NOVEL EFFECT ADDITIVES FOR INCREASING VERSATILITY OF SYNTHETIC FIBERS

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Paper presented at the *Fiber Producers Conference*

in Greenville, SC, May 21-23, 2002

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The maturity of the textile markets forces producers to constantly increase productivity and to develop innovative products. Most additives used today in synthetic fibers are required to protect the polymer during manufacturing or to extend the lifetime of the fibers. This paper presents an overview of the latest developments in functionalizing synthetic fibers through the use of appropriate effect additives. Effects such as light stability, flame retardance, antistatic properties and antimicrobial activity in polymer fibers and fabrics will be discussed.

Antistats and the New Permanent Antistat

Polymers in general and especially polyolefins are known to accumulate static charge. The charges are developed either through friction or induction and accumulate on the surface of the polymer. Up to 40,000 volts can be accumulated which is not discharged until the polymer comes in contact with an object of sufficiently different potential. Consequences of this charge accumulation and sudden discharge include:

- disruption of extrusion operations
- attraction of dust and dirt
- clinging of dust and product to packaging surfaces
- explosion of dust from sudden discharge
- difficulty in transportation of fluids and powders through feeding tubes

The surface resistivity of the polymer can be effectively lowered with the use of antistatic additives. Lowering the surface resistivity will allow the built up charge to be more easily dissipated. Antistats can be applied either as surface treatments or internally by compounding into the polymer. Internal antistats are generally used at concentrations ranging from 0.5 – 3%. Their advantages are that they are:

- easy to use
- used in low concentrations
- relatively inexpensive

These products are generally composed of a hydrophilic head and a lipophylic tail. They migrate to the surface of the polymer where they attract water. The water then acts to conduct the charge from the polymer surface. The drawbacks associated with this mode of action are that:

- there is a lag time while the antistat migrates to the polymer surface before the antistatic effect is observed
- high relative humidity is required for greatest effect

- the antistat is easily removed from the polymer surface
- the antistat is eventually depleted from continued migration and removal from the polymer surface. In fiber applications this is especially relevant due to the high surface to volume ratio of the fiber

Permanent antistatic additives can be employed to overcome these drawbacks. There are several available approaches including the use of intrinsically conducting polymers such as polyaniline or conductive fillers such as carbon black. These approaches present problems associated with compatibility and/or color. In fiber applications the use of stainless steel fibers or aluminum flakes is not practical.

Permanent and melt processable antistats based on copolymers composed of hydrophilic and hydrophobic blocks have been developed. It is possible to provide a product that has little to no effect on mechanical properties and which also, does not contribute to polymer color. As the antistat is high molecular weight, it does not migrate. The antistatic effect is provided by a conductive path that the additive forms within the polymer matrix. Figure 1 Shows a schematic representation of this conductive path as well as a micrograph where the fibrular network of the antistatic additive is revealed.

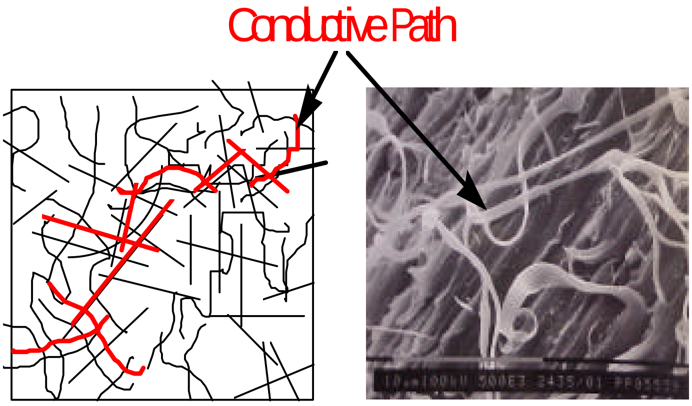


Figure 1: Conductive Path

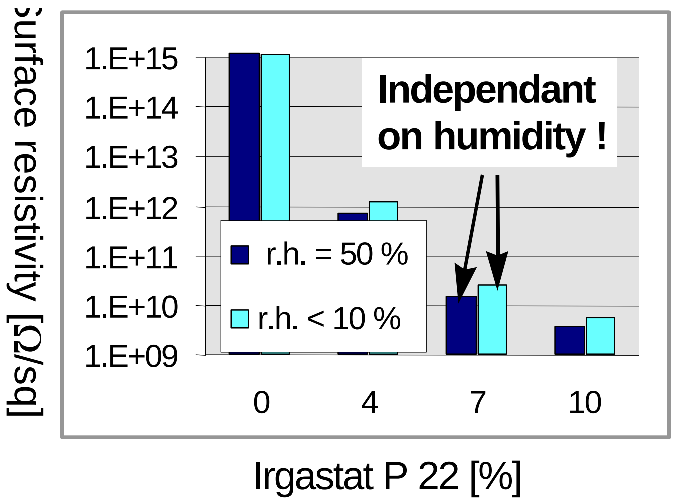
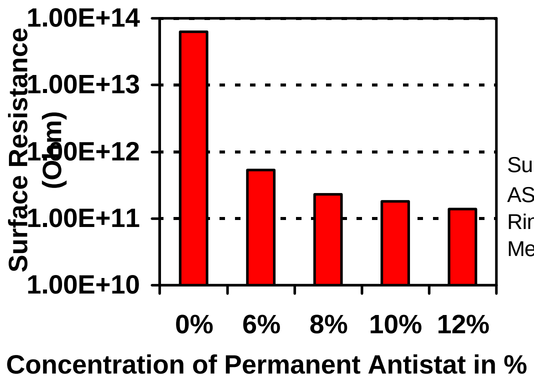


Figure 2: Surface Resistivity vs. Irgastat Concentration

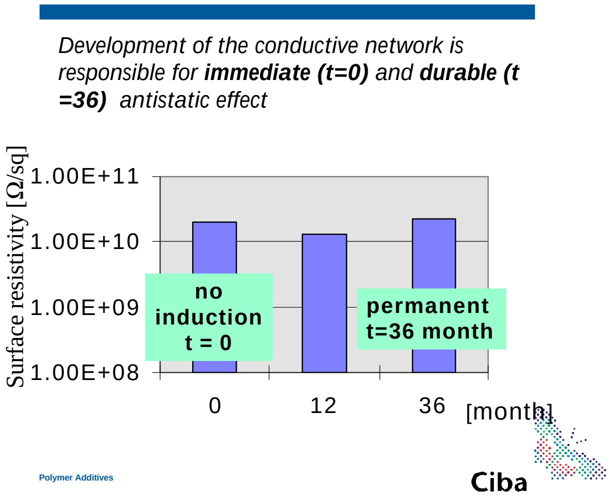
Figure 2 demonstrates the decrease in surface resistivity as a function of the concentration of the permanent antistic additive in PP fibers. Use concentrations of 7 to 10% are employed to get what is considered an antistatic effect. Also demonstrated is the independence of the effect from the level of humidity.



Surface Resistance R_{OG}
ASTM D257-93, 500V
Ring Electrode Ø 8cm
Measured on a knitted sock

Figure 3: Surface resistivity in PET fibers

These permanent antistatas can provide antistatic effects in PP and PE fibers, films and molded articles. Figure 3 alsodemonstrates the antistic effect that can be achieved in PET fibers.



*Development of the conductive network is responsible for **immediate (t=0)** and **durable (t =36)** antistatic effect*

Figure 4: Permanence of Antistatic Effect

Figure 4 shows that the antistatic effect is immediate and does not rely on additive migration. Further, the effect is durable. The same level of antistatic properties is observed after three years as was observed initially.

Antimicrobial Additives

Increasing public awareness of the risks of bacterial infection is creating a growing demand for products which decrease the risk of bacterial contamination. Although polymers themselves are frequently not the target of bacterial attack, microcracks and surface irregularities can provide a home for bacterial nutrients. Bacteria will feed on these nutrients and gain a foothold on the polymer. In fabric applications the spaces between fibers provides a place for nutrients and the bacteria that feed on them to lodge.

To address this growing demand for increasingly hygienic products several classes of antimicrobials suitable for use in polymers have come to the market. To combat bacteria chlorine containing organic products (such as Triclosan) as well as inorganic products based on silver are employed. Silver has been used for centuries as an antimicrobial. New supports and delivery systems allow for effective and non-discoloring use in polymers. Triclosan has been in use for decades in products such as hand soaps and hospital rinses and more recently in toothpaste.

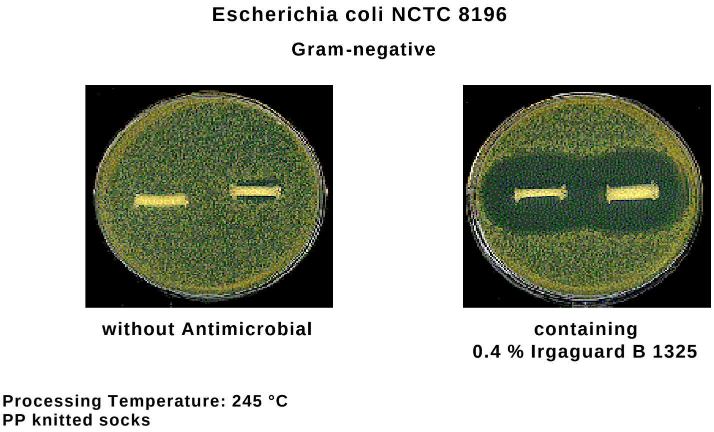


Figure 5: Growth Inhibition Test

The effectiveness of an antimicrobial in a polymer can be measured by observing the zone of bacterial growth inhibition which surrounds the polymer when it is placed in a bacterial growth medium. Figure 5 demonstrates this effect. Pieces of PP fabric are placed in a petri dish containing an agar growth medium and the medium is innoculated with e. coli bacteria. The yellow dots are the e. coli bacteria. The PP fabric without the organic antimicrobial is overrun with bacteria while the fabric containing the antimicrobial shows a distinct zone surounding the fabric where growth is inhibited.

Below is a partial list of possible applications that employ antimicrobial additives.

Apparel trimmings and linings
Aprons (food service, home)
Athletic WearAwnings (Indoor and outdoor)
Bibs
Blanket bags
Blankets
Brushes
Carpets and Rugs
Conveyor belts
Covers for counter tops
Covers for table tops
Cubicle curtains
Door and floor mats
Dresses

Exercise equipment
Floor coverings
Food Services wipes (towels)
Furniture fabrics
Garment bags
Gloves (non-medical)
Gowns (medical & consumer)
Hair brushes
Hosiery and socks
Incontinence care products (diapers and underpads)
Intimate Apparel (Underwear)
Janitorial brushes and brooms
Linens (towels, sheets, pillowcases, mattress covers,
Mattress and pillow ticking
Medical and Dental clothing
Mops
Paper mulch
Pillow and mattress stuffing
Quilt fabric
Running apparel
Service UniformsShoes, shoe inner soles and linings
Shower curtains
Silage wraps
Sporting team uniforms
Sportswear
Sweatshirts/t-shirts
Table clothes, napkins
Toothbrush bristles
Uniforms
Wall covering
Wet suits
Window curtain and draperies

Flame Retardant Systems

It has long been considered impossible to have a flame retardant PP fiber which was also UV stable. New flame retardant chemistry allows PP fiber to have the level of flame retardancy required to pass demanding FR criteria such as NFPA 701 vertical burn as well as a level of UV stability to meet the most demanding requirements. These systems are based on NOR chemistry. Products based on this new chemistry are formulated to meet the level of flame retardant performance required as well as the needed level of UV stability. These formulated products can be both halogenated as well as non-halogenated.

The table below compares the FR performance of the new Flamestab chemistry to a control in the automotive FR test, MVSS 302. This is a horizontal burn test and relatively undemanding from an FR performance perspective. As little as 0.5% of the new chemistry can be used to pass this test.

Polypropylene Fabric MVSS 302 Burn Test

Additive	Fabric Weight (g/m^2)	Burn rate (cm/min)	Rating
None	129	10	Fail
0.5% Flamestab	**139**	**Did Not Ignite**	**Pass**
1.0 % Flamestab	**139**	**Did Not Ignite**	**Pass**
1.5% Flamestab	**132**	**Did Not Ignite**	**Pass**

Table 1: Flame Retardant Performance by MVSS 302 Test

A more demanding FR test is NFPA 701. In this test the fabric is ignited while it is a vertical orientation. The weight loss of the fabric and the time that drips continue to burn after they hit the floor of the test chamber are monitored. A maximum of 40% weight loss and 2 seconds of burning drips are permitted.

Formulation	Pass/Fail?	Burning Drips (sec)	% Weight Loss
Control	Fail	50+	36
Control + 0.25% CPC Blue	Fail	50+	24
0.25% CPC Blue 1% Halogen	Fail	15	25
0.25% CPC Blue 3% Halogen	Fail	4	18
0.25% CPC Blue 1% Flamestab 1	Fail	10	23
0.25% CPC Blue 1.25% Flamestab 2	Pass	0	12

Tanle 2: FR Performance of Flamestab Systems Compared to Halogen Systems by NFPA 701 FR Test Criterion in Pigmented PP Fiber

The demands of this test on the FR are far greater than the MVSS 302 . Performance under this test can vary as a function of fabric construction and weight as well as the presence of other additives, such as pigments, in the fiber. Due to the demands of this test, it is recommended that a more robust Flamestab product be employed. Table 2 compares the performance of a halogenated FR to a Flamestab product. While 3% of the halogen proves to be inadequate, as little as 1.25% of the Flamestab product yields performance that is more than sufficient to pass the test and is cost effective when compared to the halogen due to the substantially lower concentration.

UV stability is also claimed as a feature of the new Flamestab formulated products.

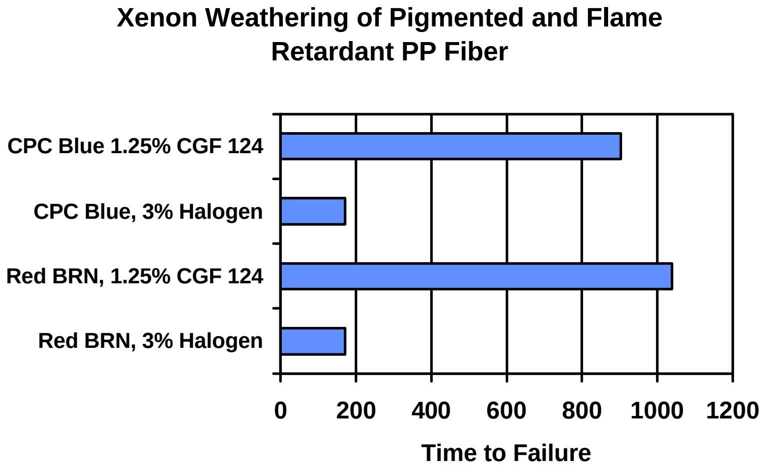


Figure 6: UV Stability of FR PP Fiber
Xenon Weathering, 63C, 0.35 Watts

Figure 6 shows that the UV stabiity if the halogen system is quite poor. The Flamestab product however demonstrates a level of UV stability more than adequate to meet most requirements.

With these new features, PP fiber can now compete with traditional FR fibers such as PET and nylon for FR applications.

UV Stabilizer Systems for High UV Demands

Synthetic fibers are used in many high UV demand applications such as in automotive fabrics and fabrics used outdoors such as for awnings, umbrellas and outdoor furniture. Evolution of UV stabilizer systems allow for selection of a greater variety of fibers as well as longer life and durability for these fabrics. High molecular weight hindered amines have long set the standard of UV stability for fiber applications. These hindered amines have been known for their ability to preserve the physical properties of fiber during UV exposure.

Most of these fiber applications are colored and the maintainence of color is often among the most critical of performance criteria. It is well known that UV absorbers function well to preserve color, especially in thick section articles. Since UV absorber performance is directly related to the thickness of the article performance in fibers would be expected to be modest. The data however reveal quite a different story. Figure 7 compares the rate of discoloration of PP fiber stabilized with HALS 1, a high performance, high molecular weight hindered amine, to PP fiber stabilized with System 1, composed of HALS and UV absorber. As can be seen, the time to a given level of discoloration is as much as 3 times greater with the UV stabilizer system.

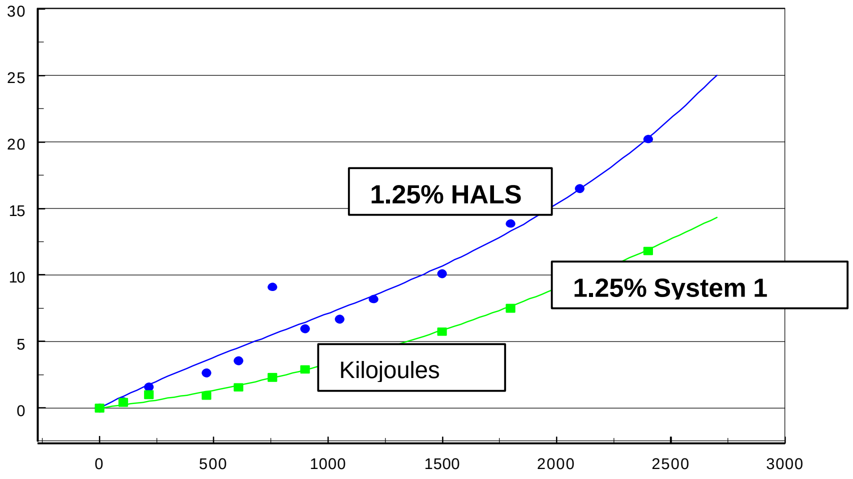


Figure 7: Xenon Weathering (Interior Automotive Cycle) of PP Fiber Pigmented with 0.25%Red BRN.

It might be anticipated that in a pigmented fiber application that the dilution of the HALS with UV absorber would lead to earlier physical failures. In fact, the opposite seems to be true. As can be seen in figure 8, the new System 1 actually extends the time to physical failure in pigmented fiber. The rational is that the degradation of the pigment can generate radicals that will contibute to the degradation of the polymer. The UV absorber slows the rate of pigment degradation and as a result contributes to the extended stability of the system.

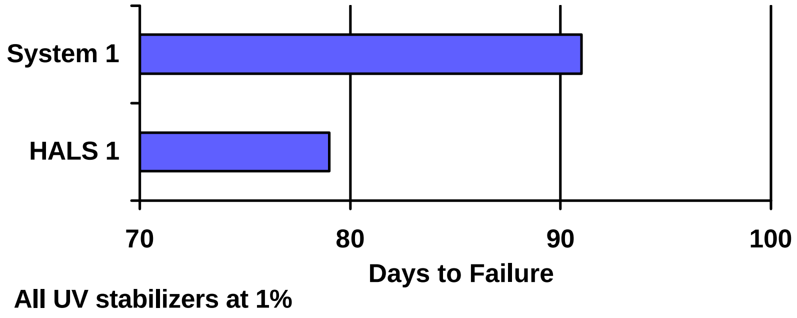


Figure 8: Interior Automotive Xenon Arc Weathering of PP Fiber Pigmented with 0.25% CPC Blue

Conclusion

Synthetic fibers can be functionalized through the use of well selected additives. Effects such as UV stability, flame retardance, antistatic and antimicrobial activity can be achieved. The data presented in this paper above are selected examples of these effect additives. In most cases, the right formulation of additives for the synthetic fibers have to be adjusted to fit the market needs. A good understanding of effects and the chemistry is necessary to make optimum recommendations for value added fibers. Our goal at Ciba Specialty Chemicals is to develop innovative additive solutions for synthetic fibers.