Green Chemistry by Design

“Building a Renewable Platform for Bio-based Nylon Intermediates”

BIO 2014 World Congress on Industrial Biotechnology

Ray W. Miller
Chief Business Officer
About Verdezyne

• Privately-held industrial biotech company
• Formed in 2008 to develop renewable fuels and chemicals
• Current product portfolio includes materials used in the nylon and thermoplastic polyurethane markets
• Headquartered in Carlsbad, California
• 58 full-time employees
• Venture backed by strategic and financial investors
CARLSBAD, Calif. & KUALA LUMPUR, Malaysia, April 28, 2014

VERDEZYNE FORMALIZES $48 MILLION FINANCING AT SIGNING CEREMONY ATTENDED BY PRESIDENT BARACK OBAMA

Investment in Verdezyne by Malaysian Conglomerate, Sime Darby, and Existing Investors to be used to Accelerate Development of Sustainable and Cost-Effective Alternatives to Petrochemicals

President Barack Obama and Malaysian Prime Minister Najib Razak overseeing Bill Radany, President & CEO of Verdezyne and Tan Dato' Seri Mohd Bakke Salleh, President & Group Chief Executive of Sime Darby Berhad at the signing ceremony.
(AP Photo/Carolyn Kaster)
Verdezyne Business Platform

**Feedstock Strategy**
- Non-food Vegetable oils
- Soapstocks and distillates
- Other palm co-products (i.e. PKO, PFAD)

**Proprietary Technology**
- Organisms engineered for yield and selectivity
- Fermentation-based production
- Highest Quality Products

**Chemical Intermediates**
- Diacids used in fibers, polymers and coatings
- Other organic acids
- Acrylic intermediates
- Amines from Acids

**End-Products**
- Nylon and polyesters
- Fibers
- Polyurethanes
- Engineered Plastics
- Resins
- Lubricants
- Coatings
- Adhesives
- Corrosion Inhibitors
- Transparent Thermoplastics

Total $70B+ Market

**Engineering Organisms & Processes for Cost-effective Renewable Chemicals**
Yeast Production Platform

- Robust under industrial processing conditions
  - Uses inexpensive feedstocks
  - Produces multiple products
  - Fermentation at acidic pH
  - Phage resistant

- Tolerant to saturating product concentrations

- Host genome sequence and advanced genetic toolbox allows rapid development for new products

Superior Host for the Production of Renewable Chemicals
**Metabolic Engineering of a Dicarboxylic Acid Production Strain**

*Parental strain utilizes alkanes or fatty acids as sole carbon source for growth via β-oxidation*

- **Gen 1** strains convert alkanes and fatty acids to the corresponding dicarboxylic acids at high yield and selectivity.
- **Gen 2** strains convert a mixture of fatty acids with different carbon length to a single dicarboxylic acid.
- **Gen 3** strains in development.
Providing Markets with Bio-based Options

Bio-Adipic acid
Bio-Sebacic acid
Bio-Dodecanedioic Acid

Thermoplastic Polyurethane ➔ Paints/Coatings

Plasticizers ➔ Resins

Polyamide N6,6 N6,10 N6,12 Others ➔ Fibers

Biodegradable Plastic ➔ Films

Polyester Polyol ➔ Spray Coatings

Office
- commercial carpet
- paints
- coatings
- adhesives

Automotive/Transportation
- Seats and dashboards
- Tire cord
- lubricants
- belts and hoses

Home
- carpets
- upholstery
- furniture

Recreation
- footwear
- apparel
- camping gear

Personal
- packaging
- cosmetics
- flavorings
With Rapid Scale-Up

- July‘11: Pilot Plant project launched
- Sep‘11: 400 liter pilot fermentor commissioned
- Oct‘11: Successful testing of first adipic acid fermentations
- Jan‘12: Polymer-grade adipic acid samples produced for customers
- June’13: Polymer-grade dodecanedioic acid produced for customer

Proof of Concept
- Functional pathway for production of target
- Measureable outputs

Lab Validation
- Design fermentation process
- Commercially relevant yield (50% of maximum)

Pilot
- Process optimization
- Demo process at scale
- Proof of concept
- Produce market samples

Demonstration
- Confirm process
- Scale up samples
- Reduce scale-up risk

Small Commercial
- Data to construct commercial facility
- Establish offtake

<table>
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<th>Pounds of annual production capacity</th>
<th>4,000</th>
<th>30,000</th>
<th>1.5 million</th>
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10x Scale Up 40x Scale Up 9x Scale Up 9x Scale Up current scale
Moving to Commercialize DDDA

- Bio-DDDA fermentation scaled up at MBI/BEI
- Process now demonstrated at ~10x larger scale than Verdezyne Pilot Plant
- Specification meets or exceeds customer’s defined requirements
- 1000kg of DDDA produced
- Have begun sampling customers
- Engineering design data will be further collected at demonstration scale later this year

President Obama visiting MBI while Verdezyne was operating in their 3000 liter fermenters (foreground) AP Photo/Jacquelyn Martin

Verdezyne’s DDDA
Feedstock is Key

**Traditional Feedstocks (petro and sugar)**
- Cost is 50% - 80% of total cost
- Competition with food and fuel create social tension
- Biofuels mandates have increased sugar price and volatility

**Co-products of Palm Oil Production**
- Expansion of the crude palm oil (CPO) market has created a dramatic increase in supply of co-products such as palm kernel oil (PKO), palm fatty acid distillate (PFAD), and other by-products
- Creates a favorable supply vs. demand pricing structure
  - Not impacting the food supply
  - By product of increasing palm production
Vision: An Integrated Palm Biorefinery

- **MILL**
  - FFB: Full Fruit Bunches
  - PKO: Palm Kernel Oil
  - POME: Palm Oil Mill Effluent
  - EFB: Empty Fruit Bunches
  - MF: Misocarb Fiber

- **REFINERY/Oleo-Plant**
  - Palm Oil
  - PFAD: Palm Fatty Acid Distillate
  - FA: Fatty Acids

- **FERMENTATION**
  - Diacid yeast which can use cellulosic sugars
  - Adipic, Sebacic, DDDA

- Allows the use of potential low cost sugars from side streams
A disruptive platform for cost-advantaged production of high-value intermediates, leveraging a combinatorial metabolic engineered yeast to ferment renewable feedstocks

- Now operating at credible pilot scales
- Projecting 30-40% cost advantage versus incumbent petroleum based products

Developing multiple nylon and PU value chain products to provide near-term revenue

- Initial commercialization of dodecanedioic acid ("DDDA"), adipic acid and sebacic acid
- Licensed/sold legacy biofuels technologies

Commercialization strategy encompasses direct/owned manufacturing, joint ventures/partnerships and technology out-licensing

- Key agreements in process with industry-leading participants encompassing feedstock, manufacturing and offtake
Thank You!

Verdezyne, Inc.
2715 Loker Avenue West
Carlsbad, CA 92010

www.verdezyne.com
760.707.5200