# Green Chemistry

## Polymerization of lactide to polylactide





Green chemistry
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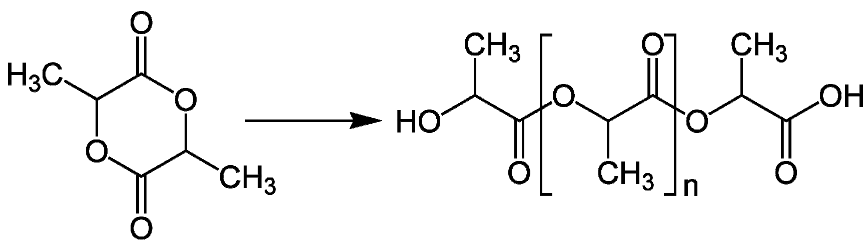
## Name of the chemical process in industry: *<u>Polymerization of lactide to polylactide</u>*




Catalytic and thermolytic ring-opening polymerization of lactide (left) to polylactide (right)

## Applications:

- Mulch film made of polylactic acid
- Tea bags are made of polylactide (PLA). Peppermint tea is enclosed.

- Biodegradable plastic cups in use at an eatery

## There are 12 principle in green chemistry:

1. Prevention
2. Atom economy
3. Less hazardous synthesis
4. Deigning safer chemical
5. Safer auxiliary substance
6. Energy efficiency
7. Use of renewable resource
8. Reducing derivatives
9. Catalysis
10. Design for degradation
11. Use of real time analysis for pollution prevention
12. Accident prevention

## 1.Prevention

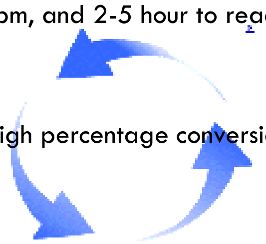
- No waste generation.
- It prevents the use of traditional method to produce plastic from fossil fuels and hence reduces the greenhouse gas generated during the production processs.

Lowering the use of petroleum

Reducing the greenhouse gas generated

## 2.Atom economy

- Typical conditions for polymerization are 180 $^{o}$C to 210 $^{o}$C, tin octoate (catalyst)concentrations of 100-1000 ppm, and 2-5 hour to reach 95% conversion




% Atom Economy= $\frac{Molecular\ Weight\ of\ desired\ product}{Molecular\ Weight\ of\ all\ reactants} \times 100$

= almost 100 %

## 3. Less hazardous synthesis

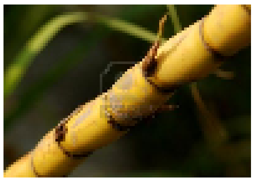
- Using renewable resources for the polymerization, such as corn starch, tapioca products (roots, chips or starch) or sugarcanes. Less or even no hazardous products are synthesized

# 4. Deigning safer chemical

- **Poly(lactic acid)** or **polylactide** (**PLA**) is a thermoplastic aliphatic polyester derived from renewable resources, such as corn starch, tapioca products (roots, chips or starch) or sugarcanes.

corn starch

tapioca products



sugarcanes

# 5. Safer auxiliary substance

- The NatureWorks PLA process substitutes renewable materials for petroleum feedstocks, doesn't require the use of hazardous organic solvents typical in other PLA processes, and results in a high-quality polymer that is recyclable and compostable.

No hazardous organic solvents

## 6.Energy efficiency

- Typical conditions for polymerization are 180 °C to 210 °C, tin octoate (catalyst)concentrations of 100-1000 ppm, and 2-5 hour to reach 95% conversion.

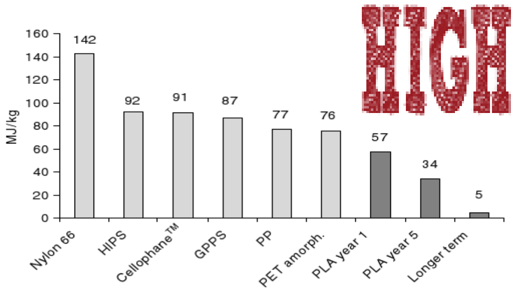



FIGURE 16.4
MJ/kg of energy required to produce various polymers (From Gruber, P., Keynote address, Massachusetts Green Chemistry Symposium, Amherst, MA, 2001. With permission.)

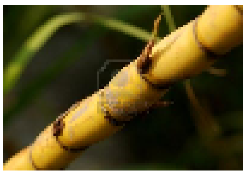

## 7. Use of renewable resource

- **Poly(lactic acid)** or **polylactide** (**PLA**) is a thermoplastic aliphatic polyester derived from renewable resources, such as corn starch, tapioca products (roots, chips or starch) or sugarcanes.

corn starch

es

tapioca product



sugarcan

# 8. Reducing derivatives

- PLA of high molecular weight is produced from the dilactate ester by ring-opening polymerization using most commonly a stannous octoate catalyst, but for laboratory demonstrations tin(II) chloride is often employed. This mechanism does not generate additional water, and hence, a wide range of molecular weights is accessible.

No generation of water

# 9. Catalysis

- Lactic acid is produced by fermenting corn and converted to lactide, the cyclic dimer ester of lactic acid using an efficient, tin-catalyzed cyclization.
- Ring-opening polymerization catalyst: stannous octoate
- Laboratory demonstrations catalyst: tin(II) chloride

# 10. Design for degradation

- It can biodegrade under certain conditions, such as the presence of oxygen.

- Through thermal depolymerization, a highly purified lactic acid is extracted and can be considered as raw material for the manufacturing of virgin PLA with no loss of original properties..

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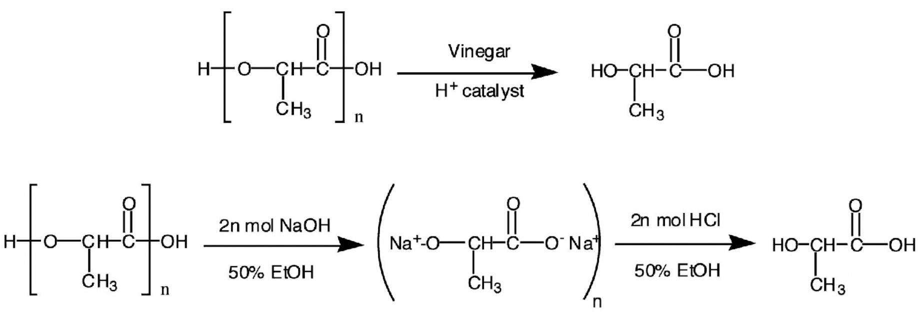
- PLA shares a similar molecular bonding structure to that of lipids or fats, which are routinely broken via acidic or basic hydrolysis



# 11. Use of real time analysis for pollution prevention

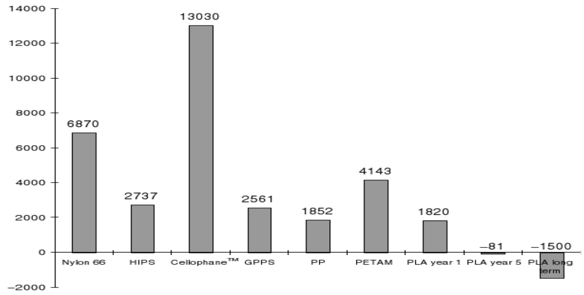



**FIGURE 16.5**
Greenhouse gas emissions (kg/ton) for production of various polymers. Long-term emissions for PLA are based on utilization of biomass for the production of lactic acid.

- The results show that PLA is a low-impact, greenhouse gas polymer because carbon dioxide generated during PLA biodegradation is balanced by an equal amount taken from the atmosphere during the growth of plant feedstock.
- Longer term, as PLA is produced from field wastes or other biomass, PLA can become a $CO_2$ sink and actually contribute to a net reduction in greenhouse gases.

# 12. Accident prevention

- Aliphatic polyesters can be assembled from lactones under very mild conditions, catalyzed anionically, cationically or metallorganically. Seldom have accident.

# Source:

- Google + Wikipedia
- useful website:
- Google: <<Polylactic acid technology>>
- http://docs.google.com/viewer?a=v&q=cache:n_k_SyTXtQoJ:www.jimluntllc.com/pdfs/polylactic_acid_technology.pdf+Polymerization+of+lactide+to+polylactide+less+hazard+synthesis&hl=zh-TW&gl=hk&pid=bl&srcid=ADGEEShhpnEYr_9LU3yESezJVIv5F2Dah3Lj_HzSlu2Z1E43I9564xspkQvKeVDrs9SDdJOdR69SAxKbHij_5O-yqnjoR-HFHEbqsXOWTA-sY_iaj44Pd7w_cZ3QIKDB3rS8f-ccbcZn&sig=AHIEtbQXB4nMrkC27WhZwj3LP7pCjNGTUQ
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- Wikipedia: <<polylactic acid>>
- http://en.wikipedia.org/wiki/Polylactic_acid#See_also
-
- Wikipedia: <<Green chemistry>>
- http://en.wikipedia.org/wiki/Green_chemistry