



Purification of Dilactide through Melt Crystallization

Soda Cups Made of Sugar

MANFRED STEPANSKI
MANFRED WÄCKERLIN
SULZER CHEMTECH

Plastics made from renewable raw materials are becoming increasingly important. Bioplastics are now available with properties similar to those of plastics manufactured from a petroleum base. One such bioplastic is polylactide (PLA), which is usually produced through polymerization of lactide. The starting material for this process is lactic acid, which is produced through the fermentation of sugar. Sulzer Chemtech has developed a method in which the lactide can be purified through melt crystallization. One major advantage of PLA is its versatility given the ability to engineer its properties so that it can biodegrade quickly or, alternatively, remain functional for years.

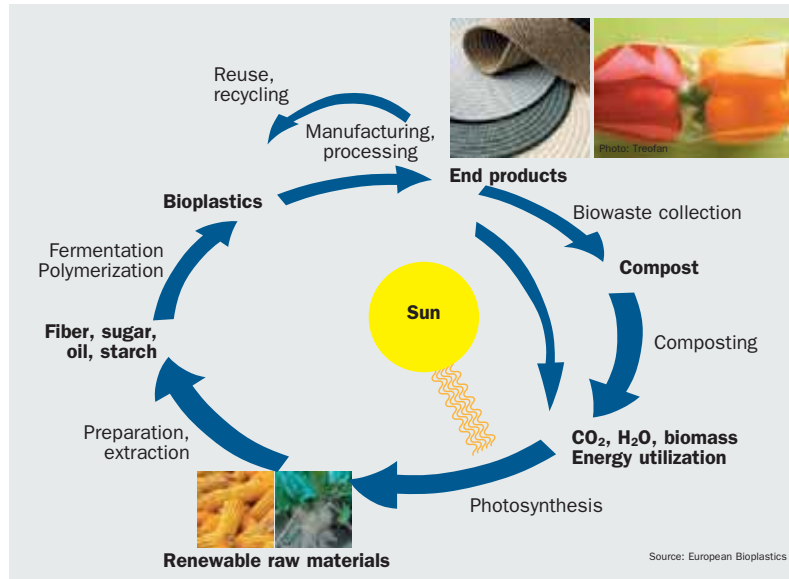
► Bioplastics are a relatively new class of materials that are produced from renewable raw materials (e.g., sugar or corn). Manufacturing, utilization, and recycling of bioplastics form a nearly CO₂-neutral cycle (Fig. 1).

Replacing Petroleum

Today, plastics are primarily manufactured from petroleum. Approximately 250 million tons of plastic are produced from petroleum globally every year. This is equivalent to roughly 5% of the total worldwide oil consumption. According to industry estimates, bioplastics could replace about 5–10% of plastic on today's market, although today they only have a market share of substantially less than 1%. Therefore, strong growth for bioplastics is expected for the coming years (Fig. 2). Market development depends primarily on 2 factors: the high price of petroleum and the obligation to reduce CO₂ output. The raw materials for bioplastics are also used as foodstuffs. It is important that the quantities of feedstock needed for the forecast growth account for only 1.5% of total production.

Great Potential

PLA has proven itself for many years in the medical sector. Screws, nails, implants, and plates made of PLA are used to stabilize bone fractures, as it can be reabsorbed by the human body. Meanwhile, PLA, a clear substance, has become a widely used bioplastic. It has properties similar to those of conventional mass-produced thermoplastics and thus can also be processed using existing equipment. The raw material has tremendous potential, above all

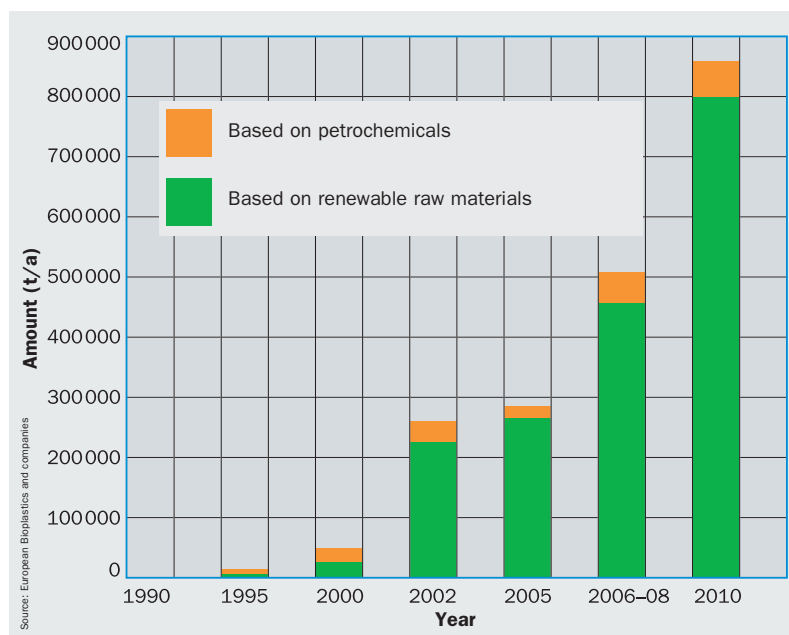


1 Life cycle of biomass-based plastics. Sulzer Chemtech technology permits manufacturing of highly pure lactide, the raw material for polylactide (PLA), a bioplastic in widespread use.

for short-lived packaging such as drinking cups or food bowls (Fig. 3). One disadvantage of the material is its low heat resistance with a low softening point of approx. 60 °C. However, using new types of processes currently in development at Sulzer Chemtech

with support from leading industrial partners, it is possible to manufacture PLA with improved temperature stability, after which the material is suitable for drinking cups for hot beverages or as an artificial fiber for clothing and home textiles (rugs).

2 Worldwide manufacturing capacity of bioplastics. Renewable raw materials (RRM) are the main feedstock.



An Industrial Process

Continuous processes already exist for manufacturing PLA from glucose (sugar) by way of the intermediate steps of lactic acid and dilactide (Fig. 4). At the moment, Sulzer Chemtech is working on the development of an industrial polymerization process, which makes it possible to produce PLA competitively in relation to conventional plastics in the medium term. In the USA, there is already a similar plant in operation with a name-plate capacity of 140 000 tons per year. In this process, PLA is produced through polymerization of lactide, a ring-type union of 2 lactic-acid molecules (Fig. 5). Pure starting materials are an important prerequisite for manufacturing a high-quality polymer, i.e., a transparent plastic with a high molecular mass and rigidity. Lactic acid can be produced

through the fermentation of glucose with the help of suitable bacteria. Lactic acid must then be separated from the dregs of fermentation so that they are available as pure raw materials for polymerization.

No Solvents Needed

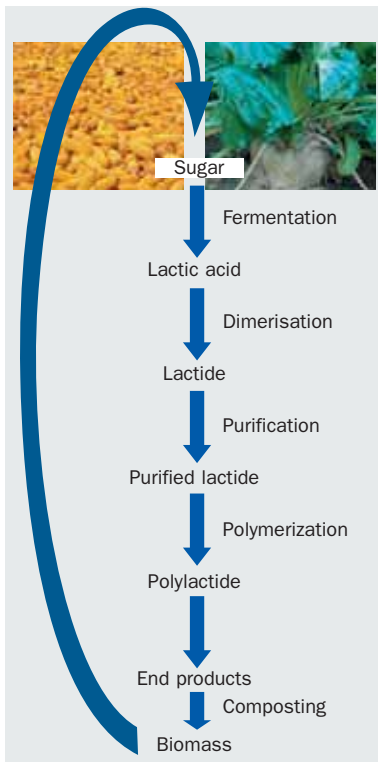
Sulzer Chemtech's melt-crystallization process purifies the lactide mixture without the use of solvents. In the process, contaminants are removed that can not be separated by other methods. High product purity and yield are attained by combining Sulzer's static and falling-film crystallization processes. The falling-film crystallizer contains vertical pipes that are cooled under controlled conditions. Inside the pipe, cooling causes a layer of lactide crystals to form from a falling film of melt. The crystals reject most impurities

which concentrate in the remaining melt fluid. After crystallization, the impurities that remain in the crystals are removed by warming the layer to just under the melting point of the lactide crystals. This step is called sweating. After sweating, the temperature is increased again in order to melt the crystals (Fig. 6). Through several repetitions of this procedure, it is possible to obtain lactide that is more than 99.9% pure.

Sulzer's crystallization process has already been successfully used for purifying chemicals employed for conventional plastics such as polycarbonate and polyurethane. The crystallizers contain no moveable parts such as stirrers or filters thus making the equipment very reliable. The purification process consumes minimal energy, as the operating temperature is comparatively low.

3 One of many applications for plastics made from organic raw materials: soda cups made of the bioplastic PLA.

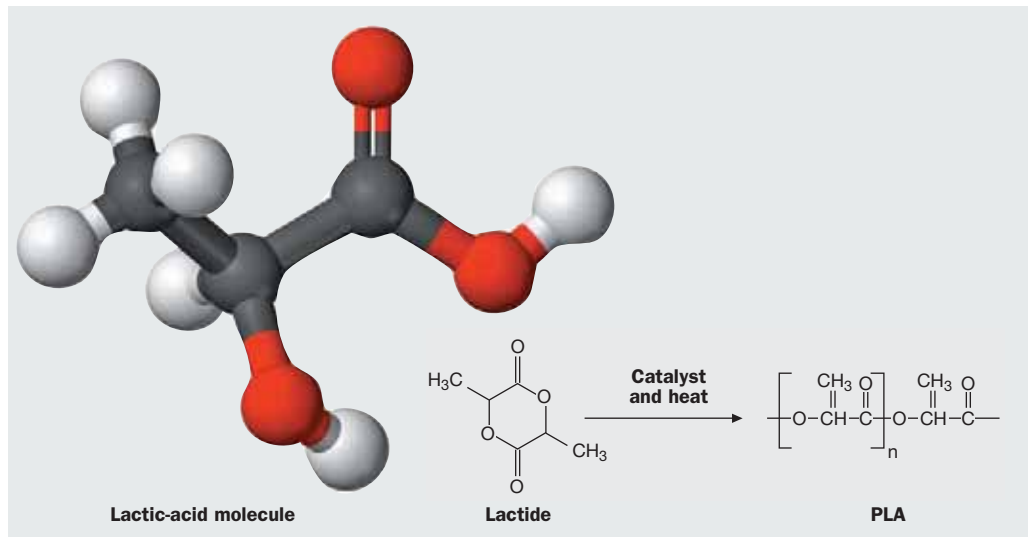




4 Polylactide cycle: The characteristics of the polymer can be engineered through selective mixing of lactides from counterclockwise D(-) and clockwise L(+) lactic-acid molecules.

Plant in Operation

Sulzer Chemtech's first lactide crystallization plant has already been in operation for several years. In view of the increasing demand, the division expects further expansion of production capacity for

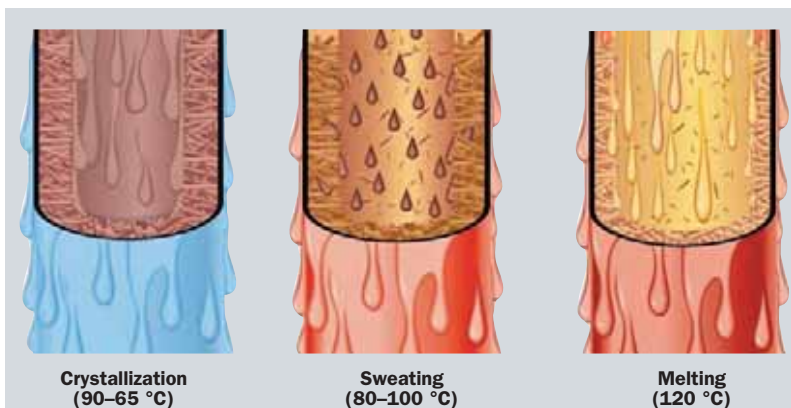


5 The dimeric ring molecule lactide is formed from 2 lactic-acid molecules ($C_3H_6O_3$). A subsequent ring-opening polymerization leads to PLA chain molecules.

plastics made from renewable raw materials. Melt crystallization is expected to be used as a purification method when producing "green" plastic due to its environment-friendly nature. Sulzer Chemtech is also spearheading developments for other process steps when it comes to manufacturing bioplastics. Besides melt crystallization, Sulzer Chemtech offers numerous additional innovative products for manufacturing bioplastics. Distillation columns that are equipped with the high-

performance packing Mellapak-Plus are used in producing lactic acid or lactide. MellapakPlus permits high product throughput with unusually low pressure loss and hold-up and thus guarantees extremely gentle handling of temperature-sensitive products. In addition to using distillation separation procedures for lactic acid, the division develops processes for polymerization of PLA in mixer reactors in cooperation with a leading industrial partner. ◀

6 Course of melt crystallization: crystallization, purification through sweating, and melting of the desired product (from left to right).



Contact

Sulzer Chemtech AG
 Manfred Stepanski
 Sulzer-Allee 48
 8404 Winterthur
 Switzerland
 Phone +41 52 262 37 86
 Fax +41 52 262 00 68
 manfred.stepanski@sulzer.com