Nanofarming oil from algae

ALGAE IS WIDELY TOUTED AS ONE OF THE NEXT BEST SOURCES FOR fueling the world's energy needs. But one of the greatest challenges in creating biofuels from algae is how to economically extract and isolate fuel-related chemicals from algae. Also, the current methods for extracting the oil from algae kill the organisms, dramatically raising production costs. Now researchers at Ames Laboratory and Iowa State University have developed groundbreaking "nanofarming" technology that safely harvests oil from the algae so the pond-based "crop" can keep on producing.

The so-called "nanofarming" technology uses sponge-like nanoparticles to extract oil from the algae. The process doesn't harm the algae like other methods being developed, which helps reduce both production costs and the production cycle. Once the algal oil is extracted, a separate and proven solid catalyst from Catilin, Inc., a nanotechnology-based company that specializes in biofuel production, will be used to produce certified biodiesel.

Victor Lin's research group is growing several strains of algae in the laboratory and testing how the organisms respond to introduction of the nanoparticles.

The three-year project is being funded with $885,000 from the DOE Office of Energy Efficiency and Renewable Energy's Industrial Technology Program as part of the 2008 Nanomanufacturing for Energy Efficiency program, $216,000 from Catilin and $16,000 from Iowa State University in matching funds. Phases one and two of the project will cover the culturing and selection of microalgae as well as the development of the specific nanoparticle-based extraction and catalyst technologies for the removal of algal oil and the production of biodiesel, respectively. Phase three will focus on scale-up of the catalyst and pilot plant testing on conversion to biodiesel.

The driving force behind this combination of nanotechnology and biofuels is Ames Laboratory Chemical and Biological Sciences Program Director Victor Lin. Since 2000, Lin, who is also a chemistry professor at Iowa State University, has been leading research on using nanotechnology to dramatically change the production process of biodiesel. This successful technology led Lin to found Catilin one and a half years ago.

Converting syngas to ethanol

ETHANOL PRODUCTION IN THIS COUNTRY IS EXPECTED TO EXCEED 10 billion gallons in 2009, representing about nine percent of the nation's gasoline supply. Nearly all of that fuel is produced through the fermentation of biomass, with corn a leading feedstock. But if grain could be replaced with more sustainable biomass like corn stover from the field, grass, wood pulp or even waste materials, ethanol could see even greater use as a green fuel.

Ames Laboratory chemist Victor Lin is working to do just that by pairing high-tech nanoscale porous catalysts with gasification, a technology that turns carbon-based feedstocks, under high temperature and pressure in an oxygen-controlled atmosphere, into synthesis gas. Lin's group is collaborating with engineers at Iowa State University's Center for Sustainable Environmental Technology, a leader in producing high-quality syngas from biomass.

Syngas is made up primarily of carbon monoxide and hydrogen (more than 85 percent by volume) and smaller quantities of carbon dioxide and methane. In studying the chemical reactions in syngas conversion, Lin found that the carbon monoxide molecules that yielded ethanol could be "activated" in the presence of a catalyst with a unique structural feature.

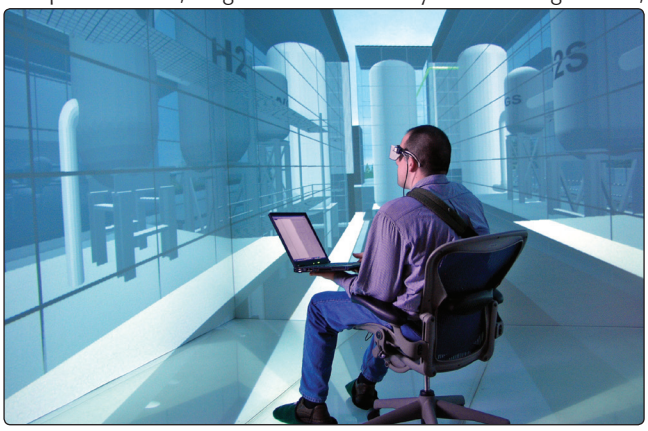
To maximize the surface area of this catalyst to promote the conversion reaction, Lin developed nanoscale catalyst particles dispersed widely within the structure of mesoporous nanospheres, tiny sponge-like balls with thousands of channels running through them. The total surface area of these dispersed catalyst nanoparticles is roughly 100 times greater than the surface area of the same quantity of catalyst material in larger, macro-scale particles.

Ground corn stover is one of the feedstocks being studied for conversion into syngas, which is then converted into ethanol with the use of nanoscale catalysts.

Visualizing tomorrow's power plants

If a picture is worth a thousand words, a 3-D virtual environment could equal a thousand blueprints. That's the hope of an Ames Lab research effort known as the Virtual Power Plant program. When completed, the project will allow planners to see a 3-D representation of every pipe, wire and bolt they design into a power-generating facility.

That kind of visualization is eons beyond computer-aided design, because instead of seeing their plans displayed on a computer screen, engineers can virtually walk through them,



Using 3-D visualization, engineers can walk inside a virtual power plant design and see and correct problems before the plans leave the drawing board.

simply by stepping inside a 3-D theater, such as the V6 Cube located inside Howe Hall at the Iowa State University College of Engineering. The Virtual Power Plant Program will let engineers spot problems simply by eyeing them. Does a pipe need to be rerouted? If so, engineers can quickly change it using a simple control interface.

Nearby, a supercomputer-like cluster of PCs will redraw the plans. Driving those computers is an open-source program called VE-Suite being developed by Ames Lab Program Director for Simulation, Modeling, and Decision Science Mark Bryden. VE-Suite is more than a rendering program. It can calculate the physics behind a power plant's operation. So when changes get made, engineers can assess how those changes will affect temperatures, pressures and other operational elements of the plant – a fact that meshes exactly with the Virtual Power Plant's overarching goal: building a platform to design the next generation of cleaner, safer and more efficient power plants that come on line faster and cost consumers less. But even that might be just for starters.

"We are working to create an interactive visual engineering environment that can be used to design new products, better power plants, new ships, new tractors, or any other engineered product. I believe this is how we will be doing engineering 10 years from now," Bryden says.

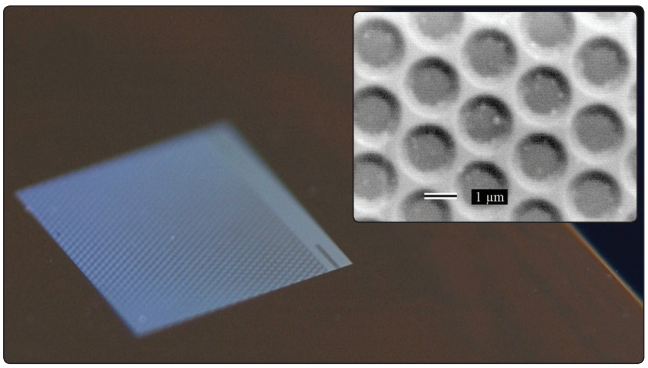
Seeking a brighter solar energy future

On paper, solar energy is a nearly perfect energy source: it's abundant, free, and produces no air or water pollutants. But in practice, solar energy conversion technologies still face cost and efficiency challenges that must be overcome before clean solar energy production can edge out fossil fuel use in the United States.

Ames Laboratory and Iowa State University researchers are collaborating to develop the next generation of solar energy technologies that are highly efficient and can be produced at a fraction of the cost of other solar conversion products on the market today. In the short term, the group plans to create thin-film solar cells from silicon alloys and to develop new solar cell structures using cutting-edge photonic technologies, an area where Ames Laboratory has world-leading expertise. Using such photonic crystal substrates enhances the absorption of red and near infrared photons and increases the current generated by the solar cell.

Theoretically, several photonic crystal designs with submicron periods have demonstrated a boost in solar cell performance. And, based on the designs, the group recently began fabricating amorphous silicon cells that show impressive performance improvements.

"These performance improvements are very cost effective and can be incorporated into manufacturing processes to boost solar cell performance," says Rana Biswas, an Ames Laboratory physicist. "Using alloys and nanocrystalline materials is an area where we can make progress that will help improve solar energy technologies."



An amorphous silicon solar cell incorporating a photonic crystal lattice fabricated to reflect light back into solar cells is shown in the bright square area.

The project brings together Ames Laboratory and ISU researchers in chemistry, physics, electrical and computer engineering and private industry leaders in thin-film solar cells. Ultimately, the research team hopes that their work will help make solar energy more cost-competitive with other forms of energy and help to spur Iowa's economic development in the solar energy sector.