Transforming the cost of lactic acid and bio-propylene glycol

Phil Goodier, CEO, Plaxica Limited
Plaxica Overview

Corporate
• Heritage: Imperial College, London
• Venture backed
• Business model: Technology licensing

Mission
• Transformational technology for green chemicals
  – Cost leadership
  – Sustainable, renewable, low cost
  – Use of non-food sugars
  – Lactic acid as a low cost platform chemical
## Plaxica’s Technology Addresses the Key Issues with Green Chemicals

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<th>Green Chemistry Issues</th>
<th>Plaxica: What’s Different?</th>
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| • Biological processes:  
  – Scale up risk / cost  
  – Need pure sugars                                                                 | • Chemical process:  
  – Known, scalable technology  
  – Uses very low cost sugars                                                   |
| • Bio-ethanol focus:  
  – Large market, low value  
  – Subsidy-dependent                                                             | • High value, high volume markets                                  |
| • High operating (variable) cost                                                        | • Low variable cost:  
  – Much lower sugar cost (90%)  
  – Hemicellulose focus                                                          |
| • High capital cost of “second generation” sugar platforms                             | • Integration with existing operations:  
  – Paper and Pulp industry                                                        |
Lactic acid as a platform chemical

Factors limiting growth:
1. Lactic acid cost
2. "Food versus fuel"
Markets today for Plaxica’s low cost lactic acid

Proven processes with existing market demand

1. Polylactic acid
   - Input raw materials cost reduced by 70%
   - Non-food raw materials
   - Stereocomplex PLA = better performance

2. Propylene Glycol
   - $3.5BN market
   - 3% bio-based: Glycerol
     - Glycerol availability constrained (biodiesel)
     - Lactic acid is a “drop in” replacement for glycerol
   - Proven hydrogenation processes exist for LA → PG
Feedstock Strategy

- Focus on low cost, non-food sugar sources

- Work with non-fermentable sugars ($C_5$, $C_6$)
  - Paper & Pulp waste streams
  - Molasses
  - $C_5$ hydrolysates from “cellulose to sugar” processes
  - *If you want to make L-lactic acid from glucose or corn syrup, ferment it!*
Plaxica’s lactic acid is much lower cost than fermentation

Variable cost of production (raw materials plus energy etc.)

Lower cost lactic acid competes with petrochemicals in the C₃ value chain
Demonstration Strategy

Industrially relevant & scalable

- Process uses known and proven unit operations
- Chemical, not biological - Proven scaling strategies
- Lab → 20L → Simulation → Pilot plant → Model validation → Full Scale
Project Example: Valorising a hemicellulose waste stream from the Paper & Pulp Industry

• An industry being forced to change

Global Packaging, Graphic and Tissue Demand vs. Real Global GDP (1990 = 100)

- Digital media a threat to print media
- Competition to fibre-based packaging from plastics
- Strong tissue growth in emerging markets

Source: IMF; PPPC; RISI
Project Example: Valorising a hemicellulose waste stream from the Paper & Pulp Industry

- Large, inflexible >$1BN assets...?
- Or existing biorefineries which can be converted to produce bio-chemicals...?

Photo courtesy of Sappi Limited
Many mills are converting to “dissolving pulp”: Chemical Cellulose

- Dissolving pulp is a rare success story in the forest-products industry: high growth, high value, high ROI

**Global Dissolving Pulp vs. Paper-Grade Pulp Demand (2000=100)**

Source: PPC, Hawkins Wright
Project Example: Valorising a hemicellulose waste stream from the Paper & Pulp Industry
• Dissolving pulp process produces a hemicellulose by-product stream which is a perfect feedstock for Plaxica’s lactic acid process
• The additional burden on the recovery boiler can reduce pulp capacity by 20-30% compared with market pulp production
Versalac® Project Example: Valorising a hemicellulose waste stream from the Paper & Pulp Industry

Wood Chips → Pre-hydrolysis process → Pulp Process → Recovery Boiler

Lignin Removal
Sugar Hydrolysis
C₅/C₆ sugars

VERSALAC®

Versalac® reaction → Lactic Acid Purification → Lactic Acid

Closed loop reagent recovery

Electricity
Steam
Plaxica’s pre-treatment technology provides further integration & financial benefits.....

• Our process takes the hemicellulose stream and isolates:
  – Hydrolysed sugars (C5 / C6)
  – Acetic Acid – as the ester
  – Lignin

• >80% of the available carbon converted into revenue-generating products

• A true bio-refinery
Plaxica’s Biorefinery Concept

Feedstock

C₅, C₆ sugars, mixtures of C₅ & C₆ or hemicellulose

Pre-treatment

Versalac®

Racemic Lactic Acid

Optipure®

Dehydration

Hydrogenation

Products

Lignin

Acetates

Valuable by-products

Acrylic Acid

Polyactic Acid

Propylene Glycol
A significant value opportunity for the mill

- Much of the core “biorefinery” exists!
  - Significant energy integration benefits too

- Debottleneck of up to 25% for the core pulp project
  - Significant NPV, minimal market risk

- Excellent project returns – excluding the debottleneck benefit
  (a) Configured to produce 30,000Te of D-lactic acid:
    - <2 year payback
    - 40% IRR
  (b) Configured to produce 25,000Te of Propylene Glycol:
    - <2 year payback
    - 35% IRR
Propylene Glycol Production Costs

Source: IHS Study for Plaxica
July 2015
Strategic partnership signed with INVISTA
INVISTA Overview

- One of the world’s largest integrated producers of polymers and fibers
  - Primarily nylon, spandex and polyester
- History of innovation and industry leadership
  - 75 years of expertise in nylon manufacturing
  - Owns world-famous brands, including LYCRA® fiber
- 1,000+ patents, 4,600 trademarks, 10,000 employees
- Operate in 20+ countries
INVISTA Performance Technologies

• Licensing technology for the manufacture of:
  – Polyester: PTA (purified terephthalic acid); Polyester polymer; Staple fiber
  – Spandex: BDO (1,4-Butanediol); THF (Tetrahydrofuran); PTMEG (polytetramethylene ether glycol)
  – Nylon: Adipic acid; N\textsubscript{2}O abatement

• Brings INVISTA’s leading technologies into new regions of the world
  – Delivered more than 150 projects in 20 countries
  – $5 billion worth of investments being constructed or recently commissioned
  – Major presence in India and China
Plaxica / INVISTA Partnership

Benefits

- Plaxica has access to INVISTA’s considerable licensing expertise & reputation:
  - Technology development; Engineering
  - Global commercial network; Licensee support
- INVISTA participates in Plaxica’s green chemicals portfolio

Deal Structure

- Plaxica responsible for technology & IP development
- INVISTA supports commercialisation and license execution
  - Responsible for development of technology packages, FEEP, commissioning
- INVISTA takes an equity stake in Plaxica and shares future revenues
Plaxica: Summary

• Robust, low cost, chemical process
  – Lactic acid (L&D): 70% cost reduction
  – Propylene glycol & Acetates
    • Production costs compete with petrochemicals

• Feedstock focus on low cost, low purity sugars

• Exciting integration opportunities with the Paper & Pulp industry
  – Valorization of an existing hemicellulose waste stream
  – Operational benefits for the mill
  – Excellent financial returns

• Robust demonstration strategy

• INVISTA deal: global industrialization expertise
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