Students Develop New Ways to Produce Renewable Fuels

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There is a frenzied push in the United States to find alternative fuels and to reduce the emission of greenhouse gases. At North Carolina State University, even student researchers have caught the alternative fuels bug. And they've got a provisional patent for one of their innovative techniques.

The students and their faculty mentor in the College of Engineering's Institute for Maintenance Science and Technology (IMST) have developed two new, cost-effective techniques – producing ethanol from wood and other biomass and capturing methane, a greenhouse gas, and converting it into methanol.

Both techniques rely on atmospheric pressure (AP) plasma processing. The AP plasma contains an approximately equal proportion of electrons and ions that respond strongly to electric and magnetic fields. Electron and ion interactions in the plasma generate ultraviolet light, charged particles, and highly reactive atomic and molecular species. By controlling these reactive species, specific chemistries can be produced in the plasma to facilitate the production of various chemical compounds.

Converting biomass to ethanol using AP processing is not easy. The student researchers knew they had to disrupt the biomass structure in order to access the valuable five- and six-carbon sugars that could be converted to ethanol by fermentation. Lignin, which is similar to a glue or binder in the biomass structure, is a significant inhibitor when accessing the sugars. This highly robust polymer surrounds the cellulose and hemicellulose, providing a protective sheath from most chemical and biological degradation processes. Breaking these tough bonds poses a challenge.

Dr. Jerome Cuomo, Distinguished Research Professor of Materials Science and Engineering and director of IMST, says he and his students have experience using AP plasmas to disrupt organic structures such as those found in bugs, so utilizing AP plasmas to degrade biomass was a natural direction for their research.

“We mineralize organic substances, thus converting them to carbon dioxide and water vapor. We can kill bugs, which are organic, and wood is organic, but lignin inhibits the enzymatic process. So our first trial was to put some wood into the AP chamber,” Cuomo said. A few simple tests demonstrated ethanol production in the samples treated in the AP chamber.

After 18 months of research, the team developed a method of disrupting the biomass structure with AP plasma. They call their technique “atmospheric pressure plasma-enhanced soft hydrolysis” and say it is less harsh, more efficient and less energy-intensive than traditional techniques like acid hydrolysis and enzymatic hydrolysis.

The students’ new technique pairs a dilute acid hydrolysis pretreatment with AP plasma and has shown greater than 50 percent improvement in the production of fermentable sugars. The process is significant and could improve the efficiency and cost effectiveness of current hydrolysis techniques. The AP plasma process utilizes a unique power supply, developed by a local start-up company, that is able to produce atmospheric plasmas in air so that continuous processing can be realized and at lower powers for greater process efficiency.

“The AP plasma process cuts the cost of equipment,” said Matthew R. King, a senior geology major. “The process can be run continuously and scaled to meet any process requirements.”

The students presented their findings at the American Vacuum Society 53rd Annual International Symposium in San Francisco in November 2006. NC State's Office of Technology Transfer (OTT) has filed a provisional application for patent for their technique and is now pursuing a non-provisional application for patent. The NC State OTT is also seeking partners interested in commercializing this technology.

In addition to the biomass project, the students are working on another renewable energy project involving the conversion of hog waste into methanol.

In partnership with Orbit Energy Inc., IMST received a Phase I Small Business Technology Transfer (STTR) research grant from the U.S. Department of Energy. Orbit Energy, a local start-up company, provides technologies for converting organic waste into methane and carbon dioxide, two greenhouse gases. The goal of the STTR project is to develop a means of capturing and converting these gases into higher valued organics such as methanol.

Waste materials from hog lagoons, fed into Orbit’s high solids anaerobic digester, produce a ratio of 67 percent methane to 33 percent carbon dioxide, which turns out to be the ideal ratio for making methanol from AP plasma. “We are in our second design of the system,” said W. Patrick Davis, doctoral student in materials science and engineering. “We know how much methane and carbon dioxide we are putting in. We soon will be able to calculate our efficiency in terms of how much we are converting into methanol.” With the help of Dr. H. Henry Lamb, associate professor of chemical and biomolecular engineering, the team will have the ability to identify each chemical produced by this process.

"The key here," said Christopher J. Oldham, doctoral student in materials science, "is that, as a greenhouse gas, methane is 20 times more harmful to the atmosphere than carbon dioxide, and people don't really talk about that. We're taking that methane and making valuable alcohols and chemicals."

"The possibility and potential of this process is to capture and sequester gases emitted from the flues of fossil fuel plants," Cuomo added. "Many people are looking at what AP plasma can do. Why are we different? We have a power supply that can be scaled to very large power levels. … The folks that are working with AP plasma are mainly in laboratories like ours, but our connection is with industry – to take this to a commercial scale. We're sequestering carbon, whether methane or carbon dioxide, and we're seeing signs of carbon compounds that, once fully examined, may have more value than methane and carbon dioxide. We have ambition to do more. Our limitation right now is funding."

The students tackling these renewable energy projects are King; Oldham; Davis; Casey O. Holder, junior in materials science and engineering; Steven M. Disseler, senior in physics; and Kristina N. Marshall, senior in materials science and engineering.

Source: NC State University

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