Additive Technology for Polyolefin Biodegradation

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ABSTRACT

ECM BioFilms, Inc., has developed a one percent load, additive technology for the manufacture of biodegradable plastic products. The company currently manufactures and sells these additives for all polyolefin packaging and products on a worldwide basis. In the near future, it is anticipated that the company will release for sale other additives based on the same technology for use in plastic resins such as the polystyrenes. The low percentage loading and a technology which does not utilize physical mechanisms such as light, heat or stress to break up the long polyolefin chains so they become "edible" to the naturally occurring microorganisms, leads to products that look and perform like the same plastic products without the additives. The low cost of the additives and their friendliness to all recycling programs allows a manufacturer to offer the added benefit and marketability to their customers in commodity-type products as well as products with more price flexibility. ECM BioFilms, Inc. believes that it has the least expensive, most widely applicable, proven technology for making plastic products biodegradable available in the world today.

INTRODUCTION

ECM BioFilms, Inc., has developed a new technology which can finally allow plastic product manufacturers a way to offer biodegradable products that can be priced competitively with, and have the same mechanical characteristics as, the traditional non-degradable plastics. The technology is an additive which, when combined as a one percent load to plastic resins, renders the finished plastic products biodegradable while maintaining their other desired characteristics. The company manufactures and sells its ECM MasterBatch Pellets (MBP) additive to polyolefin product manufacturers on a worldwide basis and is currently developing the technology for use with other resin groups, some of which should be ready for market soon.

The most obvious applications include one-use, disposable products such as waste disposal bags, all types of packaging products, disposable diapers, erosion control materials, plant containers, disposable medical apparatuses, agricultural films, food containers (i.e. McDonald's-type clam shell containers for sandwiches) and utensils, oil spill containment systems, and many others. Due to the exceptional shelf life and usable life of products manufactured with the additives, wherein biodegradation does not begin until disposal, items that are not of the "one use and then dispose of" type are beginning to be very important applications for the company's technology as well. Items such as toys, games, tableware, notebooks, computer and cellular telephone casings, auto parts, etc., are all being developed and are considered to be extremely large potential markets.

The company has developed the technology to the point that nearly any plastic product producer can use the additive without having to modify their existing methods of production any more than if they were changing color. The resulting plastic products exhibit the same desired mechanical properties, have effectively the same shelf-lives, and yet, when disposed of, are able to be metabolized into ecologically beneficial biomass by the communities of microorganisms commonly found almost everywhere on this planet.

This biodegradation process can take place aerobically and anaerobically. It can take place with or without the presence of light. These factors allow for biodegradation even in landfill conditions that are normally not conducive to any plastic degradation and keep the plastic degradation from occurring when not desired.

The company's technology differs significantly from other "degradable plastics" emerging in the market today because it does not attempt to replace the currently popular plastic resin formulizations but instead enhances them by rendering them biodegradable. The company believes that it has the least expensive, most widely applicable, proven technology for making plastic products biodegradable available in the world today.

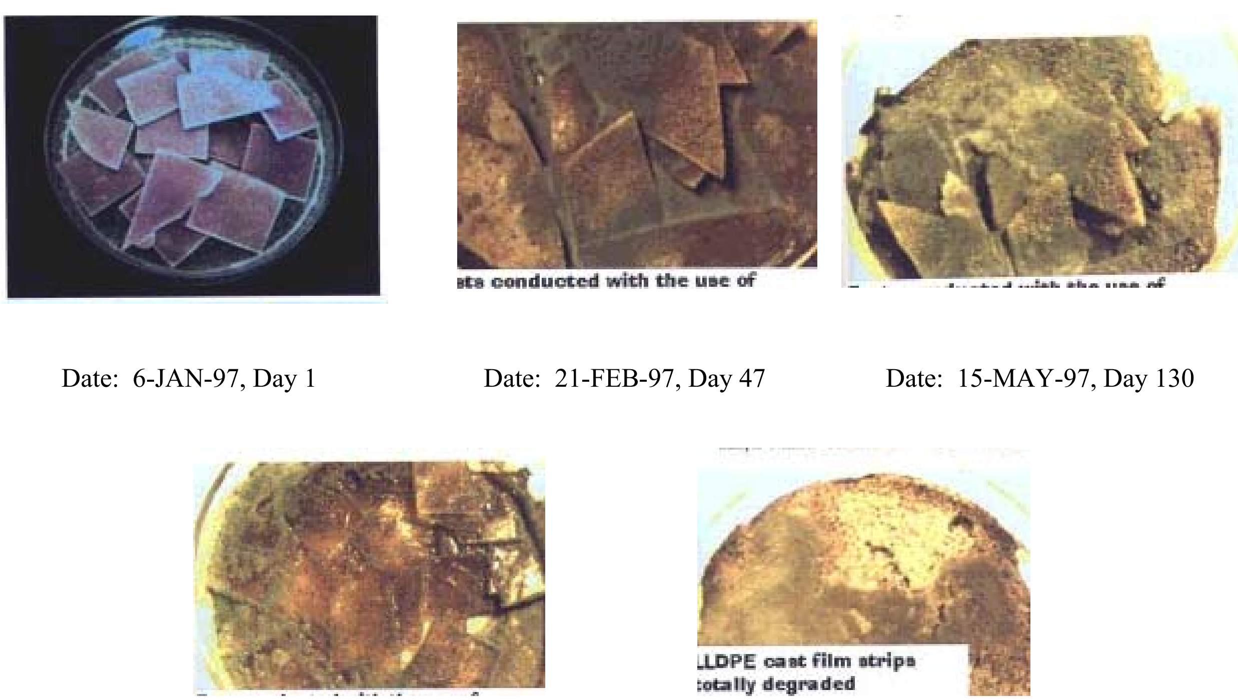
BODY

Recognizing the environmental concerns related to plastics and the market potential, the corporate and scientific communities have long sought to develop degradable plastics. However, the company believes that degradable plastics introduced to date possess several weaknesses that have prevented widespread acceptance in the marketplace. Photodegradable products, for example, do not degrade in landfills due to the lack of sunlight (they are typically covered with another layer of trash before the degradation can occur). At the same time these photodegradable products present difficult circumstances for storage, or during their use, due to their reactivity to light. Similarly, plastic products manufactured with high amounts cornstarch and cottonseed fillers fail to breakdown the molecular structure of the products' plastic components and often do not achieve the requisite physical properties. Replacement resins tend to be too expensive to be widely applicable both because they cost much more than commodity resins and, being total replacements for the resins such as the polyolefins, they disrupt the long years of product development and supply chain work that has gone on before forcing companies to, in a sense, start from scratch.

The company's technology is a process that enables the microorganisms in the environment to metabolize the molecular structure of plastic films into a humus form that can be further metabolized and eventually rendered as minerals that are beneficial to the environment and conducive to plant growth. The company’s process is a proprietary formulation that is mixed with carrier resins to make a masterbatch pellet. The masterbatch pellets can then be easily added to plastic resins using a plastic product manufacturer’s existing equipment.

The company has used several renowned testing laboratories to independently conduct the tests that establish the biodegradability of polyolefin plastic products produced with the MBP. An independent environmental assessment company has taken all the data and has concluded that the polyolefin products are fully biodegradable under aerobic and anaerobic conditions and has asserted that the biodegradation of these products does not produce any toxic residue harmful to living organisms in land or water.

Figure 1.
Time Elapse Photographs of the MBP Formula in 5-Mil Cast LLDPE Film on Tryptic Soy Agar Plates



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Date: 15-MAY-97, Day 130

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The company's additives only nominally affect production costs. This is largely because the MBP technology does not alter the current production process. Biodegradability can be achieved by merely adding a small percentage of MBP to existing resins. In nearly all applications, producing 100 pounds of biodegradable plastic only requires slightly more than one pound of MBP.

The biodegradability of the plastic products produced with the MBP does not jeopardize the product's quality. Plastic products using the company's technology can be manufactured to be clear or opaque and in any color.

The Mechanism for the Biodegradation of Plastic Products

It is only possible to discuss the general concepts behind the company's technology for producing biodegradable plastic products in that the precise mechanism and intricacies of the technology are the company's closely guarded trade secrets.

We have determined, through years of testing both internally and through independent laboratories, that plastic products that are manufactured with at least a one percent (1%) load, by weight, of the MBP will be fully biodegradable once they are placed in conditions wherein they are in constant contact with other biodegrading materials.

Originally it was not known precisely how the process worked and what was the threshold amount of material necessary to initiate and sustain the process. Much of the early testing was done with plastics manufactured with five percent (5%) or higher loads of the additives but it has been determined that all that is required is a minimum of a one percent (1%) load. This amount will properly initiate the process and any significant amount less than this amount will not permit the process to begin or be sustained.

People often wonder whether significantly greater quantities of the company's additives will reduce the biodegradation times. The answer is yes, but the difference is so marginal that it is rarely worth the potential issues concerning other physical properties in the finished plastic products. To explain this more fully, it will be helpful to understand the basics of the mechanism.

The presence of at least one percent of the company's additives in a plastic product, which is in contact with other biodegrading organic materials, structures communities of such organisms as are there present on the surfaces of the plastic in such a way that their interaction produces the ability to break down the long hydrocarbon chains of the "non-biodegradable" petrochemical plastics.

As most people are aware, an example of a biofilm would be the scum that can form on the surface of a pond. There the surface layers with chlorophyllic, aerobic organisms gain benefit and support from other layers of organisms that cannot make their own food who thereby benefit from the food produced by the layers above and those organisms' waste products. So it can go, layer upon layer, until the structure can even, in some instances, support anaerobic organisms in the deeper layers and the interaction of all of the organisms makes for an ecosystem that produces byproducts that would not be formed without the interaction (some new ones have been discovered that may even be able to treat sleep disorders such as jet lag). The same can be said of the biofilms formed by the interaction of the company's additive materials and the naturally existing biota. They produce substances that break apart the long polymer chains to the point that the segments can then be used as a food source for the biota. Importantly, this structuring of communities of microorganism proceeds in anaerobic as well as aerobic conditions.

Once there are the structured communities of microorganisms interacting to produce byproducts that cause schisms to be formed in the long hydrocarbon chains of the polymers, the process continues until all the hydrocarbons are eventually transformed into humus material and eventually into carbon dioxide and water in the case where the biodegradation proceeds aerobically or methane and water when it proceeds without the presence of free oxygen (anaerobically).

This leads us back to the reason why greater quantities of the company's additives do not significantly speed up the time for biodegradation. If you have four, otherwise identical 100 kilograms samples of PE products: one with no additive (100% PE), one with a half a percent of our additives (99.5% PE), one with one percent additive (99% PE) and one with seven percent additive (93% PE) disposed of under the same conditions you will see why this is.

The one with no additive does not form the necessary biofilms that can break apart the long polymer chains and thereby 100-kg of PE sits in the ground in that form for hundreds of years or more.

The one with a half a percent of additive either does not form the biofilms or does not give them sufficient sustainability to initiate and continue the biodegradation process so at the most only the very surface amounts of the additive biodegrades and you will have remaining all of the 99.5-kg of PE and most of the 0.5-kg of additive for hundreds of years in that form.

The product that has the one percent of our additive will form and sustain the biofilms that will continue to break apart the long chains of the 99-kg of PE until the entire quantity of PE is biodegraded.

The sample that has 7 percent additive will do the same thing as is the case where there is one percent; the only difference is that there will be only 93-kg of the slow-and-difficult-to-biodegrade PE to degrade rather than 99-kg. The difference in biodegradation time is not terribly dramatic but it is less.

It may be helpful to illustrate how the mechanism employed by this unique biodegradation technology is an important reason as to why the technology will continue the path it is on to become one of the world's leading technologies used in the production of plastic products.

The fact that the mechanism is not based on photodegradation or thermal degradation means that the shelf life and usable life of the plastic products will be the same as they were without the company's additives. The fact that there is a threshold quantity necessary for the initiation and sustainability of the biofilms responsible for the biodegradation means that the plastics with the company's additives do not have to be segregated out of the plastics that might be recycled into plastic products that are not meant to biodegrade. And finally, the fact that the threshold quantity is so low (one percent by weight) means that the manufacturer is able to immediately make plastic products with all the same other properties they had when they were not biodegradable and at nearly the same cost.

Life Expectancy of Products

In order to give someone helpful information concerning the life expectancy of plastic products that are manufactured with a one percent (1%) load, by weight, of the company's additives, the first and most important point to make is to distinguish between the types of life expectancy that we are talking about. First to be addressed is the life expectancy of the plastic when it is on the warehouse or store shelf, in regular usage as packaging or as a bowl or as any other such normal plastic product. The other life expectancy to be discussed below has to do with the situation when the same plastic has been put in conditions wherein it has constant contact with other materials that are biodegrading.

Plastic products manufactured with MBP will have the same life expectancy as the same plastic product manufactured without the company's additives under all but the conditions mentioned above where they are placed in constant contact with other materials that are biodegrading.

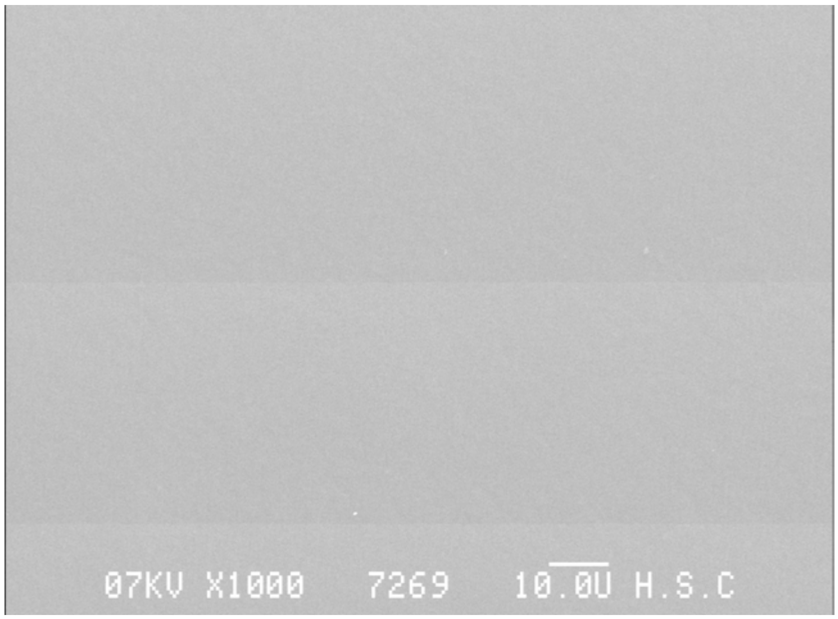
The principles concerned with the degradation of plastics using MBP technology are truly involved with "bio"-degradation. The company's technology does not rely on the use of photosensitivity or thermal sensitivity to photodegrade or thermally break down the plastics. For this reason, a blow-molded HDPE shampoo bottle or motor oil bottle manufactured with one of our additives will last in the warehouse and on the store shelf as long as it would without our additives. There is a considerable amount of interest in the company's additives for the plastics for the automotive and aviation industries for this reason.

There is the real concern for the technologies that make use of thermal or photodegradation that they are simply leaving smaller particles of plastic in the soil rather than having the material truly become soil. This is especially of concern in the agricultural industry and for those needing erosion control products. Agricultural films, erosion control nettings, and other such products manufactured with the company's additives will last long enough to get the required use but will completely biodegrade into the soil. Such plastic products completely biodegrade in a period of from 9 months to 5 years or less. It is not a "poof, it's gone" system but simply makes the plastic product biodegrade as if it were a stick or a branch off a tree rather than "sticking around" for hundreds of years.

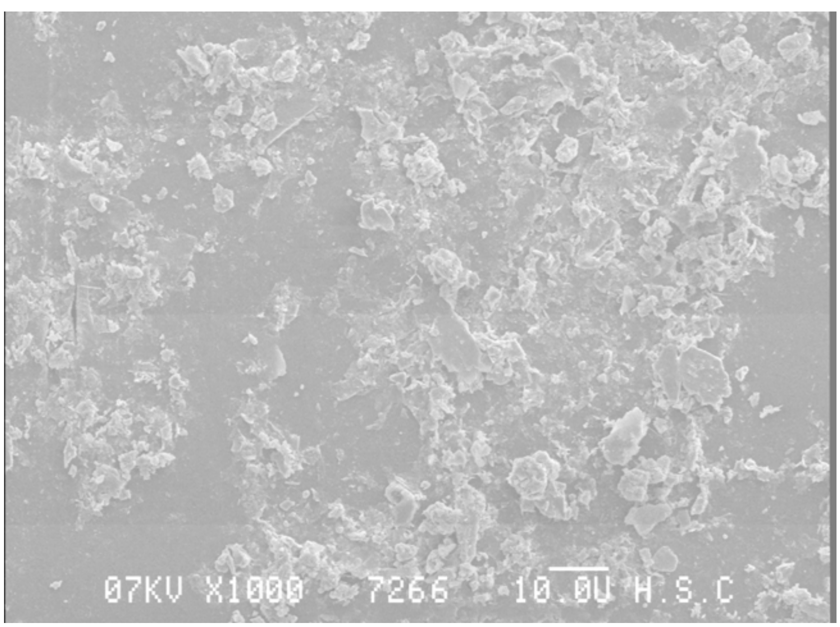
Figure 2.

Study of Film Samples Buried in Soil for One Month

Otherwise identical 40 µm LLDPE blown film samples (the test samples contained one percent load, by weight of the company's MBP while the control samples were without the company's additive) were buried in the same soil conditions for one month then removed and photographed using a scanning electron microscope.



Control



Test

Photographs courtesy of Hyosung Corporation, Korea

(As an aside, for those that need quicker biodegradation times, the company has been developing an accelerator spray that can be used by composting facilities and farmers on bags, agricultural films and other plastic products made with our additives to get dramatically shorter periods of biodegradation [down to even 45 days]. The company expects that they will be ready to market this adjunct spray to the world within a few months.)

To summarize the concept, the key to the company's technology is that the right conditions for biodegradation are not those found when the plastic product is in use, is on the store shelves or is being warehoused somewhere. Just like a wood bowl or piece of furniture, which can be used for many lifetimes, is unquestionably biodegradable, a plastic product with the company's additives can be used for essentially the same period of time as the same plastic product without our additives could be used and yet is fully biodegradable when disposed of.

Concerning the life expectancy of the plastic products manufactured with the company's additives once they are placed in constant contact with other biodegrading materials, the company certifies to its customers, and through them to their customers, the full biodegradation of all polyolefins manufactured with at least a one percent load of the company's additives. The company can certify this situation due to the internal and external studies that have cost hundreds of thousands of dollars. The company's additives have been tested in all of the types of polyolefins, and combinations thereof, with much of the testing having been performed using the various world-standardized tests in independent laboratories by independent scientists. The company has had the various test data analyzed by independent scientists and the their conclusions are what the company bases its certification on.

The basic concept is that biodegradation is a natural process that occurs around the world but at various speeds due to various conditions. Plastics with the company's additives behave like sticks, branches or trunks of trees. Due to this fact, the company does not guarantee any particular biodegradation time because the time depends on the same factors that the biodegradation of woods and most other organic materials on earth depend – ambient biota and other environmental conditions – but the time frame of between nine months to five years will give a good general idea for most conditions. Under specific vermiculture composting conditions or with certain accelerator sprays, some customers and other external and internal trials have reported biodegradation in as little as a couple of months. Under the ASTM standard for commercial composting conditions using high heat processes, a time frame of around one year is a reasonable expectation.

Petrochemical plastics would normally take from 100 to over 500 years to "biodegrade." With the company's additives, these same plastic formulas biodegrade in a hundredth of that time or less.

One should not try not be confused by the claims of some companies that say that products made from their resins fully biodegrade in 2 months or 3 months and that try to blur the distinction between something being "biodegradable" and something that passes the ASTM test protocol for commercial composting conditions. They are speaking of biodegradation under very specific conditions. This has lead to some confusion when the plastic products are in the end-consumers' hands, such as in the Kassel project in Germany when the bags and other plastic products marked with a "compostable" label were found not to be compostable by the town's citizens in their backyard compost heaps (they were only "compostable" under the very specific commercial composting standard of a high heat, controllable moisture level, aerobic environment).

When I spoke at the Biodegradable Plastics Conference in Frankfurt, Germany a couple of years ago, I argued with the companies involved in that project that they should be careful in not trying to confiscate generic terms for too specific conditions. As the use of our technology continues to grow to become the world's leading technology for the production of biodegradable plastics, our viewpoint will continue to gain more and more adherents.

CONCLUSIONS

Plastics manufactured with our additives will fully biodegrade in home compost heaps, commercial composting operations (both in high heat and in low heat [vermiculture] processes), buried in the ground, buried in landfills, tilled into the soil, having been littered, etc. Most importantly, our process is by far the least expensive, most widely applicable, proven technology for the biodegradation of plastics in the world.