Effect Additives for Polypropylene Fibers

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Innovative fibers and productivity increase while maintaining high quality standards are the keys to grow in mature market such as the Polypropylene fibers and tapes. Additives, particularly antioxidants, processing stabilizers and light stabilizers have largely contributed to support polypropylene market growth in textile applications. Without appropriate processing stabilizers systems, PP fibers would not reach the high quality required by today's market. Polypropylene fibers would not be suitable for durable applications such as carpets or geotextiles without high performance light stabilizer systems and pigments. New additives are used today in Polypropylene fibers to increase the functionality and enter new markets. New effects will increase the versatility of PP fibers. Besides the creation of totally new textile products the substitution of traditional synthetic and natural fibers is possible.
This paper presents an overview of latest developments in functionalizing PP fibers through the use of appropriate effect additives. Besides the light stability, other effects such as flame retardant, permanent antistatic, antibacterial and antialgae activity in Polypropylene fibers, tapes and non-woven fabrics will be discussed.

LIGHT STABILITY OF POLYPROPYLENE FIBERS

HALS (hindered amine light stabilizers) have largely contributed to support polypropylene market growth in textile applications. Without appropriate light stabilizers, Polypropylene fibers would degrade rather quickly and would not be suitable for durable applications such as carpets or geotextiles. A new HALS Chimassorb® 2020 was introduced to improve important ancillary properties of the additive. Chimassorb 2020 is an oligomeric HALS with a narrow molecular weight distribution providing excellent UV stability, long-term thermal and melt flow stability [1]. As a high molecular weight HALS, it imparts high extraction-resistance and low volatility.

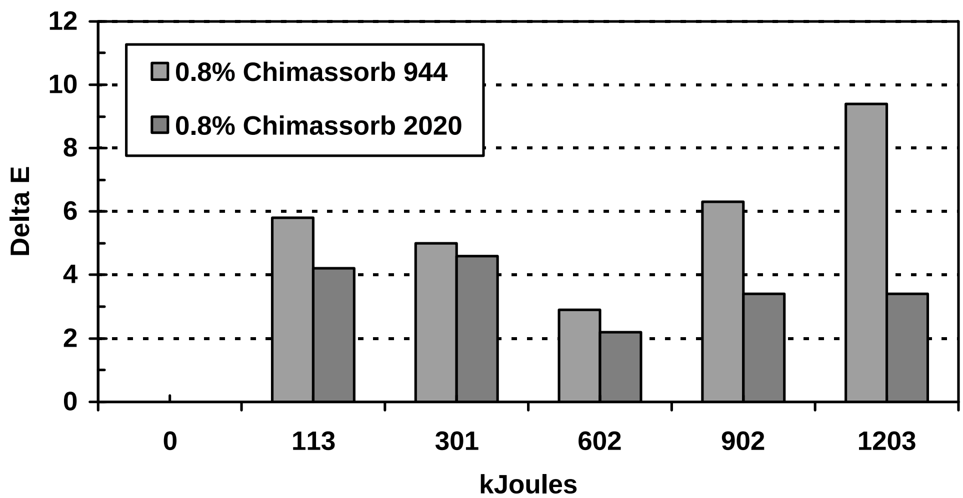


Figure 1: UV Exposure of PP fibers for automotive applications. Samples: PP multifilaments, 152/37 dtex, blue pigment. Base stabilization: Fiberstab® L112 + Ca-stearate. Exposure: SAEJ1885, WOM Ci65, 0.55 W/m^2 at 340 nm, bpt 89°C

Fig.1 shows the superior UV stability performance of Chimassorb 2020 in comparison with state-of-the-art light stabilizers in a hot-light exposure test required by the automotive industry (SAEJ 1885 test). The fibers are colored with a blue pigment.

One other important feature of a HALS is the effect it has on the melt flow of the polypropylene fibers after spinning. It was observed that this effect is generally more important for finer dtex fibers. Fig. 2 shows the superior behavior of Chimassorb 2020 in comparison with state-of-the-art light stabilizers in melt flow retention during fiber spinning.

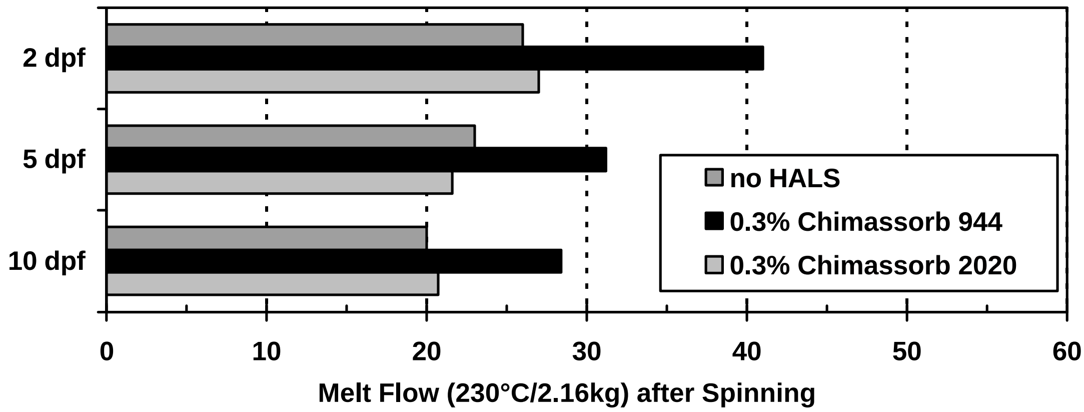


Figure 2: Influence of HALS on melt flow of PP after spinning at 270°C. PP multifilaments, white pigmented (TiO_2); base stabilization: Irganox® B501W + Ca-stearate.

FLAME RETARDANT POLYPROPYLENE FIBERS

Typically, bromine and phosphorous containing flame retardants are used in polyolefins. Halogen containing flame retardants detrimentally affect the performance of UV stabilizers. Moreover, environmental concerns could arise with conventional flame retardants. The necessity to use high levels of these flame retardants to achieve efficacy can also have a significant negative impact on the physical and mechanical properties of the fiber.
A revolutionary non-halogenated, UV-stable flame retardant was introduced primarily to the polypropylene fiber market and is commercially used in PP fiber applications. Flamestab® NOR 116 is a N-alkoxy (NOR) hindered amine which provides flame retardant efficacy to polypropylene fibers at unexpectedly low concentrations [2]. With addition levels between 0.5% to 1.5% industrial flame retardant standards like NFPA 701, MVSS 302, DIN 4102/B2 can be passed.

Additive	**Fabric Weight (g/m^2)**	**Burn rate (cm/min)**	**Rating**
None	129	10	Fail
0.5% Flamestab NOR 116	139	Did Not Ignite	**Pass**
1.0% Flamestab NOR 116	139	Did Not Ignite	**Pass**
1.5% Flamestab NOR 116	132	Did Not Ignite	**Pass**

Table 1: Flame retardancy results from MVSS 302 Burn Test/ PP nonwoven fabrics.

Table 1 demonstrates the excellent performance of Flamestab NOR 116. If no flame retardant is used the nonwoven fabric burns and fails the test. With addition of only

0.5% Flamestab NOR 116 the fabric did not ignite and passes the MVSS 302 test. Due to its efficacy at low concentrations, mechanical properties can be retained, which is a significant advantage compared to classical flame retardants. Since it is melt processable there is no reduction in physical or mechanical properties.

Recent advances in research and development show that this additive synergizes with conventional brominated and phosphorus flame retardants to provide improved performance. These synergistic systems allow to pass some of the more stringent industrial flame retardancy tests. Furthermore these synergistic systems allow a significant reduction of the level of conventional flame retardants that affect light stability and mechanical properties of the fiber (Table 2).

Additive	**Drip Burn Time (s)**	**Weight Loss (%)**	**Rating**
No flame retardant	> 50	> 40	Fail
4% DBDPO	0.8	7	Pass
2% DBDPO	5	10	Fail
1% DBDPO 0.5% Flamestab NOR 116	0	4	**Pass**

Table 2: Reduction of brominated flame retardant with addition of Flamestab NOR 116.
Samples: Polypropylene knitted socks (15 dpf).
DBDPO = Decabromodiphenyl Oxide

Since Flamestab NOR 116 is a NOR HALS it is also a highly effective light stabilizer and provides thermal stability. It provides light stability performance similar to high molecular weight hindered amines used in polypropylene fibers or nonwowens. The excellent UV stability performance of Flamestab NOR 116 is shown in Figure 3. The flame retardant fabrics passes the DIN 4102 B2 test done. The applications for these nonwovens are in the construction area.

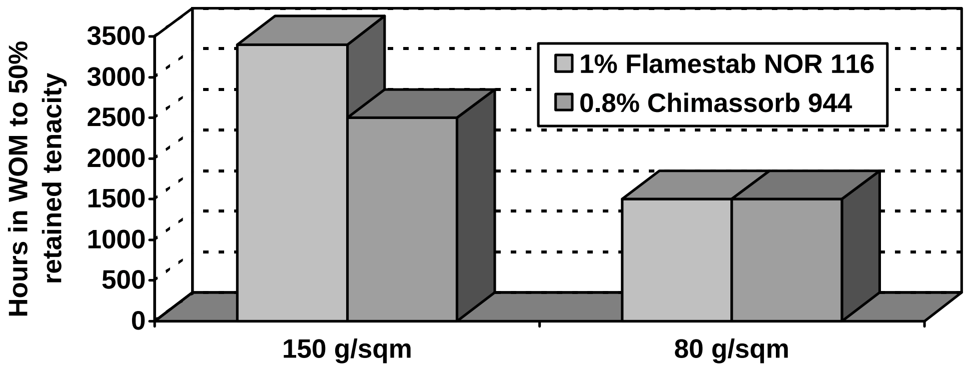


Figure 3: UV stability of PP nonwoven fabrics. Comparison of Flamestab NOR 116 with Chimassorb 944

PERMANENT ANTISTATIC POLYPROPYLENE FIBERS

Static electricity is a natural phenomenon occurring during many industrial and commercial operations. Polymers with their insulating properties show very high

surface resistivity (>10^{14} Ω/m^2) and are therefore strongly affected by the problem of static electricity.
On the basis of polyether block amides the permanent antistatic products Irgastat® P were introduced to the industry. These are inherently static dissipative additives, working by formation of a dissipative network throughout the polymer [3] that results in a permanent antistatic performance of the polypropylene fiber.
Different to conventional antistats, these new additives are non migratory thus permanent and showing an immediate effect after processing. Due to the inherent static dissipative characteristics of the network, the polymer matrix shows antistatic effect at relative low humidity levels.

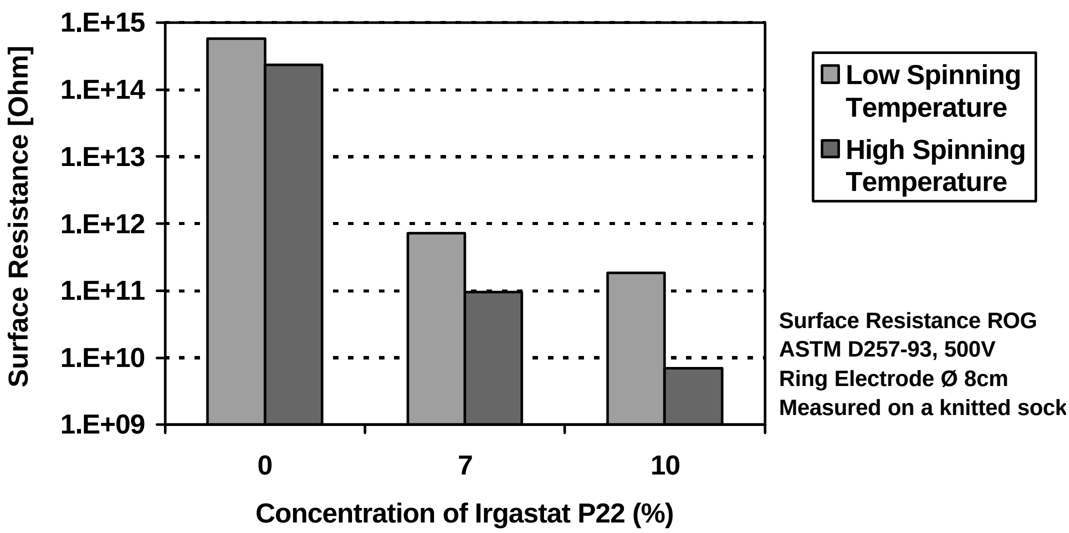


Figure 4: Surface Resistivity of PP Fibers. PP MFI (230/2.16)=13; draw ratio 3.3. Multifilaments 17 dpf. Measured at 50% rel. humidity.

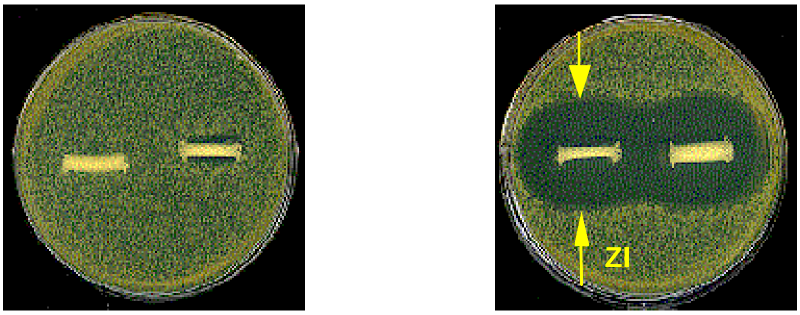
Figure 4 shows the surface resistivity related to different concentrations and spinning temperatures of Irgastat P22 in PP fibers. The surface resistivity decreases with increased concentrations of antistatic agent. Efficacy can be optimized, by adjusting the fiber spinning conditions and the concentration. Irgastat P22 is designed for processing temperatures higher than 220°C. Recommended use levels range from 4 to 10%. It is available in granular form.

This permanent antistat opens new fields for polypropylene fibers and tapes as well for nonwoven fabrics, especially in applications requiring a durable effect or where low relative humidity can prevail.

ANTIMICROBIAL FOR POLYPROPYLENE FIBERS AND TAPES

In recent years increasing public concern about hygiene has been driving consumer demand for antimicrobials in synthetic fibers. A variety of bacteria are known for their pathogenic relevance and their odor formation. In order to address hygiene requirements the antimicrobial additive Irgaguard® B1315 for polypropylene has been introduced to the market. It is highly effective against a wide range of Gram-positive and Gram-negative bacteria by inhibiting their growth [4].

Figure 5 demonstrates the efficacy of 0.7% Irgaguard B1315 in PP fibers. It was incorporated in the PP melt. PP fabric is placed on an agar nutrition medium inocculated with Escherichia coli bacteria. After 24 hours the result is the following: the dots around the control sample represent colonies of Escherichia coli. The dark zone around the sample containing 0.7% Irgaguard B1315 represents the zone of inhibition (ZI).



without antimicrobial **with 0.7 % Irgaguard B1315**

Figure 5: Antimicrobial efficacy in PP knitted fabric. Fiber spinning at 245°C. Escherichia coli NCTC 8196 Gram-negative

Irgaguard B1315 is an antimicrobial additive containing 15% active ingredient. The excellent compatibility of the active ingredient with the matrix controls the migration rate thus improving the long-term efficacy. The activity of Irgaguard B1315 is maintained after simulated washing tests as illustrated in Table 3.

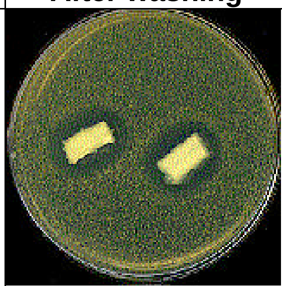
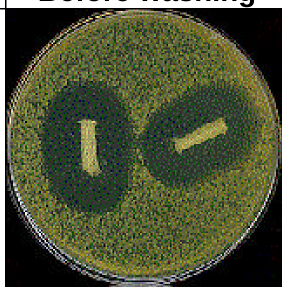
	Staphylococcus aureus ATCC 9144		**Escherichia coli NCTC 8196**	
	Before washing	**After washing**	**Before washing**	**After washing**
				
ZI	18 / 17	4 / 4	10 / 11	2 / 3
VR	4 / 4	4 / 4	4 / 4	4 / 4

Table 3: Antimicrobial efficacy of Irgaguard B1315 in PP multifilaments after simulated washing (According to Washtest AATCC 61-2A). ZI = zone of inhibition in mm; VR = Vinson Rating, for growth under the disc (*L.J. Vinson et al. J.Pharm. Sci. 50, 827-830, 1961*) 4 = no growth (good activity), 2 = isolated colonies, 0 = strong growth (no activity). All tests were performed twice and both results are given in the table.

In synthetic fibers spun at rather high temperatures the use of Irgaguard B1315 can be limited due to the volatility of the product. For those applications Irgaguard B5000 and Irgaguard B7000 are recommended. Irgaguard B5000 and Irgaguard B7000 are inorganic antimicrobials effective against a wide range of Gram positive, Gram negative bacteria, mold and yeast by inhibiting their growth. Both products have been optimized for bio-availability of the Silver-ions and to withstand the discoloration during sun light exposure, typical for standard Silver antimicrobials. Irgaguard B7000 is particularly recommended for finer dtex fibers.

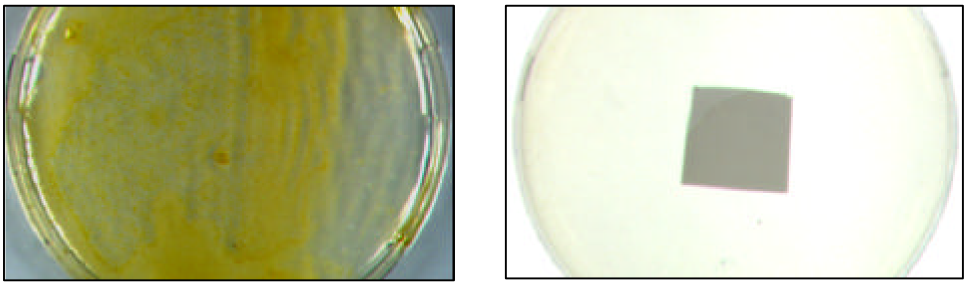
Table 4 shows an comparative example of Irgaguard B1315 and Irgaguard B5000 performance in PP fibers with two bacteria. The inhibition zone observed with Irgaguard B5000 is small or non-existing which demonstrates the non-migratory character of this antibacteria. However the Vinson Rating (VR), which can be used as a qualitative judgment of the bacteria growth directly on the fibers, is high. Combinations of Irgaguard B1315 and B5000 or Irgaguard B7000 are of course possible.

PP fabrics	**Staphylococcus aureus** ATCC 9144		**Escherichia coli** NCTC 8196	
	ZI	**VR**	**ZI**	**VR**
no antibacterial	0 / 0	0 / 0	0 / 0	0 / 0
3.3% Irgaguard B1315	20/22	4 / 4	10/12	4 / 4
0.5% Irgaguard B5000	5 / 7	4 / 4	0 / 0	4 / 4
0.25% Irgaguard B5000 + 1.6% Irgaguard B1315	19/20	4 / 4	13/14	4 / 4

Table 4: Antimicrobial efficacy of Irgaguard B1315 and Irgaguard B5000 in PP multifilaments (15 dpf). ZI = zone of inhibition in mm; VR = Vinson Rating, for growth under the disc (*L.J. Vinson et al. J.Pharm. Sci. 50, 827-830, 1961*) 4 = no growth (good activity), 2 = isolated colonies, 0 = strong growth (no activity). All tests were performed twice and both results are given in the table.

Algae and moss deteriorate the appearance of textiles fabrics such as shade cloth and awnings used outside. In some particular case such as artificial grass it can even affect the functionality. Cleaning is not always feasible. Recently Irgaguard A2000 has been launched as antialgae and antimoss for synthetic fibers. Irgaguard A2000 is a highly specific inhibitor of photosynthesis and therefore controls very effectively the growth of algae and moss on the surface of synthetic fabrics. The optimum balance between substrate compatibility and migration rates provides efficacy over the useful life of the article.

An example of the efficacy of Irgaguard A2000 in polyolefin fibers is shown in Figure 6. The algicidal activity on the unicellular green algal species *Pseudokirchneriella subcapitata* (= *Selenastrum capricornutum*) was determined in a 7 days static test. Cultures of algae growing on agar plates were exposed to the treated and untreated fibers. The inhibition effect was determined qualitatively by visual assessment of the algae growth on the agar plates. The surface of the agar plate with no sample (left) was completely covered by a layer of green algae, no zone of inhibition was observed. With the polyolefin tapes containing 0.2% of Irgaguard A2000 no growth of algae was observed at the surface of the agar plate. The zone of inhibition corresponded to the diameter of the agar plate (88mm).



without antialgae **0.2% Irgaguard A2000**

Figure 6: The algicidal activity of Irgaguard A 2000 in PE tapes.

These results show the excellent efficacy of antimicrobial additives incorporated in polyolefin tapes. The combination of relatively good polymer compatibility and very high activity gives the treated article long-term efficacy against bacteria and algae growth. These effect additives lead to improved hygiene, odor control, appearance and less maintenance in fiber applications which allows product differentiation.

CONCLUSIONS

Polypropylene fibers can be functionalized through the use of properly selected additives. Effects such as UV stability, flame retardant, 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 PP fibers have to be adjusted to fit the market needs. A good understanding of effects and the chemistry are necessary to make optimum recommendations for value added fibers. Our goal at Ciba Specialty Chemicals is to develop integrated additive solutions for synthetic fibers.

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REFERENCES

1. P. Holbein, et al., “The High Molecular Weight Hindered Amine Stabilizer for the New Millennium”, *Addcon World ’98*, London, UK, Rapra Technology Ltd., 1998.
2. R. Srinivasan, B. Rotzinger, “Advances in a Revolutionary Flame Retardant Systems For Polyolefins”, *Retec 2000*, Houston, USA, SPE, 2000.
3. M. Grob, E. Minder, “Permanent Antistats: New Developments For Polyolefin Applications”, *AddPlast 2000*, Wiesbaden, Germany, Rapra Technology Ltd., 2000.
4. H. Herbst, N. Ergenc “Improved Hygiene for PP Applications”, *Polypropylene 2000*, Zürich, Switzerland, Maack Business Services, 2000.