

The Introduction of deTerra™ Biobased Flame Retardant Polymers

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Abstract

For many years specialty polymer compounds have existed that meet various industry standards for flame retardant (FR) performance. These materials include polymers that are inherently flame retardant as well as a variety of common polymers that are combined with FR additives to produce specialty compounds that meet the required flame resistance tests put forth by various industries. However, changes stemming from agency mandates as well as increased focus on environmental stewardship in some industries have driven the need for revised formulations in FR materials to provide more “green” alternatives. As changes are made to meet the new product requirements, material product performance trade-offs need to be addressed. This work describes one set of materials, specifically named deTerra™, a biobased non-halogenated FR product line, developed to meet the needs of the changing FR material market.

Introduction

The market for flame retardant (FR) polymers has seen dramatic changes over the last few years. Those changes are due in part to mandates from various agencies restricting the use of specific chemical elements that have long been used in traditional FR products. The electronics industry has been a leader in this regard, and focus in that industry has been on the elimination of halogens, which include chlorine (Cl) and bromine (Br). Beyond that, many industries have announced an interest in moving away from polyvinyl chloride (PVC). These market changes have created new needs for FR compounds, especially for those that offer a more environmentally friendly material composition.

The move to “greener” FR products does not come without the need to address associated trade-offs in material properties that are typically associated with the new formulations. Many biopolymers offer good property values in regards to strength and stiffness at typical ambient temperatures, but in contrast may have shortcomings in the areas of impact strength and temperature resistance.

The critical factor in developing formulations for new “green” FR plastics is the consideration of the trade-off effects on properties and processing when evaluating possible raw materials and additive ingredients.

Developing compounds based on biopolymers and utilizing only non-halogen flame retardant additives requires research and development work in an area where little effort has previously been committed. A significant investment in process and material development including chemical analysis and mechanical property characterization was required to successfully develop these materials. The screening process for formulation development and material composition must take into consideration raw material chemistry, effects on material properties, product manufacturability, availability and cost. In the end, the product must meet the needs of industry in regards to overall product value, which is the ratio of product performance to product cost.

Objectives

A list of the performance objectives for this specific development work were to have the new FR products:

- 1) highly biobased, not petroleum based
- 2) include only non-halogenated FR components
- 3) show improved impact strength as compared to common lower cost biopolymers
- 4) achieve high FR performance level
- 5) capable of processing by means of profile extrusion and injection molding

The resulting product line achieving these objectives was given the tradename deTerra™ biobased polymer from Interfacial Solutions, LLC of River Falls, WI.

Materials

The materials chosen as base polymers for the initial grade development work are from the biopolymer family of products, which are produced from renewable agricultural resources, and contain no petroleum content. The biobased polymer content for all grades developed in this product line exceeds 80% . The initial commercial grade, deTerra™ XP331, is greater than 90% biobased. The biopolymers chosen for this product line are also grades that meet ASTM D6400 test requirements for compostable materials. The FR components utilized for this product line are all halogen free additives.

Impact Strength

Shown below in Table 1 are typical impact strength values for common biopolymers along with

developmental FR grade XP 331. The impact strength values were determined per ASTM D256 for notched izod impact testing. As noted in the table, the impact strength of the FR grade developed exceeded the values of common biopolymers currently available today.

Table 1. Impact Strength Comparison

Grade	Impact Strength	Description
2002D	.24 ft-lbs/in	Ingeo™ PLA commercially available from Natureworks® LLC (Minnetonka, MN)
6001	.85 ft-lbs/in	Starch + renewable resource material grade commercially available from Cereplast, Inc (Hawthorne, CA)
P1003	.50 ft-lbs/in	Mirel™ PHA based biobased grade available from Telles (Lowell, MA)
XP331	1.04 ft-lbs/in	deTerra™ flame retardant (FR) development grade from Interfacial Solutions, LLC (River Falls, WI)

Flame Retardant Performance

The flame retardant performance of the initial material developed, XP331, was tested to UL 723, “Test for Surface Burning Characteristics of Building Materials,” (ASTM E84-08). The two primary resulting outputs of the test are a Flame Spread Index (FSI) and a Smoke Developed Index (SDI). Flame spread is the ability of a flame to travel along the surface of a material away from the flame source. The smoke developed is a measure of the concentration of smoke given off as the material burns.

Building and fire safety codes contain requirements that limit interior wall and ceiling finishing materials to three classes as shown below in Table 2.

Table 2. Code Classifications

	Flame Spread Index	Smoke Devel. Index
Code Class	(FSI)	(SDI)
I/A	0-25	< 450
II/B	26-75	< 450
III/C	76-200	< 450

Results from the UL 723 testing on the initial product, grade XP331, are shown in Table 3. The results showed a FSI of 0.0 and an SDI of 75, values that are considered

extremely low for this test, and which clearly put the material in the class 1/A category.

Table 3. UL 723 Test Results, XP331

	Flame Spread Index	Smoke Devel Index
Grade	(FSI)	(SDI)
XP331	0.0	75

Subsequent efforts were focused on the development of grades specifically designed for injection molding and profile extrusion applications requiring flame retardant performance to meet UL 94 tests and achieve a V-0 rating. This requirement is very common in a wide variety of industries, including electronics, small appliances, and office furniture and partitions. Grades developed to meet the V-0 flame requirement include XP345 and XP351, both of which are in excess of 80% biobased content. The XP345 is formulated for extrusion, while XP 351 targets injection molding applications.

Material Properties

Material property data was developed for the FR grades previously mentioned, and that data is summarized in Table 4. Property data was generated following the appropriate ASTM test standards as shown in the table, with the exception of the UL 94 test which is the basis for the flammability results for grade XP351.

Table 4. Material Properties

Property	deTerra™ XP331	deTerra™ XP351	ASTM Test
Specific Gravity	1.31	1.30	-
Tensile Strength	6,400 psi	5,980 psi	D638
Tensile Modulus	620 ksi	496 ksi	D638
Tensile Elong.	4.7%	3.7%	D638
Flex Strength	13,900 psi	11,200 psi	D790
Flex Modulus	498 ksi	478 ksi	D790
Notched Impact	1.04	.94	D256
MFI	6 - 8	18 - 24	D1238
Flammability	Class 1/A	-	E84
Flammability	-	V-0	UL 94

Processing

The grades of deTerra™ biobased polymer mentioned above have been successfully processed into extruded

sheet, profile extrusion, and injection molded articles.
The information below shows typical processing conditions for extrusion and injection molding processes.

Profile Extrusion:

Drying Time: 2-4 hours at 120 deg F
Feed throat temperature: 100 deg F
Melt temperature range: 330 – 360 deg F
Die temperature range: 350 – 360 deg F

Injection Molding:

Drying Time: 2-4 hours at 120 deg F
Feed throat temperature: 100 deg F
Melt Temperature: 340 – 380 deg F
Nozzle Temperature: 360 – 380 deg F
Mold Temperature: 90 – 150 deg F

Conclusion

The demand for new FR polymer compounds that are more environmentally friendly has been driven by industry regulations as well as select corporate initiatives at forward thinking companies. Given the performance limitations of existing commercially available biopolymer grades, and the lack of flame retardant biopolymer compounds on the market, extensive research and development work was required to create new products to address this product gap. As a result, deTerra™ biobased, non-halogenated polymer compounds from Interfacial Solutions, LLC offer one possible solution to industries looking for a more “green” FR polymer compound.