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MODERN PACKAGING MATERIALS FOR ELECTRONIC EQUIPMENT: BIODEGRADABLE AND VAPOR PHASE CORROSION INHIBITOR TREATED

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ABSTRACT

Biodegradable products are becoming an ever increasing forced decision rather than a choice, due to the swelling landfills in the U.S. and throughout the world. With the biodegradation rate of roughly one hundred years for standard petrochemical derived plastics, there is simply no more room for these plastics. One of the biggest culprits of this problem, are non biodegradable plastic bags or films used for consumer use and in industrial shipping. More and more companies are distributing biodegradable bags or films but with customer's alike, giving feedback that price and mechanical properties of these mainly starch based materials, are less than adequate for their application. Therefore, there is a demand for a biodegradable bag or film, with mechanical properties comparable to non biodegradable plastics but with a similar cost. With this in mind, the packaging of electrical equipment using a biodegradable film with similar properties and price to a non biodegradable film is sought [1]. This paper presents a description of a biodegradable film that will provide excellent contact, barrier and vapor phase corrosion inhibition, along with static decay and surface resistivity values, that fall into the anti-stat range, otherwise known as a Anti-stat Biodegradable Corrosion inhibiting film (ABC film).

Keywords: Vapor phase corrosion inhibitor, anti-stat, biodegradable, static decay, surface resistivity.

INTRODUCTION

Thorough protection of electronic equipment during shipment or storage through the use of polymer films, should take into account the prevention of electrostatic discharge, corrosion and the disposal of the film after use. An ABC film, is a polymer film that provides thorough protection, offering anti-stat ESD protection, corrosion inhibition and biodegradation. These properties in the film provide for a modern packaging material for electronic equipment that is truly a complete packaging film. The most recent property addition to this film is the property of biodegradability. Biodegradation is a term used for materials that convert to another species, within a reasonable amount of time. Such that the original material is no longer present. Understandably, this conversion has to take place within a reasonable amount of time in order for the film to be regarded as a biodegradable film. With this time factor, there are several organizations such as the Biodegradable Products Institute (BPI) that require specific test procedures and biodegradation rate requirements, in order for a film to be certified biodegradable under their trade name. The BPI uses the test method ASTM D 6400 to test for biodegradability [2].

A second property that allows an ABC film to become a product that is a modern packaging material for the protection of electronic equipment is the films ability to eliminate electrostatic discharge. Electrostatic discharge is distributed between two or more objects whenever two or more objects come into contact. Electrostatic discharge is the flow of electrical current between two objects at different electrical potentials. This flow of electrical current is often irrelevant, but in the case of equipment such as electrical, serious damage can occur during storage and shipping if the proper precautions are not met. Damage such as tribocharging can occur where friction generated between the rubbing of materials can lead to large differences in electrical potential. Even more damaging are the effects of electrostatic induction, which happens when the electrically charged object is placed near a conductive object isolated from ground. The presence of the charged object creates an electrostatic field that causes electrical charges on the surface of the other object to redistribute. Even though the net electrostatic charge of the object has not changed, it now has regions of excess positive and negative charges. This can cause irreversible damage to several types of electrical equipment, most notably in microelectronic components [3].

Electrostatic discharge prevention through the use of film packaging, must be done using a conductive material such that it can be incorporated into a film. Three types of materials are available for incorporating into a film. They are anti-stat, static dissipative or conductive materials [Table 1], [4].

Table 1
surface resistivity of common materials [4]

Material	Surface resistivity (Ohms/square)
Plastics	$>10^{12}$
Anti-static	10^{10}-10^{12}
Static Dissipative	10^{6}-10^{12}
Conductive	10-10^{6}
EMI Products	10-10^{4}
Metals	10^{-1}-10^{-5}

For static dissipative and conductive materials, an entire layer of the film or a significant amount of the material, is incorporated into the film to cause the film to become static dissipative or conductive. Since a significant amount of static dissipative or conductive material must be incorporated into a film, the film will not biodegrade within a reasonable amount of time. Anti-stat materials have a lesser degree of conductivity, and therefore the loading amount in a film is very little. Therefore, anti-stat materials are a prime candidate to use for the prevention of ESD damage. An ABC film contains an internal anti-stat as opposed to an external topographical anti-stat, that is incorporated into the film at a 1% or less value. This internal anti-stat additive initially has a homogenous distribution throughout the film but eventually has an equilibrium where the diffusion to the surface of the film occurs. This buildup on the surface of the humidity dependent anti-stat additive is hydrophilic and therefore humidity is attracted to the surface. The film surface then pulls any buildup of charge on the enclosed item away from the item and towards the film surface. Two distinct tests measure for the films ability to perform this task, of which are surface resistivity and static decay [5].

Corrosion inhibiting properties are an additional property that can prolong the lifetime of a wrapped item. Often corrosion is unseen within an item and premature failure of the item is the result. A manufacturer of electrical equipment could possibly limit the lifetime of his or her product due to corrosion, not knowing, that an ongoing corrosion problem is the culprit of the failure. Several types of corrosion inhibition protection are available such as contact phase, vapor phase and barrier phase corrosion inhibition. Contact phase corrosion inhibition, is where the corrosive solution is in direct contact with the metal and the corrosion inhibiting substrate is in direct contact with the corrosive solution. The next type of corrosion inhibiting protection is barrier phase corrosion inhibitor, where the corrosive species has to penetrate through the corrosion inhibiting material in order to reach the surface of the metal. A third type of corrosion inhibiting protection is the vapor phase corrosion inhibitor where the inhibitor has to act at a distance.

Experimental

Surface Resisitivity measures the resistance of electrical current flow across the surface of the film. This property is measured in accordance with ASTM-D257, where a film sample is exposed to a conditioning period of 48 hours at a temperature of 73 +/- 5 deg F, and a relative humidity of 50% +/- 2%. Another 48 hours of conditioning is done in the test chamber where the temperature is at 73 +/- 5 deg F and a relative humidity of 12% +/- 3%. After conditioning, the film sample is tested at six points on one face of the film, and tested at six points on the opposite side of the film, using a Monroe Electronic Surface resistivity meter. The recorded value for surface resistivity must fall in the range of 10^{10}-10^{12} Ohms/square [5].

Static Decay is an extremely important test because it allows the user to know how fast a material will dissipate or remove an applied charge. For the ABC film, the test procedure MIL-STD-3010 test method 4046 [6] was used to test for static decay because it is a United States Department of Defense Test Method Standard for Packaging Materials. In addition, the performance requirement MIL-PRF-81705D [7] is the industry standard for static decay and so during research and development of this product any product that did not have a static decay of 2 seconds or less was eliminated.
The test procedure calls for the film sample to be exposed for 48 hours of conditioning at a temperature of 73 +/- 5 deg F, and a relative humidity of 12% +/- 3%. After the conditioning period, a faraday cage is charged to + 5000 volts and the film is tested for static decay on both faces of the film. Immediately after, the film is charged to -5000 volts and the film is tested for static decay on both faces of the film again. Four test scores are tabulated for each film sample. Six film samples are tested for each lot of produced film [5].

Corrosion inhibiting properties should be considered when allowing a product to be used in a modern packaging material for the protection of electronic equipment. Contact, barrier and especially vapor phase corrosion inhibition are properties that allow the material to have a longer useful life and prevent the material from corroding which would allow product failure. Contact phase corrosion inhibition testing is performed by what is called the Razor blade test. Carbon steel panels composed of 1010 carbon steel and 100% copper panels measuring one inch by four inches are cleaned in methanol. Two drops of DI water are then placed onto the surface of the metal and the film is then placed onto the water (thus forming a sandwich of metal, water and film). After two hours, the film is removed, water is wiped away, and the surface is observed for any signs of corrosion [6].

Barrier phase corrosion inhibition testing is performed using the SO_2 Test. This test is performed by creating a sulfur dioxide gas environment in a one gallon jar where the film is wrapped around carbon steel 1010 panels. After a twenty hour conditioning period the sulfur dioxide gas is created and a twenty four hour test period is started. At the end of the twenty four hour test period, the panels are observed for any signs of corrosion. Testing is done in triplicate with one control panel, of which is wrapped in a non corrosion inhibiting film [7].

Vapor phase corrosion inhibition ability (VIA) testing is performed by sanding carbon steel plugs, such that all lines on the plugs are in straight lines, with 120 grit and 240 grit sand papers. The plugs are then inserted into rubber stoppers that are attached to one inch diameter aluminum pipes, that are attached to plastic lids. These lids are one quart glass jar size. One inch by six inch strips of film, are then hung from the underside of these lids. The test jars are then placed onto a laboratory bench for a period of twenty hours. After the twenty hours, a glycerol/water solution is added to the jars. The jars are then placed again on a laboratory bench for two more hours before placing into a forty degree C oven for two more hours. After the test period, the plugs are observed for corrosion.
Again, the test is performed in triplicate along with a control plug. The control plug corrodes heavily at the end of the test period, and the ABC film plugs are unchanged from their original appearance. See figure 1 [8].

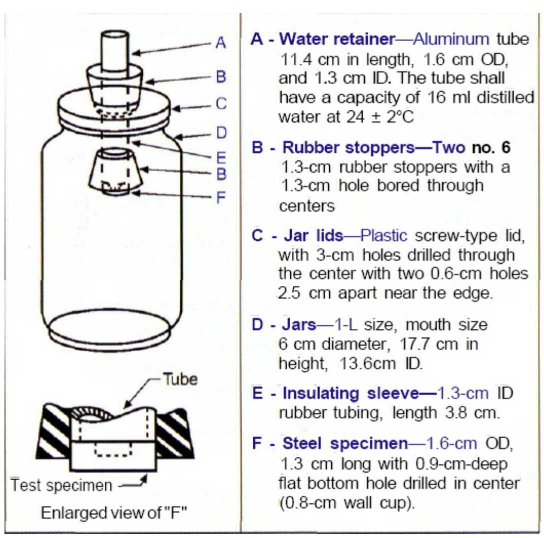

Figure 1, Cortec Corporation VIA Test [8]

Biodegradability testing was conducted in accordance with ASTM D 6400 section 6.1 with requirements listed in sections 6.2, 6.3 and 6.4. These requirements are that no more than 10% of its original dry weight will remain after sieving on a 2.0 mm sieve after exposing to laboratory-scale composting found in section 7.2.1 of ASTM D 6002 [2].

Results & Discussion

Laboratory tests performed were surface resistivity, static decay, razor blade test, VIA test, SO_2 test and ASTM D 6400 testing.

Table 2
Outside film Surface resistivity

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	4.6 x 10^10	2.8 x 10^10	2.3 x 10^10	1.6 x 10^10	1.6 x 10^10	1.4 x 10^10

Table 3
Inside film Surface resistivity

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	1.2 x 10^10	1.7 x 10^10	1.2 x 10^10	1.2 x 10^10	1.1 x 10^10	1.1 x 10^10

Table 4
Static Decay outside Surface +5000 Volts

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	0.86	0.91	0.92	0.93	0.93	0.93

Table 5
Static Decay inside Surface + 5000 Volts

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	0.88	0.92	0.93	0.93	0.95	0.96

Table 6
Static Decay outside Surface, - 5000 Volts

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	0.86	0.91	0.89	0.92	0.92	0.94

Table 7
Static Decay inside Surface, - 5000 Volts

Material	Position #1	Position #2	Position #3	Position #4	Position #5	Position #6
ABC Film	0.82	0.86	0.86	0.87	0.87	0.89

Results for anti-stat testing [Table 2-7] clearly show that an ABC film is a product that will provide for static decay and surface resistivity when exposed to extreme conditions [9]. For static decay, applying a voltage of +/- 5000 volts to the film has been determined as a sufficient way to test a film for surface resistivity, and test results show that an ABC film can clearly eliminate this charge quickly, removing the charge in less than 1 second, well below the requirement of two seconds. For surface resistivity, the resistance to electric current flow across surface of film falls within the acceptable range for an anti-stat material [10].

For contact phase corrosion inhibition, testing shows that a razor blade test [6] was conducted to show that if moisture becomes trapped between the item and the film, the film will be able to prevent the item from corroding. A control film with no corrosion inhibitors is used as a control [Table 8-9]

Table 8
Razor Blade Test Results for carbon steel

Material	Panel #1	Panel #2	Panel #3
ABC Film	Pass	Pass	Pass
Control Film	Fail	Fail	Fail

Note: Razor blade test is graded on a pass or fail scale

Table 9
Razor Blade Test Results for copper

Material	Panel #1	Panel #2	Panel #3
ABC Film	Pass	Pass	Pass
Control Film	Fail	Fail	Fail

Note: Razor blade test is graded on a pass or fail scale

Barrier phase corrosion testing as already mentioned, is tested in accordance with a sulfur dioxide test [7]. This test will determine if a corrosive gas can penetrate through the film, and then be able to displace the corrosion inhibitors that have deposited on the surface of the metal [Table 10].

Table 10
SO_2 Test Results

Material	Panel #1	Panel #2	Panel #3
ABC Film	Grade 4	Grade 4	Grade 4
Control Film	Fail	Fail	Fail

Note: The SO_2 test is graded on a grade 1, grade 2, grade 3, grade 4 scale. A grade 4 signifies no corrosion, whereas, grade 1 is extreme corrosion.

Vapor phase corrosion testing is arguably the most significant of the corrosion testing due to the level of sophistication involved in developing a product with this attribute. Often a product will have contact phase corrosion inhibition and also barrier phase corrosion inhibition, but more than likely, vapor phase corrosion inhibition will be absent. Vapor phase corrosion is a property where the inhibitor sublimates from the solid phase into the gas phase, and then condenses onto the metal surface. This condensation forms a layer of corrosion inhibitor on all metal surfaces of the part, thus preventing contaminants from reaching the surface and corroding the surface. The VIA test [8] as mentioned previously was performed on ABC Film with the following test results [Table 11].

Table 11
VIA Test Results

Material	Plug #1	Plug #2	Plug #3
ABC Film	Grade 3	Grade 3	Grade 3
Control Film	Fail	Fail	Fail

Note: The VIA test is graded on a grade 0, grade 1, grade 2, grade 3 scale. A grade 3 signifies no corrosion, whereas, grade 0 is extreme corrosion.

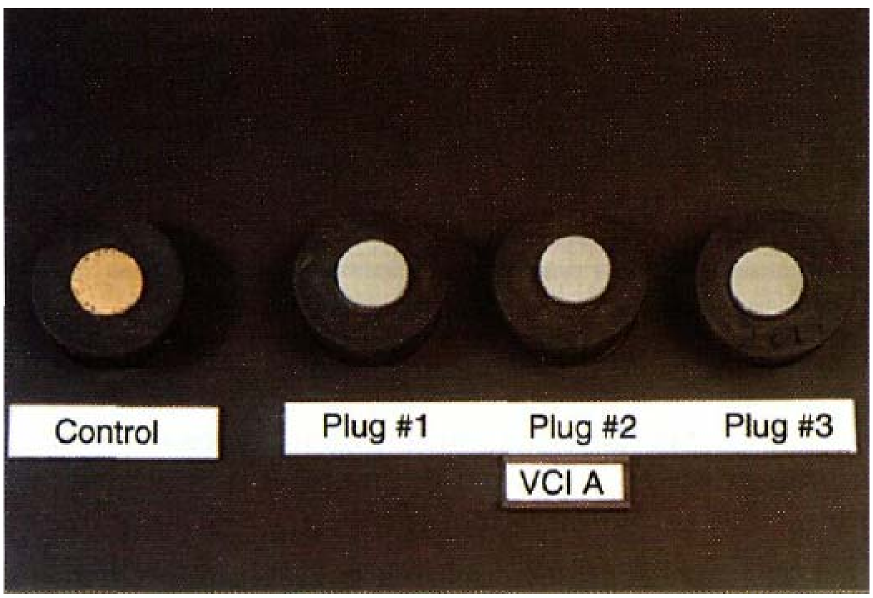

Figure #2, VIA Test Results for ABC Film [8]

For Biodegradability testing, results provided by an independent lab must show that ASTM D 6400 requirements will be met, with an original weight of no more than 10% of the original dry weight remaining after the test period [2]. Testing is to be conducted according to laboratory-scale composting as found in ASTM D 6002 [11]. Figure #3 refers to a life cycle of the biodegradation process, starting with film prior to insertion into compost pile, three week midterm to the six week end time [11]. In Figure #3, the ABC film is stretched across the frame and placed into the compost.

Figure #3, shows prior to insertion into compost pile, after three weeks in compost pile and after six weeks in compost pile. Less than 10% of the original weight of the film is remaining after six weeks in compost pile [11].

Conclusion

Modern packaging materials for electronic equipment are becoming more and more important in the age of our highly sophisticated electronic equipment that becomes more readily available. Packaging through the use of polymer films must take into consideration all that might damage this type of equipment, such as electrostatic dissipation, corrosion and disposal concerns of the bag after use. A product such as an ABC film will provide static dissipation, prevent corrosion and biodegrade when exposed to compost conditions.

References

(1) Berkesch, S. Biodegradable Polymers; A Rebirth of Plastic, March 2005, pp 1-14
(2) ASTM D 6400, 1999. Standard Specification for compostable plastics.
(3) Danglemayer, G. Theodore, *ESD Program Management: A Realistic Approach to Continuous Measurable Improvement in Static Control, pp 1-20*
(4) ASTM D-257, 2007. Standard test methods for DC resistance or conductance on insulating materials.
(5) MIL-STD-3010, Test Method 4046, 2002. Electrostatic Properties.
(6) Hannan, D., Razor Blade Test (Cortec Corporation work instruction), pp 1-3, May 2000
(7) Hannan, D., SO_2 Test (Cortec Corporation work instruction), pp 1-3, May 2000
(8) Hannan, D., VIA Test (Cortec Corporation work instruction), pp 1-4, May 2000.
(9) MIL-PRF-81705D, 1998. Barrier Materials, Flexible, Electrostatic Protective, Heat Sealable, pg 7.
(10) RTP Company, Conductive & Anti-Stat Plastic Compounds, October 2007
(11) ASTM D 6002 Guide for Assessing the Compostability of Environmentally Degradable Plastics.