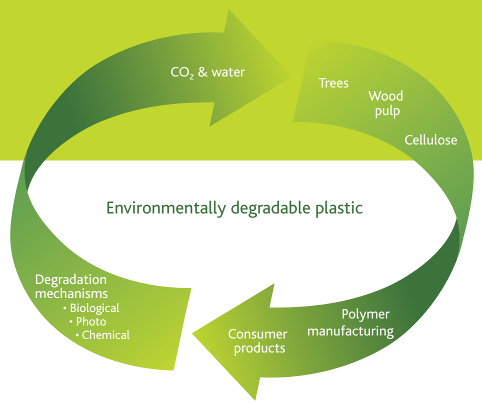
Cellulose Acetate Polymer

Environmentally degradable material made from a modified natural polymer (cellulose)

Biocycle for cellulose acetate materials



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1 Introduction

In this document, GAMA provides background information on the ecological behavior of cellulose acetate.

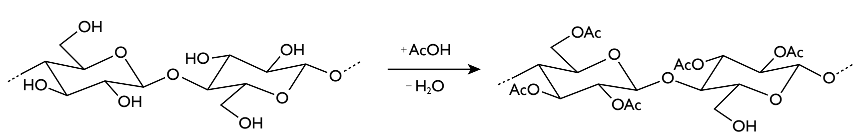
This information is provided by manufacturers of cellulose acetate and is based on best practices known to the industry*. For more information on GAMA and its members please visit the GAMA website, http://www.acetateweb.com/membership.htm

2 Raw materials utilized in manufacturing cellulose acetate polymer

The basic raw material used to manufacture cellulose acetate polymer is purified plant-derived cellulose. Cellulose, the structural component of the primary cell wall of green plants, makes up 40 to 50 percent of a tree's composition. The most common source of cellulose is pulp derived from trees, grown in responsibly managed forests. Some of the wood pulp is obtained from third party forest certification standards such as the *Sustainable Forestry Initiative*® Inc. (http://www.sfiprogram.org/).

Cellulose is modified with raw materials containing acetyl groups to form cellulose acetate polymers. The raw materials used to manufacture these polymers are acetic acid and acetic anhydride. Acetic acid, one of the simplest organic acids and a main component of vinegar, may be produced by either natural or synthetic chemical processes. Acetic anhydride is a molecule that is produced when one combines two acetic acid molecules and removes water molecule.

Cellulose acetate—A modified natural polymer



Cellulose **Cellulose acetate**

Cellulose, acetic acid, and acetic anhydride are mixed together and reacted to form cellulose acetate polymers. This process is aided by the addition of a small amount of sulfuric acid which is subsequently neutralized during processing.

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3 End uses

The unique properties of cellulose acetate enable a great variety of end-use applications.

Fabrics

Cellulose acetate gives fabrics a silk-like appearance and it can be blended easily with fibers from other materials. Its texture is soft and cool against the skin, is naturally absorptive, breathable, has good drape and is excellent at combatting static cling.

Cellulose acetate is frequently used for linings in suits or coats, for formal wear including wedding gowns. Other examples of cellulose acetate use in fabric are home furnishings, such as window treatments and upholstery, decorative ribbons and medical tapes.

Films

With the use of additives, the physical properties of cellulose acetate films can be modified to accommodate a wide range of film applications. For many film manufacturers cellulose acetate is the material of choice due to its excellent transparency, breathability to moisture vapor, scratch resistance and it is easy to cut. Examples of end-use applications are clear tapes, window cartons, paper and book covers, athletic glasses, personal care products and wrapping material for hot foods. An application which has increased strongly during the last several years is the use of cellulose acetate films in the production of liquid crystal display screens (LCD).

Cigarette filters

A major application for cellulose acetate is for the filtration of cigarette smoke. Cellulose acetate has prevailed as the filter material of choice because it combines good filtration properties with good acceptance of the taste signature. It also has a good biodegradability profile which is an advantage in the event the filters end up in the environment.

Separation technology (liquid filtration/osmosis)

Cellulose acetate was one of the first materials used in membrane separation technology and still finds utility in many filtration applications. Membranes made from cellulose acetate are characterized as having outstanding formability, reasonable resistance to degradation by chlorine, less fouling and in some applications higher flux compared to alternative materials. They are also a cost-effective alternative to other filtration materials available in the market. Apart from membrane filters for laboratory use, cellulose acetate is used today in seawater desalination, drinking water purification, waste water treatment, concentration of fruit juices, and as artificial kidneys.

Molded goods and plastics

Mixtures of cellulose acetate with softeners and additives result in the form of granules or sheets that are in turn used for the production of plastic articles. Processing plastic sheet is carried out by extrusion, molding technologies and cutting, respectively.

Typical products are e.g. screw driver handles, toothbrushes, costume jewelry, hair ornaments, eyeglass frames, safety goggles and visors, casino chips, buttons or electrical insulations.

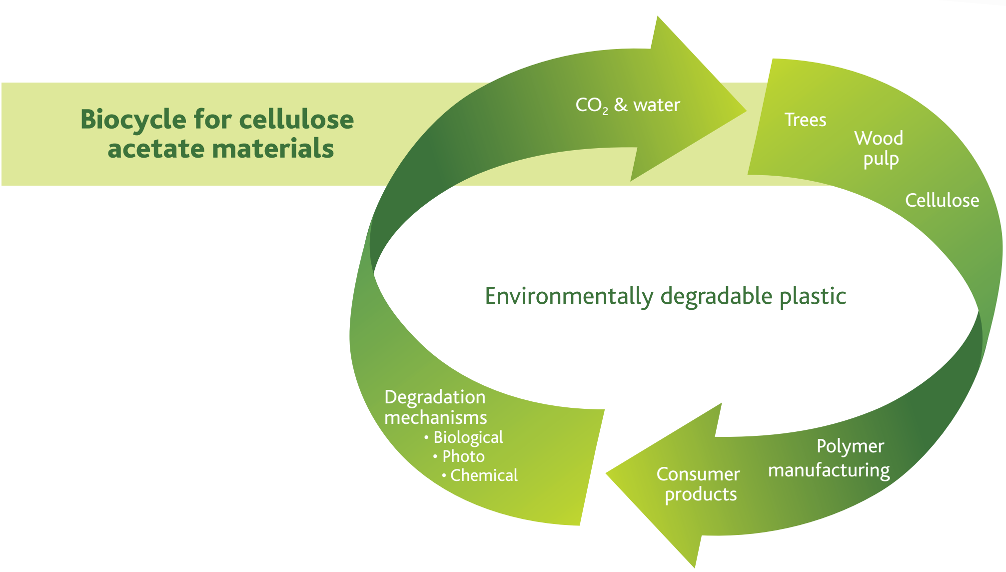
Cellulose acetate helps impart certain favorable characteristics into plastic, such as no odor, no taste, it is non-toxic and hypoallergenic, enables a variety of coloring possibilities, is tough, transparent, glossy, imparts anti-fog properties, has a "natural" feel, is an excellent electrical insulator, is oil resistant, mitigates of temperature contrasts and is resistant to atmospheric conditions.

Special applications

Some special applications of cellulose acetates are ink reservoirs, medical wound dressings, hygiene products and specialty papers.

4 Degradability mechanisms

Cellulose acetate has many environmentally favorable properties (1). It is made from a renewable resource (cellulose) and is readily degradable by a variety of mechanisms as detailed below:



Biodegradability

The degradation by microbes has been extensively studied (2-7). The key findings are that biodegradation requires two steps to achieve polymer decomposition. The first step is to remove the acetyl group which is accomplished in microbial enzymes. Acetyls are common functional groups on natural products and thus enzymes to remove them are readily available in microbes.

Next the cellulose is further broken down by other microbial enzymes that are widely used in natural environments to degrade plants. Many studies have shown that biodegradation of cellulose acetate occurs in a variety of environments including soils, composts, and waste water treatment facilities.

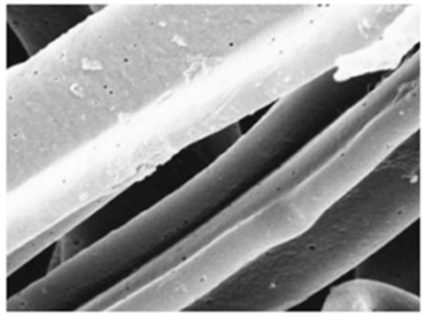


Photo degradation

The process by which a substance is able to absorb light and use the energy to initiate reactions that result in the degradation of a material is known as photo degradation.

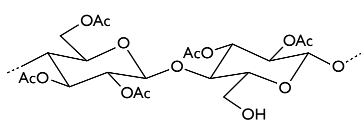
The photo degradation of cellulose acetate happens by so called secondary mechanisms, which comprise other substances absorbing light and generating radicals for reacting in a degrading way with the cellulose acetate structure. These could be substances from the surrounding environment (air, water, contaminations etc.) attacking from the surface or substances incorporated deliberately into the cellulose acetate matrix (e.g. photoactive titanium dioxide particles).

During photo degradation the cellulose acetate is partly deacetylated, i.e. reduced again to structures resembling pure cellulose, and the size of the cellulose acetate molecules is decreased. By this, photo degradation can enhance the enzymatic reactions utilized in biodegradation. In special formulations photo degradation can be used for the complete degradation of a cellulose acetate material.

Chemical degradation

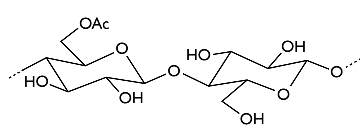
Cellulose acetate polymer is chemically degraded by a process called hydrolysis, which means breaking apart by the addition of water (9). This is a chemical reaction in which water is added to the cellulose acetate polymer causing the release of acetic acid molecules. This process proceeds stepwise until all the acetate groups are released resulting in the reformation of cellulose. This chemical degradation occurs naturally during composting and during other environmental processes in which mild acidity is present. The resulting acetic acid and cellulose can serve as food sources for soil microorganisms and thereby it is in synergy with biodegradation.

Degradation of cellulose acetate in environment—steps and mechanisms



1st step:
Removing of acetyl groups

Mechanisms:
- Biodegradation
- Photo degradation
- Chemical degradation



2nd step:
Breakdown of cellulose structure

Mechanisms:
- Biodegradation
- (Photo degradation)

CO_2 H_2O CH_4

Disintegration

The ability to disintegrate is not a question of the chemical nature of a material but of product design. In contrast to the degradation mechanisms described above, disintegration is a purely physical process leading to smaller units of the material without transferring the elements back into the natural life cycle. However, it can support the other degradation mechanisms by providing a larger contact surface.

5 Conclusion

Cellulose acetate polymer is used to make a variety of consumer products. This paper is a brief summary of the end uses and the mechanisms of degradation. Extensive research shows that this polymer does not persist long term and can be degraded under a variety of mechanisms.

6 Frequently asked questions:

Q: What is the rate of degradation?

A: The rate is dependent upon the environment with studies showing degradation within weeks to years.

Q: Is cellulose acetate compostable?

A: Yes. The number of cycles needed for total disintegration depends on the composting conditions, but the degradation products are environmentally friendly.

Q: What are the by-products of degradation?

A: Since cellulose acetate is made from carbon, hydrogen and oxygen, the ultimate products of aerobic degradation are carbon dioxide and water.

Q: What is the fate of litter?

A: Unfortunately discarded goods, even cellulose-based materials such as paper products do not degrade instantaneously and are therefore an eyesore—research does indicate that this eyesore is temporary and will degrade according to ambient environmental conditions. Although most cellulose acetate-based consumer products are disposed of responsibly the improper disposal resulting in surface litter is clearly undesirable. The proper disposal of unwanted items is the only practical solution to litter.

Q: What is the recommended disposal?

A: Because cellulose acetate materials are cellulosic based, it is recommended that one dispose of the discarded good in a similar way as paper based products. The material will degrade under appropriate composting conditions.

7 References:

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Further information is available from GAMA at http://www.acetateweb.com/.

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