Green Chemistry Challenge Awards Ceremony



2022
Green Chemistry Challenge Awards Ceremony

June 6, 2022 – 6:15 pm

26th Annual Green Chemistry & Engineering Conference, Reston, Virginia

OPENING & REMARKS

Welcome:

David Widawsky
Division Director, Data Gathering and Analysis Division, Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency

Science Address:

Dr. Thomas M. Connelly
CEO, American Chemical Society

Congratulatory Address:

Jennie R. Romer, Esq.
Deputy Assistant Administrator for Pollution Prevention, Office of Chemical Safety and Pollution Prevention, U.S. Environmental Protection Agency

Presentation of Awards

Dr. Thomas M. Connelly
Jennie R. Romer, Esq.

Closing Remarks

David Widawsky

Reception immediately following the ceremony

Grand Ballroom, E-G, 7:00-8:30 p.m.

Independently sponsored event graciously offered by the American Chemical Society

PRESENTATION

2022

Greener Synthetic Pathways

Merck & Co., Inc.

Greener Reaction Conditions

Amgen

Small Business Award

Provivi

Academic Category

Professor Song Lin (Cornell University)

Specific Environmental Benefit—Climate Change

Professor Mark Mascal (University of California, Davis)

2019

Greener Synthetic Pathways
Merck & Co., Inc.

Greener Reaction Conditions
Bristol Myers Squibb Company

Designing Green Chemicals
Colonial Chemical

Small Business Award
XploSafe LLC

Academic Category
Professor Srikanth Pilla
(Clemson University)

2020

Greener Synthetic Pathways
Genomatica

Greener Reaction Conditions
Merck & Co., Inc.

Designing Green Chemicals
Johns Manville,
a Berkshire Hathaway Company

Small Business Award
Vestaron Corporation

Academic Category
Professor Steven Skerlos (University of Michigan and Fusion Coolant Systems)

2022

Greener Synthetic Pathways

Merck & Co., Inc.

Developed a greener way to make LAGEVRIO™ (molnupiravir), an antiviral medicine for the treatment of COVID-19

The Merck & Co., Inc., team is being recognized for developing a greener way to make LAGEVRIO™ (molnupiravir), an antiviral medicine for the treatment of COVID-19. This new production method has greatly reduced organic waste such as solvents and energy use. Merck reduced waste by improving the efficiency of the reaction and by improving the methods used to isolate and purify the product. Merck has also developed an additional production method that further reduces waste and hazards from the synthesis of molnupiravir.

Summary of Technology: The ongoing COVID-19 public health emergency has led to the development of antiviral medications. Given the large number of antiviral doses required worldwide, creating medicines sustainably is important for human health and the environment. The Merck & Company, Inc., team created LAGEVRIO™ (molnupiravir), an antiviral medicine for the treatment of COVID-19. At first, molnupiravir was produced using a five-step sequence from uridine. However, this five-step synthesis had low overall yield and generated large quantities of solvent waste. The Merck team subsequently created a novel synthesis process that will reduce the creation of waste with a 1.6-fold improvement in overall yield and led to the invention of a process (aspirational biocatalytic cascade) that enables a three-step synthesis of molnupiravir from abundant chemicals while also providing a new and general platform for green nucleoside synthesis. These achievements came from several key breakthroughs:

- Dynamic crystallization – This innovation avoids an inefficient and wasteful crystallization step, with product selectively crystalizing as it is formed, improving recovery, reducing generation of waste, and improving productivity.
- Direct isolation – The team changed the organic base and reaction solvent, which decreased byproduct formation and increased purity. This allowed for water to be added at the end of the reaction to crystalize the product, resulting in substantial reductions in organic solvent use and energy use.
- Development of a second-generation synthesis route utilizing a novel multi-enzyme cascade to directly use uracil and ribose as building blocks, avoiding the inefficient synthesis of uridine from those building blocks.

Greener Reaction Conditions

Amgen

Improved Manufacturing to Enable a Greener Process for LUMAKRAS™ (sotorasib)

Amgen is being recognized for creating an improved manufacturing process to enable a greener synthesis process for LUMAKRAS™ (sotorasib), a novel drug for treatment of certain non-small cell lung cancers. The improved manufacturing process substantially reduced waste and decreased manufacturing time by cutting the number of steps involved and eliminating a purification step that created large quantities of solvent waste. Amgen also implemented a recycling process for a harmful substance which improved efficiency and reduced the amount of waste generated. Amgen estimates these improvements will reduce waste by up to 31.7 million pounds per year while also improving the yield, cost, throughput, and overall sustainability of sotorasib production.

Summary of Technology: LUMAKRAS™ (sotorasib) is an atropisomeric molecule, or a molecule where rotation of one or more chemical bonds is limited because of limitations on the speed of chemical reactions due to the spatial arrangement of atoms in a molecule, known as steric hindrances. Amgen improved the commercial manufacturing process for sotorasib by implementing improved telescoped syntheses for two isolated intermediates, reducing the number of reaction steps. A telescoped synthesis, also called a one-pot synthesis, occurs by adding reagents to a reaction vessel one at a time to cause multiple sequential reactions in one vessel, instead of performing one reaction in the vessel and separating and purifying intermediates before performing the next step. This can minimize chemical waste and save time. Further, implementing a recycling process allowed for the recovery of the undesirable P-atropisomer back into the reaction. Amgen made many changes to improve the process and increase efficiency. Previously, solvent-intensive, slow, processes (chiral chromatography and recrystallization) were used to separate the M and P atropisomers; Amgen replaced these steps with resolution with the inexpensive chiral-pool derived reagent (+)-DBTA. Combined, Amgen estimates these improvements will reduce waste by up to 31.7 million pounds per year while also improving the yield, cost, throughput, and overall sustainability of sotorasib production.

Small Business Award

Provivi

Sustainably Produced Pheromones to Control the Fall Armyworm

Provivi is being recognized for creating ProviviFAW®, a greener product for controlling the fall armyworm moth—a destructive pest that feeds on corn and other vital crops. ProviviFAW® is a pheromone produced from renewable plant oils that targets the fall armyworm, reducing the insect's ability to mate and thereby reducing the need for traditional pesticides to eliminate this pest. Reducing reliance on traditional pesticides can, in turn, reduce human and ecological exposure to pesticides and can improve populations of beneficial insects, such as pollinators.

Summary of Technology: The fall armyworm (FAW) is a destructive pest that feeds on more than 80 crops, including corn. To help manage this pest, Provivi created ProviviFAW®, a pheromone product that targets the fall armyworm. ProviviFAW® consists of two pheromones that disrupt fall armyworm mating by confusing male fall armyworm moths, greatly reducing the next generation of larvae and thereby increasing crop yield and reducing the need for conventional insecticide applications which may harm beneficial insects. In addition to being the first commercial pheromone product targeting the fall armyworm, ProviviFAW® also represents an improvement in the methods used to produce this type of pheromone. Provivi developed new reaction methods that reduce the need for fossil-fuel based raw materials and solvents, using fermentation to produce key raw materials from plant materials instead of petroleum. The improvements to the synthesis result in many-fold decreases in aqueous, solid and organic waste generation and the number of reaction steps, raw materials and organic solvents needed.

Academic Category

Professor Song Lin (Cornell University)

Developed An Improved Way to Perform chemical processes widely used in the pharmaceutical industry

Professor Song Lin is being recognized for developing an improved way to perform chemical processes widely used in the pharmaceutical industry. Many chemicals in use today, particularly pharmaceuticals, are large and complicated molecules that are precisely engineered for a specific function. These complicated molecules are often created by joining together parts of smaller molecules. One important way to accomplish this is by cross-coupling reactions, which create new bonds between carbon or silicon molecules. Traditionally, cross-coupling reactions require a transition metal-based catalyst, which typically use rare and potentially hazardous metals. Professor Lin's group has developed a new way to perform these reactions that does not use these metals and also decreases energy use and waste.

Summary of Technology: Oxidation and reduction reactions are two types of chemical processes widely used in synthesizing organic compounds in the pharmaceutical industry. However, these reactions can use a lot of energy, hazardous metals and create hazardous byproducts. To combat this issue, Professor Song Lin of Cornell University developed an electrochemical strategy that enables organic transformations without the use of potent chemical oxidants or reductants, which can be hazardous. First, Professor Lin's group developed a series of coupling reactions that can selectively forge C-C, C-Si, and Si-Si bonds from readily available alkyl halides and chlorosilanes feedstocks. Second, the group advanced an electrooxidative C-H functionalization reaction that operates under simple, catalyst-free conditions. These reactions use inexpensive carbon or magnesium electrodes rather than transition metal catalysts. Lastly, Lin's group created an electrochemical reactor that is compatible with current industrial infrastructure for high-throughput experimentation. These high-impact, productive coupling reactions could have a significant impact in the pharmaceutical industry and could reduce the creation of hazardous materials and energy usage.

Specific Environmental Benefit—Climate Change

Professor Mark Mascal (University of California, Davis)

Biobased Chemicals from Non-Food Biomass

Professor Mark Mascal and his lab at the University of California Davis, in partnership with CEO John Bissell and his team at Origin Materials, are being recognized for the development and implementation of a novel technology for the production of chemicals from biomass (such as forestry, agricultural, and municipal wastes) that can replace products that are commonly made from petroleum. This technology could have positive environmental impacts, particularly in the plastics industry, as the chemicals produced can be used to make materials which are both net zero-carbon and recyclable.

Summary of Technology: Calls to limit the use of fossil carbon in the production of industrial materials such as plastics have helped bring about the advancement of sustainable technologies, in particular those that make use of biobased feedstocks. The molecule 5-(hydroxymethyl)furfural (HMF) has generated strong interest as a biobased platform molecule. However, HMF is only practically derived from the food sugar fructose, which is extracted from cereal grains and is relatively expensive. To overcome the limitations of HMF, Professor Mascal's team developed

a process that involves acidic digestion of carbohydrates in a two-phase reactor, which produces 5-(chloromethyl)furfural (CMF) in high yield directly from raw biomass. CMF is even more synthetically versatile than HMF and can be used to make a wide variety of chemicals that would otherwise be produced from petroleum. For example, Origin Materials have developed a commercial process for the generation of biobased, net zero-carbon polyethylene terephthalate (PET plastic) and associated products starting from CMF. This novel chemistry could have significant environmental impacts by replacing fossil resources with biomass, especially when the technology is scaled to a mainstream commercial industry.

SUMMARY OF AWARD-WINNING TECHNOLOGIES

2021

Greener Synthetic Pathways

Merck & Co., Inc.

Gefapixant Citrate

Merck's Process Research and Development Team developed a green and sustainable commercial manufacturing process for gefapixant citrate, an investigational medicine for refractory and unexplained chronic cough. This innovative process reduces costs and waste, potentially facilitating worldwide access.

Summary of Technology: Chronic cough is a serious and often underdiagnosed condition that has been estimated to affect as many as 5–10 percent of adults globally. Gefapixant is an antagonist of the purinergic receptor P2X3. In Phase 3 trials, adult patients treated with gefapixant 45 milligrams twice daily demonstrated a statistically significant reduction in 24-hour cough frequency versus placebo. The initial supply route to produce gefapixant involved many steps and was characterized by a high process mass intensity (PMI). PMI provides a measure of process efficiency for biopharmaceutical production. Although the initial PMI of 366 was suitable for commercial manufacturing – the Merck Team thought they could do better.

Merck applied green chemistry techniques to synthesize gefapixant citrate, ultimately developing a green and sustainable commercial manufacturing process with a PMI of 88 from commodity raw materials, a greater than four-fold improvement over the initial process. The key innovations in this process are: (1) the implementation of a highly efficient two-step methoxyphenol synthesis; (2) an innovative diaminopyrimidine synthesis using a hybrid flow-batch process; (3) a simplified direct sulfonamide synthesis; and (4) a novel and robust salt metathesis approach to consistently deliver the correct salt form with high productivity. Merck also achieved a significantly higher yield and a six-fold reduction in raw material costs. Furthermore, the alkylation step, that involved highly hazardous chemicals, has been replaced, rendering this a safer and more robust commercial process. Merck also implemented energy-saving processes that reduced carbon dioxide and carbon monoxide emissions.

Key to the sustainable process was the development of a SMART PMI tool which sets aspirational PMI targets to continuously spur innovation in new synthetic methods. This tool helps Merck's scientists find the most direct and sustainable route from commodity chemicals to active pharmaceutical ingredients. The approach combining both green chemistry principles and SMART PMI demonstrated by Merck has potentially wide-ranging application for the manufacture of pharmaceuticals.

Greener Reaction Conditions

Bristol Myers Squibb Company

Five Sustainable Reagants

The chemical process development team at Bristol Myers Squibb has developed a new, sustainable class of reagents. Their work demonstrates that innovative advances in chemistry lead to more efficiency and greener processes. These reagents are also easy for other chemists to use and are broadly applicable to multiple systems.

Summary of Technology: Bristol Myers developed five mutually compatible reagents. A reagent is a compound or mixture added to a system to cause a chemical reaction. The reagents created allow access to phosphodiesters, phosphorodithioates, homochiral and racemic phosphorothioates, homochiral phosphonates, and chiral tertiary phosphines.

These reagents can be used in solid phase synthesis. Solid phase synthesis is a widely-used method where molecules are bound to a solid support material and synthesized step-by-step in a single reaction. One key element of Bristol Myers' technology is the use of phosphorous reagents in solid phase synthesis instead of the traditional non-strategic oxidation reaction. Using phosphorus reduces the amount of reagent and solvent required and improves the stability of the reagent and intermediate products, leading to substantial environmental benefits. The enhanced air and moisture tolerance of the phosphorous reagents also eliminates the need for expensive technology and specialized shipping and storage. Additionally, these reagents are derived from limonene, a sustainable waste product from discarded citrus peels.

Lastly, these new reagents are highly versatile. They can be used with a variety of chemical and biological systems. For example, these reagents allow rapid synthesis of products relevant to chemical catalyst and biological probes used in studying diseases, such as COVID-19.

Designing Green Chemicals

Colonial Chemical

Suga®Boost Surface Cleaner

Colonial Chemical is being recognized for developing Suga®Boost surfactant blends that use more environmentally friendly chemicals than traditional cleaning surfactants. Specifically, Suga®Boost surfactants consume less energy to create, are biodegradable, and are derived from plant-based materials, with performance that demonstrates potential to replace EO-containing surfactants such as SLES and APEs.

Summary of Technology: Many surfactants used in traditional cleaners are derived from petroleum-based raw materials and pose several issues including high environmental toxicity or a need for high-energy processes in their manufacture. Many of these surfactants are found in laundry and surface cleaners. One group of chemicals often found in cleaners is alkylphenol ethoxylates (APEs). The U.S. Environmental Protection Agency has identified this class of chemicals as toxic to aquatic organisms, especially because they bioaccumulate in mollusks, soils, and sediments. Additionally, APEs can mimic natural hormones and induce endocrine disruption in aquatic and land organisms.

Colonial Chemical discovered that blends of functionalized alkyl polyglucoside (APG) surfactants provide cleaning performance that is equal to or better than APEs' while avoiding environmental issues related to aquatic toxicity, endocrine disruption, and carcinogenic impurities. Suga®Boost surfactants are blends of derivatized APGs prepared by attaching functional groups such as sulfonate, phosphate, quaternary ammonium, glycinate, and citrate. The APG feedstocks are made by reacting natural ingredients glucose (sugar) and palm-derived fatty alcohols. The resulting APGs in turn are reacted with functionalizing agents made at Colonial to complete the syntheses of the derivatized APGs. The functionalizing agents, as well as the functionalized APGs (and all Suga®Boost blends), are all made in water at moderate temperatures and result in no discharge to the atmosphere or wastewater. Suga®Boost blends do not yield toxic substances as they biodegrade. In addition, they contain no known carcinogens and do not cause endocrine disruption. Lastly, Suga®Boost requires less energy to manufacture and requires only water as a solvent during manufacture and cleanup.

These functionalized APG surfactants have the potential to replace EO-containing surfactants used in North America. Furthermore, Suga®Boost and its underlying chemistry has the potential to expand into wipe products, disinfecting cleaners, dish washing, carpet cleaning, and fabric care.

Small Business Award

XploSafe LLC

PhosRox, a Novel Sorbent

XploSafe is recognized for creating PhosRox, a novel sorbent. PhosRox is a single material uniquely capable of simultaneously capturing ammonia, phosphate, and nitrate from wastewater and other contaminated waters and then being applied as a time-release fertilizer.

Summary of Technology: Excess nitrogen and phosphorus in water systems causes eutrophication, a widespread and costly environmental problem. Eutrophication begins with uncontrolled algae growth that disrupts natural ecosystems by lowering the amount of dissolved oxygen in the water. This leads to reduced water quality, reduced food resources, and the overall

collapse of a habitat. Additionally, these algal blooms can be harmful to animals and humans when they consume contaminated fish or water or even inhale water droplets

PhosRox simultaneously removes ammonia, phosphate, and nitrate from aquatic systems and turns it into granules that can be used as a fertilizer. This is accomplished by the combination of various metal-oxides (which can adsorb various nutrients) to create a porous ceramic material. The ability to absorb nitrate is incorporated by an imprinting process whereby a gel containing nitrate ions is formed and is then calcined to a ceramic material, creating pockets with the correct shape and arrangement of metal ions to adsorb nitrate. The manufacture of PhosRox also produces aqueous potassium nitrate as a by-product during the formation of the precursor gel. The potassium nitrate or saltpeter can be used directly in the manufacture of quick-release fertilizers with minimal additional energy input. Since it lowers the dependence on manufactured fertilizer by recycling nutrients, this technology offers sustainable cost and utility advantages over industry-standard biological and chemical treatment solutions. This technology will also help wastewater treatment operators maintain compliance and generate revenue from the sale of nutrient-rich fertilizer. Furthermore, when the sorbent is added to agricultural soils, it will not only release plant nutrients slowly but, in future years, could enhance the nutrient-holding capacity of the soil, preventing fertilizer runoff and protecting the watershed.

Hydra Water Technologies (a technology spin-off from XploSafe) manufactures PhosRox. It is evaluating PhosRox for use in additional settings such as household aquaria, watering ponds, swimming pools, and water features.

Academic Category

Professor Srikanth Pilla (Clemson University)

Nonisocyanate Polyurethane Foam

A team led by Professor Srikanth Pilla of Clemson University is being recognized for creating the first lignin-based nonisocyanate polyurethane (NIPU) foam. This new technology replaces traditional polyurethane foams, one of the most commonly used plastics in the industry. Traditional polyurethane foams are typically manufactured from diisocyanates, a known carcinogen that has significant health and safety effects in its manufacturing.

Summary of Technology: While the lignin-based NIPU foams have the same mechanical properties as traditional polyurethane foams, they are specifically designed for chemical recycling at their end of life. Clemson University's innovation uses lignin directly to bypass fractionation and purification steps that typically complicate a sustainable application. The Clemson team first created a reactive, carbonated lignin precursor by using organic carbonates

SUMMARY OF AWARD-WINNING TECHNOLOGIES

as a reagent. The application of organic carbonates creates a unique opportunity to break down the polymer structure and regenerate the lignin by creating "molecular zippers." These zippers break down the structure of the foam and recover the lignin. Recycled lignin can be readily used to create a new NIPU foam. The sustainability of the process is also enhanced by the ability to recycle the catalyst (e.g., potassium carbonate) used in multiple synthetic steps. The true innovation of this chemistry lies in the formation of reactive precursors using non-toxic and 100 percent biobased reagents. In the past, lignin has been made into a reactive precursor using oxypropylation with propylene oxide and added diisocyanates to mimic the synthesis of conventional polyurethane foams. With the lignin-based NIPU foams, the curing agent is derived from environmentally friendly vegetable oils.

2020

Greener Synthetic Pathways

Genomatica

Biobased Butylene Glycol

Genomatica is being recognized for creating Brontide™ a new brand of 1,3-butylene glycol, commonly used in cosmetics for moisture retention and as a carrier for plant extracts. Butylene glycol is traditionally produced from fossil fuels. However, Brontide™ is produced by fermentation of renewable sugars using engineered E. coli in a one-step production process. This reduces greenhouse gas emissions and avoids the use of hazardous chemicals in the production process.

Summary of Technology: 1,3-Butylene glycol is a common ingredient in cosmetics and personal care products, used for moisture retention and as a carrier for plant extracts. Butylene glycol is conventionally produced from fossil fuels using acetaldehyde, which is derived from petroleum and is a probable carcinogen. Conventional synthetic methods also use environmentally hazardous heavy metal catalysts and require multiple reaction steps, increasing waste from the process.

Genomatica has developed a method to produce butylene glycol from fermentation by E. coli using renewable sugars in a one-step production process. This production method eliminates the need for heavy metals and petroleum feedstocks such as acetaldehyde used in conventional butylene glycol synthesis. Brontide™ has received 100 percent biobased certification from the U.S. Department of Agriculture's BioPreferred program, and a life cycle analysis determined that the global warming potential for Brontide™ was 51 percent lower than the global warming potential for conventional butylene glycol. Brontide™ is also of a higher purity than conventional

butylene glycol, and the Brontide™ fermentation process produces exclusively the R-enantiomer of butylene glycol, compared to the traditional process that produces a mix of the R- and S-enantiomers. The "all-R" butylene glycol may have new applications for human physical and cognitive performance enhancement, which require pure R-butylene glycol.

Genomatica has already begun producing butylene glycol at a commercial scale, producing more than 1,500 tons through 2019. Genomatica expects that Brontide™ butylene glycol will replace a significant share of worldwide butylene glycol demand over the next several years. The company estimates that if all butylene glycol were made with its process, nearly 100,000 tons of greenhouse gas emissions and 50,000 to 60,000 tons of acetaldehyde use would be avoided every year. Brontide™ butylene glycol may be able to replace certain other fossil fuel-derived glycols in some applications, further expanding its market share and creating the potential to reduce greenhouse gas emissions and fossil fuel use for those other applications.

Greener Reaction Conditions

Merck & Co., Inc.

A Green Solution to the ProTide Snthesis Problem: Design of a Multfunctional Catalyst that Stereoselectively Assembles ProDrugs

Merck is being recognized for improving the process used to produce certain antiviral drugs used for the treatment of diseases including hepatitis C and HIV. The new process improved manufacturing efficiency and sustainability of one important antiviral by more than 85 percent. This reduces waste and hazards associated with the existing process and results in substantial cost savings.

Summary of Technology: ProTide drugs were invented to increase cell permeability of nucleoside drugs, which are common antiviral and anticancer drugs. Nucleosides currently represent almost half of all antiviral and anticancer drugs on the market. Development of the ProTide strategy allowed breakthrough developments such as the discovery of sofosbuvir used to treat hepatitis C. However, ProTides are chiral molecules that require stereoselective and chemoselective installation of a 5'-aryloxyphosphoramidate moiety. Existing syntheses are inefficient due to poor chemoselectivity and require chiral reagents and many reaction steps, including the use of expensive, hazardous, and wasteful reagents.

Merck has developed a catalyst that can be used to synthesize uprifosbuvir with very high purity in just two reaction steps. The initial catalyst identification used high-throughput experimentation and optimization to identify an effective catalyst for stereoselective direct coupling of nucleosides to

SUMMARY OF AWARD-WINNING TECHNOLOGIES

chlorophosphoramidates. Kinetics of the catalyzed reaction exhibited an unusual second-order dependence on catalyst, indicating involvement of two catalyst molecules and leading to the development of a dimeric catalyst. The dimeric catalyst itself can be synthesized with high yield and low PMI, contributing less than 15 percent of PMI to the overall synthetic process. Further, dichloromethane was able to be replaced in this process with 1,3-dioxolane. The catalyst was tested in syntheses of other ProTides including fluorouridine and azidothymidine and found to be effective in most cases with improved selectivity, demonstrating potential to green the syntheses of these and other ProTides.

Merck has used this new synthetic method to produce more than 150 kilograms of uprifosbuvir for clinical trials and anticipates that this method will be used in other ProTide syntheses. Merck's life cycle analysis indicated that the new process resulted in greater than 75 percent improvements in PMI, energy use, water depletion, and other metrics compared to the first generation synthesis pathway.

Designing Green Chemicals

Johns Manville, a Berkshire Hathaway Company

Biobased Formaldehyde-Free Thermoset Binder Formulation

Johns Manville is being recognized for developing a biobased, formaldehyde-free thermoset binder for fiberglass reinforcement applications. Thermoset binders are used to bind glass fibers of fiberglass mats used in carpet tile backing. This technology eliminates the use of hazardous chemicals, reduces water and energy use, and produces a product with a longer shelf life.

Summary of Technology: Thermoset binders for fiberglass reinforcement are mainly used in the carpet industry for binding glass fibers of fiberglass mats. Current binders can be formaldehyde-based or polyacrylic acid-based and may use phosphorus-containing catalysts. Formaldehyde is considered a probable carcinogen, and acrylic acid is a strong irritant; phosphorus can be harmful to aquatic ecosystems. Both systems can release hazardous chemicals over their life cycle, exposing building occupants to these chemicals.

Johns Manville has developed a formaldehyde-free biobased binder formulation for carpet mats that uses approximately 90 percent biobased content and is completely formaldehyde free. The binder uses renewable carbohydrates such as dextrose, which is nontoxic and non-hazardous and is produced from corn, potato, or wheat starch. The binder is produced using a phosphorus-free biodegradable acid catalyst at temperatures about 40oC lower than conventional acrylic binders. The dextrose-based

binder provides a much improved shelf life of about 12 months, compared to less than one month for traditional binders, reducing the possibility of waste generation when unused product expires. The novel binder also uses less water and requires less energy for the evaporation of water.

The company's data indicate that mats made with the novel binder have improved stability to heat and humidity and have better delamination strength than standard controls, adding a performance advantage to the product's improved safety and environmental characteristics. While the commercialized version of the new binder is 91 percent biobased, Johns Manville believes 100 percent biobased binders are possible. The company also estimates the new product will reduce water usage by as much as 17,000 gallons per day and reduce energy usage by the equivalent of 138,000 cubic feet of natural gas per day at its plants.

Small Business Award

Vestaron Corporation

SPEAR® Insecticide: First Member of a New Class of Biopesticides that Show Efficacy Comparable to Synthetic Insecticides

Vestaron is being recognized for producing a new biopesticide called Spear®. This pesticide is based on a naturally occurring component inspired by spider venom that can effectively control target pests while showing no adverse effects on people, the environment, and non-target wildlife like fish and bees. Spear® should provide growers with a new pest management tool that also lessens environmental impacts.

Summary of Technology: Insecticide development faces many inherent challenges: for example, insecticides must be toxic to pests without major toxicity toward other organisms and must be persistent enough to protect crops in fields while remaining environmentally benign. Insects can develop resistance to insecticides, requiring continuing development of insecticides with new modes of action, and insecticides are traditionally produced from non-renewable feedstocks, further increasing their environmental impact.

Vestaron Corporation's Spear® pesticide is a novel peptide insecticide, based on a peptide found in the venom of the Blue Mountains funnel-web spider that acts against the nicotinic acetylcholine receptor. The Spear® peptide is produced by yeast fermentation whose primary input is a commodity sugar derived from corn. The Spear® peptide is selective for action ion channels in targeted species of insects, while showing no activity against mammalian or non-target invertebrate ion channels, and shows

SUMMARY OF AWARD-WINNING TECHNOLOGIES

minimal to no toxicity toward humans and environmental targets such as bees and fish. Spear® has been approved with a zero-day pre-harvest interval and four-hour re-entry time, demonstrating its low potential for harm toward handlers, consumers, and workers. Because Spear® is peptide-based, it biodegrades into nontoxic amino acids.

Spear® has shown comparable or better crop protection compared to current synthetic chemical pesticides. Insecticides targeting the nicotinic acetylcholine receptor account for approximately 30 percent of the global insecticide market, and existing insecticides in this market (neonicotinoids) are controversial due to possible environmental impacts such as possible toxicity to bees. Vestaron anticipates sales of $6 to 9 million in 2020 and should provide growers with a new tool for difficult-to-manage pests as well as a means to lessen their environmental impact.

Academic Category

Professor Steven Skerlos (University of Michigan and Fusion Coolant Systems)

Pure-Cut

Professor Steven Skerlos, of the University of Michigan and Fusion Coolant Systems, is being recognized for creating Pure-Cut™, an alternative to traditional metalworking fluids that uses high pressure carbon dioxide (CO_2) instead of oil-based lubricants. Pure-Cut™ can improve performance and machining tool lifespan compared to traditional metalworking fluids, while greatly reducing hazards to the environment and worker health.

Summary of Technology: Traditional metalworking fluids used for lubrication and cooling during metalworking are most commonly aqueous emulsions, which often employ hazardous additives such as surfactants and biocides that can be hazardous to workers and the environment. Even non-hazardous metalworking fluids can dissolve heavy metals during use, making the used fluid hazardous and difficult and costly to dispose of safely. Additionally, metalworking fluids often require expensive treatment to reduce biological oxygen demand, oil contamination, and nitrogen and phosphorus content. If not properly treated, used metalworking fluids can be harmful to aquatic ecosystems, for example by reducing the amount of oxygen available to some aquatic life forms.

Pure-Cut™ uses supercritical CO_2, a physical state of CO_2 that is between a liquid and a gas and is produced by pressurizing CO_2 to high pressure. CO_2 is a common byproduct of industrial processes such as combustion, fermentation, and reactions, and this waste CO_2 can be used to produce supercritical CO_2. Pure-Cut™ is a drop-in technology that replaces traditional metalworking fluids, using little or no oil lubricant, and can be used on most existing machine tools. The system completely eliminates most of the hazard and toxicity concerns associated with traditional metalworking fluids. Pure-Cut™

serves as a coolant as well as a lubricant because CO_2 cools as pressure in the system decreases. Compared to traditional metalworking fluids, Pure-Cut™ can improve tool life and cleanliness of parts, which can reduce waste and save money for facilities adopting Pure-Cut™. The system can be adjusted to meet the needs of each process, such as by increasing pressure to increase oil solubility and cooling. Testing indicates that Pure-Cut™ performs as well as or better than other metalworking fluids across many metrics, including lubrication and cooling as well as environmental health and safety.

Pure-Cut™ was created at the University of Michigan, and Fusion Coolant Systems was launched to commercialize the technology. Manufacturers have begun to adopt Pure-Cut™ in several industries including the aerospace and medical device industries, wherever performance and cleanliness of metalworking fluids are critical.



Green Chemistry Challenge Awards Ceremony

See the full list of Green Chemistry Challenge Award winners, visit www.epa.gov/greenchemistry