coated titanium dioxide. The conductive compound is incorporated into the fiber using a bicomponent technology that delivers durable antistatic properties. A typical example of an antistatic nonwoven fabric is shown in Table 2.

**GREEN COLORING TECHNOLOGY**

PET, commonly referred to as polyester, is the most important manmade fiber and comprises the largest segment of the synthetic fiber industry with more than 30 million tons of polyester filament and staple produced globally in 2012. It has also seen extensive use in carpets over the recent years. Sustainability is at the center of the growth strategies in the synthetic fiber industry. There are many ways that the industry is addressing sustainability, including fibers from recycled polyester and bio-polyester, as well as sustainable developments in production and processing of fibers and yarns. Since a large proportion of polyester textiles and carpets are colored, eco-friendly coloring of textiles is of paramount importance. Solution dyeing or dope dyeing offers an environmentally friendly way to color polyester and other manmade fibers and nonwovens. In this process, color in the form of a masterbatch is added to the polymer melt during the extrusion phase of the fiber manufacturing process. Thus, fiber spinning and coloring are achieved in one step without the use of

<table>
<thead>
<tr>
<th>Contact time (hour)</th>
<th><strong>Staphylococcus aureus</strong>&lt;br&gt;ATCC 6538 CFU/sample</th>
<th><strong>Escherichia coli</strong>&lt;br&gt;ATCC 8739 CFU/sample</th>
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<tbody>
<tr>
<td>Control</td>
<td>$2.6 \times 10^8$</td>
<td>$2.7 \times 10^8$</td>
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<tr>
<td>0 hour (C)</td>
<td>$2.5 \times 10^8$</td>
<td>$2.4 \times 10^8$</td>
</tr>
<tr>
<td>0 hour (B)</td>
<td>$2.2 \times 10^8$</td>
<td>$2.6 \times 10^8$</td>
</tr>
<tr>
<td>24 hour (A)</td>
<td>$&lt;100$</td>
<td>$&lt;100$</td>
</tr>
<tr>
<td>% Reduction (R)</td>
<td>$&gt;99.96$</td>
<td>$&gt;99.95$</td>
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Table 1: Efficacy of Americhem antimicrobial masterbatch in PET at 3% use rate.
water, reducing the environmental footprint and eliminating effluent treatment while offering cost benefits. Further, solution dyed yarns offer several advantages over traditionally dyed yarns, including:

- Superior color fastness to light, bleach and durability
- Softer/better hand than traditionally dyed fiber and comparable to natural un-dyed yarn
- Customized products by combining color and additives, such as antimicrobials, UV enhancement, etc.

At the core of solution dyeing is the masterbatch. It is more than just concentrated color. It defines color quality, lot-to-lot consistency, and offers yarn producers value in terms of extended pack life, fewer spin breaks and higher yield. Americhem has been supplying masterbatches for solution dyed manmade fibers (carpets and textiles) for more than 25 years.

Solution dyed recycled fiber is a step ahead in green coloring. PET is by far the most widely recycled polymer in the world. Historically, recycled polyester has been used to make black fibers. However, with recent advancements in recycling, it is used in a wide range of color and additive applications.

Recycled polyester typically has a yellow tint and sometimes it is necessary to enhance the internal viscosity (IV) for better processing. When used as a natural or white fiber, it can have a dull look. Americhem can offer a renewal additive that helps to mask the color and increase the value of the product. Americhem is also working towards the development of an additive system for enhancing the IV of the resin.

Many of the additive technologies, such as antimicrobials and UV protection, can be adapted to recycled fibers. The recently introduced masterbatch FR technology is particularly beneficial for recycled polyester and offers performance similar to that of virgin polymerized FR resin.

A number of other attributes are desired in fibers and nonwoven applications such as soft hand, dye enhancement (especially for polyesters), stain resistance for carpet and more. Many of these properties require custom design and can be developed on a case-by-case basis.