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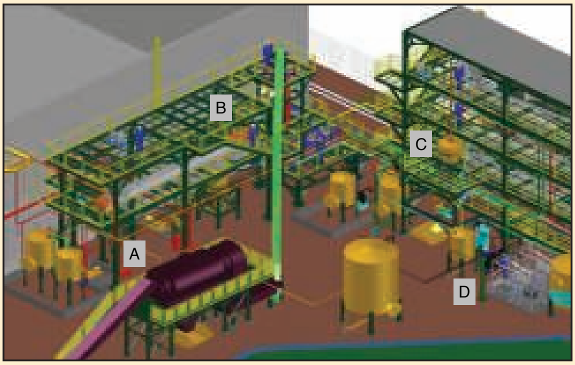
CHEMENTATOR

Edited by Gerald Ondrey September 2014

Demonstration plants for biomass-to-sugar technology under construction

Edeniq Inc. (Visalia, Calif.; www.edeniq.com) announced progress in building demonstration facilities in Brazil and China that feature the company's proprietary process for converting cellulosic biomass into industrial sugar for fermentation or catalytic conversion (diagram).



A. Pre-processing B. Pre-treatment C. Saccharification D. Separations and product recovery

In Brazil's São Paulo state, Edeniq is partnering with Usina Vale to build a 10-ton/d demonstration plant that will bolt onto an existing sugarcane-to-bioethanol production facility, allowing it to increase ethanol production by utilizing waste biomass. Meanwhile, in Jilin province, China, Edeniq is partnering with Global Bio-chem Group (Hong Kong, China) to build a commercial demonstration facility that will eventually produce 50,000 metric tons (m.t.) per year of sugar from corn stover at an attractive transfer price, the company says.

Both facilities feature Edeniq's patented continuous biomass-pretreatment technology, which hydrates the biomass, and mechanically grinds and mills the material. They also feature a closely integrated continuous saccharification process that depends on a proprietary reactor design to reduce residence times and increase enzyme-hydrolysis efficiency.

Among three types of mechanical shearing equipment deployed in the process, Edeniq's pre-treatment step features the Cellunator, which produces a homogenous, high-density slurry of biomass solids, while reducing average particle size to the several-hundred-micron range, explains Tom Griffin, chief technology officer at Edeniq. The comprehensive shearing and homogenization action gives enzymes enhanced access to biomass particles, which allows higher conversion rates to fermentable sugars. Further, the use of mechanical shearing obviates the need for high temperatures and corrosive chemicals in the pretreatment stage, he adds.

Edeniq has also developed a unique solid-liquid separation process that generates a solids-free sugar solution as a product, which is continually removed. The enzymes, additives and unreacted substrate are continuously recycled in the process. The separation step features a high-throughput tangential-flow filtration (TFF) system that has been customized for biomass. The Edeniq process also includes a step in which solid lignin is captured as a co-product; it can be used as a fuel to heat process boilers, or further developed into a livestock feed component.

Edeniq currently operates pilot facilities at its California headquarters and an Omaha, Neb. based business unit that utilizes the company's technology to enhance ethanol yields from corn. The Brazil plant has begun qualification testing of preprocessing unit operations, with construction completion planned for late 2014. The China plant will be constructed in late 2014, with Edeniq enhancements integrated in stages through 2015.

Mercury removal with modified aluminosilicate clay

The first commercial contract delivery was recently made for an emissions control product that removes mercury from fluegas without the use of activated carbon. The product, known as AS-HgX, is made by Novinda Corp. (Denver, Colo.; www.novinda.com), and will be used in the utility power-generation industry to help users meet limits on mercury emissions.

The product is a departure from the use of activated carbon to adsorb mercury from fluegas, as is done with conventional technology, and offers a host of advantages over the current approach. In power plants where activated carbon is used to remove mercury, the activated carbon often contaminates the flyash, rendering it useless as a replacement for ordinary Portland cement. Using flyash in concrete can reduce carbon emissions considerably and save significant money, notes Jim Butz, vice president of product management at Novinda. Butz further explains that a cradle-to-grave analysis of AS-HgX (manufacturing, transport, and so on) shows that its carbon footprint is one-tenth that of activated carbon. Another advantage of the product over activated carbon is its inertness. It does not present flammability and explosion risks, as activated carbon does.

Starting with an aluminosilicate clay, Novinda has developed a patented formula that infuses a proprietary metal

(*Continues on p. 12*)

CO_2-to-syngas . . .

Scientists from the University of Illinois at Chicago (www.uic.edu) have developed a catalytic system — molybdenum disulfide and an ionic liquid — to convert CO_2 into synthesis gas, (syngas; a mixture of CO and H_2 that is used for making liquid fuels and chemicals, such as methanol). Unlike alternative CO_2-reduction processes, which only generate CO, the new catalyst system enables the production of syngas directly. The catalyst is also said to be less expensive

(*Continues on p. 12*)

Note: For more information, circle the 3-digit number on p. 76, or use the website designation.

This process realizes large costs savings for manufacturing silicon wafers

Crystal Solar Inc. (Santa Clara, Calif.; www.xstalsolar.com) is preparing for high-volume production of silicon wafers using a process that forms the wafers directly from trichlorosilane (TCS) gas using a chemical vapor deposition (CVD) epitaxy process that can significantly lower the manufacturing costs for solar photovoltaic cells.

By eliminating several steps used in the traditional solar-wafer manufacturing process, including melting down polysilicon pieces, formation of a monocrystalline silicon ingot and slicing the wafers, Crystal Solar's "Direct-to-Wafer" technology allows for a 50% reduction in the wafer's production cost, which represents almost half of the cost of the final solar cell.

"Epitaxy has been well known for silicon production in the past," says T.S. Ravi, Crystal Solar co-founder and CEO, but the approach has not been economical for use in solar cell applications because growing the silicon layer has been too slow, and conversion rates from TCS to solid Si have been too low. "The key for us was to find good solutions to the problems of how can you grow the wafers faster and how can you achieve higher conversion rates?" Ravi says.

By using a vertical reactor concept, the company has been able to achieve 40% conversion rates of TCS to silicon, with the ability to make several hundred wafers at a time at atmospheric pressure. The reactor combines solar-grade TCS gas with hydrogen to deposit monocrystalline silicon on top of a porous silicon release layer.

Capital costs associated with this production method are said to be half what is required for traditional polysilicon plants. Another advantage of the Crystal Solar method is its amenability toward automation, Ravi notes. The technology was developed in part as a component of a National Renewable Energy Laboratory (Golden, Colo.; www.nrel.gov) program, and has garnered an R&D 100 award in 2014.

Crystal Solar has been making wafers in a pilot phase, and generating positive feedback in tests with cell manufacturers, Ravi says, and the company is gearing up to add capacity now.

This portable device measures Hg^{+2} in water samples

An ultra-sensitive, low-cost and portable system for detecting mercury in water has been developed by University of Adelaide (Australia; www.adelaide.edu.au) researchers, in collaboration with the Universitat Rovira i Virgili (Tarragona, Catalonia, Spain; www.urv.cat).

Project leader Abel Santos, of the Adelaide's School of Chemical Engineering, says there are systems capable of monitoring mercury at trace levels, but they are huge, expensive machines and are complicated to use. Also, samples require chemical treatment before analysis in such instruments. "Our system, on the other hand, is very cost-competitive, only as big as a mobile phone and easy to use," he says.

The researchers have engineered a nanoporous material, called nanoporous anodic alumina, to make a special structure called a rugate filter. The surface of the filter has been modified to make it selective to mercury ions. As water flows through the pores, the mercury ions become attached to the surface. Reflection spectroscopy measures the amount of mercury present.

The system has a linear working range from 1 to 100 µM of Hg^{+2}. Its low limit of detection is 1 µM of Hg^{+2} ions. Tests were successfully carried out at the River Torrens, demonstrating the suitability of the system for developing environmental point-of-analysis systems. The system also proved to be highly selective in a complex mixture of other metals and environmental samples.

MERCURY REMOVAL (*Continued from p. 11*)

sulfide material into the clay particles. After blending and milling processes, the AS-HgX product can be injected into fluegas streams, where it reacts with mercury to form mercuric sulfide, a very stable and insoluble compound, notes Butz. By altering the structure of the metal sulfide and the manufacturing process, Novinda can make related products using the same product platform. Novinda has partnered with several manufacturers of injection systems that work well because the dispersal of the material in the fluegas is a key factor in the product's effectiveness.

Novinda's product has been tested in full-scale coal power plants burning several types of coal in various locations, and has shown the ability to remove over 90% of mercury present in plant fluegas, Butz says. He adds that the tests suggested that AS-HgX is particularly effective in plants that use dry scrubbing to remove SO_2. In the future, AS-HgX may also be applied for mercury removal in fluegas from industrial boilers and cement kilns.

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than alternative reduction catalysts that are based on gold or silver. The results are described in the July 30 issue of *Nature Communications.*

. . . and CO_2-to-methanol

Meanwhile, a new catalytic system that directly converts CO_2 into methanol has been developed by scientists at the U.S. Dept. of Energy's Brookhaven National Laboratory (Upton, N.Y.; www.bnl.gov), in collaboration with researchers from the University of Seville (Spain; www.us.es) and the Central University of Venezuela (Caracas; www.ucv.ve). The catalyst is composed of copper and cerium oxide (ceria) nanoparticles.

The research team found that the interface of the two types of nanoparticles is critical to the reactivity of the catalyst system. Laboratory studies showed that the catalyst converts CO_2 to methanol more than 1,000 times faster than plain copper particles, and almost 90 times faster than a common copper/zinc-oxide catalyst currently used industrially. The results are described in the August 1, 2014 issue of *Science*.