Industrial Solutions

PLA*neo*®

Polylactide Technology

UIF Polycondensation Technologies
State-of-the-art process for a sustainable polymer

thyssenkrupp

Polylactic Acid (PLA)

A sustainable polymer

Polylactic acid (PLA)

Polylactic acid or polylactide is a biodegradable and sustainable thermoplastic aliphatic polyester derived from renewable resources. The feedstock for the UIF Polycondensation Technologies PLA*neo*® process is lactic acid. PLA can be used as a substitute for a vast number of materials such as PET, PP and PS, helping to conserve fossil resources, such as petroleum, while at the same time reducing CO_2 emissions. It is also well-known for its biodegradability as well as very good recycling properties.

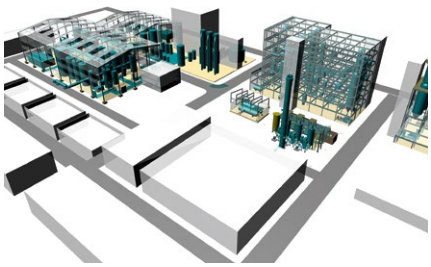
Process Development

The process is based on continuous PLA polymerization of polymer grade lactic acid, produced by fermenting glucose or sucrose, which is then converted into lactide and subsequently purified. PLA polymerization is similar to other melt-phase processes such as PA 6 and PET production, areas in which UIF Polycondensation Technologies has a wealth of experience and a range of proven equipment.

The development of the PLA*neo*® process involved several steps: After successful lab-scale polymerization, Uhde Inventa-Fischer set up a continuously operated miniplant in Berlin in 2005 to optimize the design of reactors and equipment. Then, in 2011 an industrial-scale pilot plant was successfully started up in Guben, Germany. The PLA*neo*® process licensed by UIF Polycondensation Technologies is based on more than 50 years of experience in the development, engineering and design of leading polymerization processes and in the construction of more than 400 production plants throughout the world.

The 500 t/year pilot plant in Guben was built in order to demonstrate the PLA*neo*® process and to set up a reliable, industrial-size scale-up. This enables UIF Polycondensation Technologies to license their PLA production technology for plants with annual capacities up to 100,000 tonnes. The PLA*neo*® technology can also be customized to produce a variety of polymer grades. Samples can be produced at our pilot facilities.

A complete basic engineering package for an fully integrated industrial-scale PLA production plant starting from glucose or sucrose as the feedstock has been prepared (see 3D layout on the right). In June 2016, UIF Polycondensation Technologies signed its first contract for a PLA production plant with a capacity of 10,000 t/year.



Lab and bench-scale testing | Pilot plants: PLA, LA, PET, rPET, PBT, PA, PBS, PTT | Industrial scale

Long track record of process development and scale-up from bench scale to industrial scale

PLA*neo*® Technology

Process description

The lactic acid (LA) required for polymerization is fermented from glucose or sucrose. In order to meet the high purity requirements, LA is subjected to several subsequent purification steps to obtain thermally stable polymer-grade LA.

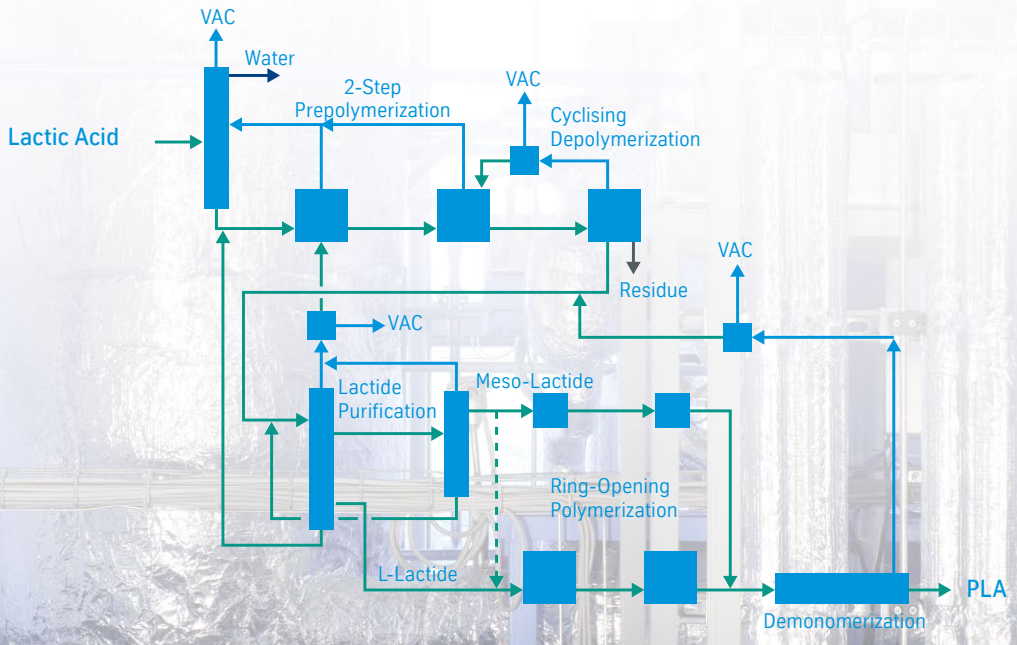
In the first polymerization step, lactic acid is concentrated to remove any residual water. An oligomer of limited molecular weight is then produced in the subsequent polycondensation stage. This prepolymer is thermally depolymerized to form lactide, the cyclic dimer of lactic acid.

In order to obtain high molecular weight PLA, the monomer lactide has to be very pure prior to polymerization. A purification step for the crude lactide, stemming from the depolymerization, is therefore necessary. UIF Polycondensation Technologies has developed a unique, patented distillation technology, using dividing-wall columns to produce high-quality lactide. In addition, the quality of the lactide can be tailored for the different grades of PLA. In the subsequent ring-opening polymerization, the PLA*neo*® process uses a combination of a specially designed stirred-tank reactor and an efficient plug-flow reactor. Before pelletizing, the polymer melt must be stabilized and the remaining lactide removed. UIF Polycondensation Technologies' proprietary recipe for the stabilization of PLA, in combination with its unique one-step demonomerization technology, guarantees a very low residual monomer content.

As a new biodegradable and bio-based polymer, PLA faces stiff competition from standard, petrochemical-based polymers, such as PET, PS and the polyolefines – not only on a technical, property-related basis, but also, and not least, price-wise.

In this regard, the efficient use of the feedstock is very important as the feedstock cost has a huge impact on production cost. Here lies the main advantage of the PLA*neo*® process from UIF Polycondensation Technologies. The conversion of lactic acid to PLA is close to its theoretical maximum thanks to the unique purification and polymerization techniques for meso-lactide. Meso-lactide, which is a side-product of the PLA process, usually has to be separated and hydrolyzed back to lactid acid, thus reducing the overall efficiency and increasing the feedstock conversion cost. In the PLA*neo*® process from UIF Polycondensation Technologies, meso-lactide is polymerized and blended with standard, crystalline PLA, without adversely affecting the properties of the PLA produced in the PLA*neo*® process. On the contrary, some properties, such as elongation at break are even improved. The PLA*neo*® process from UIF Polycondensation Technologies is able to produce all PLA grades available on the market: from fast crystallizing types to nearly amorphous ones.

PLA*neo*® Process Flow Diagram



PLA Product Features

Properties and Applications

Outstanding mechanical properties:
- Excellent tensile strength

High modulus of elasticity
- Glossy and very clear

Easily printable
- Low surface tension

Wicking properties
- Highly comfortable sportswear

Low water vapor barrier
- Vegetables stay fresh

Very good aroma barrier
- Fruit, cheese and sausages keep their flavor

PLA grades

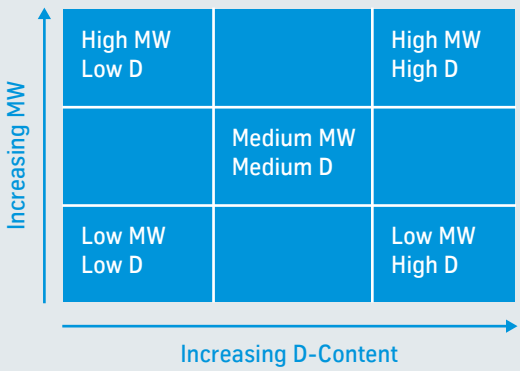
PLA can be produced in many different grades. The two main parameters distinguishing the grades are molecular weight and crystallinity of PLA. The crystallinity is directly related to the D-lactide content. In general the following rule can be applied: the lower the D-lactide content the higher the crystallinity. Fast-crystallizing types are e.g. required for fiber applications or injection molding, whereas medium or high-D-content grades are used for thermoforming or film applications. Thanks to its high flexibility of use, the PLA*neo*® process from UIF Polycondensation Technologies is particularly suitable for producing PLA with a wide range of viscosities and crystallinities for various downstream applications.

Applications

PLA can be processed for all types of applications: Packaging material such as extruded sheets for thermoforming, biaxial-oriented films and plastic bottles; textile materials such as filaments, staple fibers, and nonwovens; and compounds, such as biodegradable films and injection-molded materials.

PLA Properties	
Crystallinity (%)	10–40
Glass transition temperature (°C)	55–60
Melt index range (g/10 min.)	2–20
Melting temperature (°C)	130–170
Molecular weight Mw (Dalton)	100,000 to 250,000
Specific gravity	1.25

Available PLA Product Portfolio



Lactic Acid Process

A fully integrated process

Lactic acid (LA)

Lactic acid is a naturally occurring acid which plays an important role in the metabolism of most organisms. It was first isolated from sour milk as early as the late 18th century; industrial fermentation processes have now been in use for more than one hundred years.

Today, lactic acid is considered a high-potential chemical platform. It is not only widely used in the food and cosmetics industries, but also serves as feedstock for the polymer polylactic acid (PLA). Many other organic substances, for example acrylic acid, can also be obtained from lactic acid for use as feedstock.

thyssenkrupp Industrial Solutions has built a pilot plant for the production of lactic acid from glucose or sucrose in Leuna, Germany, to demonstrate the feasibility and economic efficiency of their process.

Process description

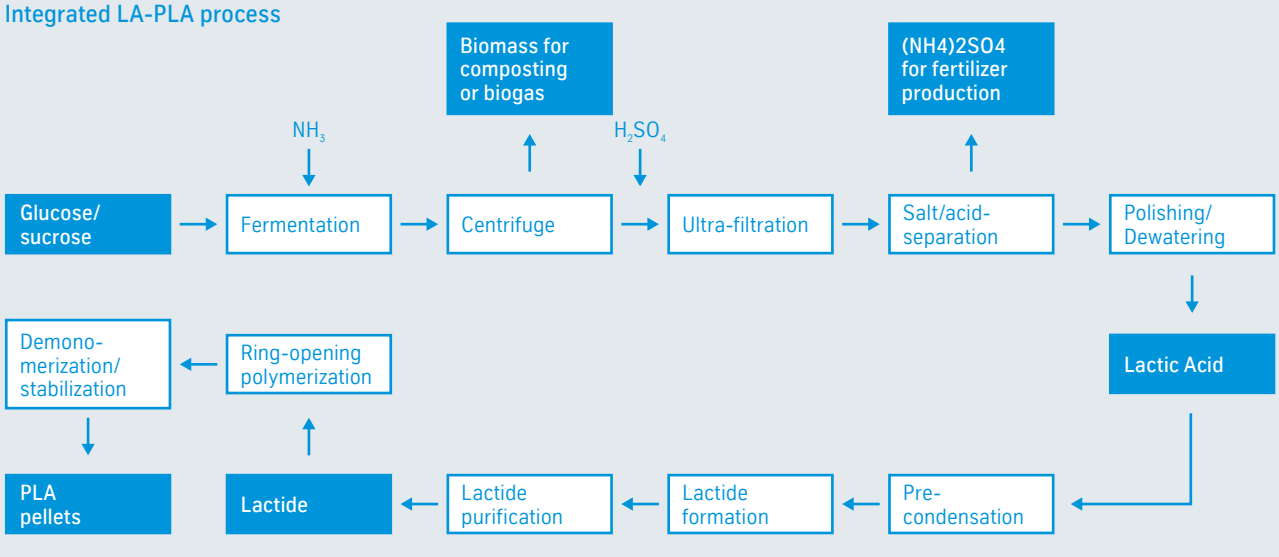
Polymer-grade lactic acid must be very pure in order to ensure maximum conversion into a highly crystalline PLA. Not only the chemical purity (e.g. residuals from the feedstock and side products) but also the optical purity (the content of L-lactic acid) are of utmost importance.

thyssenkrupp's lactic acid technology ensures both. It delivers an excellent lactic acid which fulfills the highest purity requirements. In addition, it is a very economic process. Instead of delivering huge amounts of low-value gypsum as a by-product, as most industrial processes do, thyssenkrupp's technology produces ammonium sulfate, a highly valuable product which can be used as fertilizer.

The fermentation process uses sugar or glucose as feedstock, which can stem from any agricultural source, such as sugar cane, sugar beet, corn, cassava or cellulosic material. A a wide range of very productive bacteria strains guarantees a cost-efficient production process.

Both technologies, the fermentation and purification of lactic acids developed by thyssenkrupp as well as Uhde Inventa-Fischer's PLA*neo*® process, have been merged into one integrated process in order to further reduce production costs and ensure that the overall process is as cost-efficient as possible.

Integrated LA-PLA process



Product Range

A one-stop technology provider

UIF Polycondensation Technologies provides a full range of plant design options:

1. Plants for the exclusive production of LA, lactide or PLA
2. Plants for the combined production of either LA and lactide or lactide and PLA
3. Fully integrated plants for the production of the complete process

Advantages

- UIF Polycondensation Technologies offers the whole range of processes from the production of lactic acid to the production of PLA
- Both L and D-lactic acid can be produced and used as feed-stock for the production of stereo-complex PLA
- More than 95% lactic acid conversion is achieved with minimal by-products
- Effective demonomerization unit
- Fully continuous process and stable product properties
- Flexible production of various grades
- The PLA granulate produced is ready for sale with no further treatment required
- Conversion of lactic acid to PLA is close to the theoretical mini-mum by-product thanks to the unique purification and polymer-ization techniques of meso-lactide

Additional bioplastic technologies

UIF Polycondensation Technologies also offers technologies for the production of Co-PBT, PBS, PTT and other bioplastics based on their worldwide proven polyester and polyamide processes.

UIF Polycondensation Technologies Plant Design Portfolio

Lactic Acid Technology	Lactide Technology	PLA Technology
From sugar to LA		
From sugar	to lactide	
From sugar		to PLA
	From lactic acid	to PLA
		Lactide to PLA

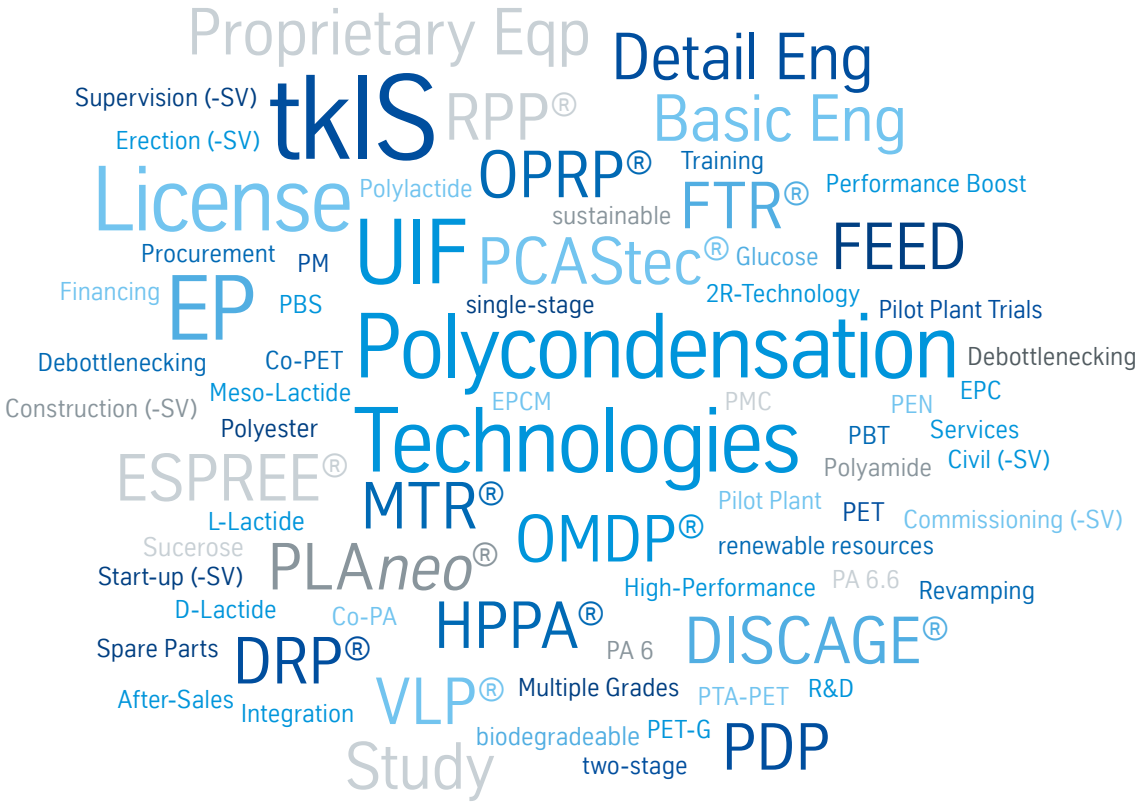
The Power Of True Efficiency

Optimal solutions for specific requirements

thyssenkrupp Industrial Solutions is one of the world's leading engineering companies for licensing, planning and constructing high-tech chemical plants. Around 19,000 specialists at over 70 locations around the globe ensure the highest degree of productivity as well as cost-effective, innovative and custom-made solutions to meet the technological and economic challenges of our customers. We offer a comprehensive array of services covering the entire life cycle of a plant.

UIF Polycondensation Technologies offer our proprietary, cutting-edge polycondensation technologies for producing various grades of polyesters, polyamides and sustainable biopolymers, such as polylactic acids, with customizable viscosity levels ranging from high to medium to low. These technologies are based on Uhde Inventa-Fischer's know-how, the engineering experience gained in the construction of more than 450 polymer plants worldwide since 1924 and through intensive research and development work in close cooperation with prominent scientific and industrial partners. UIF Polycondensation Technologies has successful established a large variety of self-developed, patented technologies and processes in the global market. Our customers can take advantage of these technologies to gain an edge over their competitors.

UIF Polycondensation Technologies, as part of thyssenkrupp Industrial Solution's polymer division, are located in Berlin, Germany and Domat/Ems, Switzerland. Around 150 polymerization specialists and engineers cover the entire field of professional project execution, from plant engineering with the delivery of proprietary and key equipment only up to procurement and construction services for turnkey EPC projects, working in close cooperation with local organizations of thyssenkrupp Industrial Solutions.



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