Molecular matchmaker: Professor develops process, device to aid in sustainable energy practice

Playing the role as a chemical bond matchmaker, Kansas State University’s Mary Rezac, ConocoPhillips professor of sustainable energy and professor of chemical engineering, is improving possibilities for sustainable energy.

Rezac, in collaboration with Peter Pfromm, professor of chemical engineering, and their research groups, is making the conversion of bio-oil to biofuel more efficient by developing membrane contactors. In the new reactor, a membrane, decorated with metal catalyst particles, provides a suitable place for the bio-oil to easily bond with hydrogen.

“Making and breaking chemical bonds is somewhat difficult to do,” Rezac said. “It is easy to write down on paper but it is hard to force the molecules together in a reactor, so we are using membranes to help bring two molecules together.”

The bio-oil is derived from plant material that contains many carbohydrates and has too much oxygen to be used directly as fuel. Instead, the oxygen is removed in a process called hydrotreating, Rezac said. In conventional hydrotreating, pressure is used to force hydrogen into the liquid bio-oil where it chemically reacts and strips away some of the oxygen from the oil, making water as a by-product.

“In this conventional method you need a great deal of hydrogen and the reactor has to be really big,” Rezac said. “There has to be a lot of catalyst for a little bit of oil and it has to be done at very high pressures. Typically it takes 2,000 pounds of pressure per square inch to force the gas down to the catalyst to react with the oxygen.”
The group has been able to reduce the amount of hydrogen and pressure needed by using the membrane to serve as a contact point between the liquid and gas phases. In the membrane contactor, the hydrogen is supplied by diffusion through the membrane while the oil flows past the metal surface. In this way, the hydrogen avoids direct solution in the oil and the subsequent diffusion through it. In the membrane system, the hydrogen is supplied directly to the catalytic site making it readily available for reaction.

“We did an early-stage run with about 30 pounds of pressure per square inch, which is about the same amount of pressure you’d have in your bike tire,” Rezac said. “We’ve demonstrated that we can effectively hydrotreat bio-oil on the small scale. Now we are confirming how to do it on a larger, more continuous scale.”

Once the bio-oil is relieved of its extra oxygen molecules, it is similar to petroleum oil and can go through the same process for final conversion into fuel, Rezac said. The decreased hydrogen dependency should help make the process a more viable option for sustainable energy.

“Hydrogen availability is a very fair concern since we are currently hydrogen poor,” Rezac said. “The membrane is not necessarily going to solve the whole hydrogen deficiency problem — because it’s a big problem — but if we reduce hydrogen demand for this system, then that will make it better.”

As co-director of the university's Center for Sustainable Energy, Rezac is creating partnerships across the university with scientists, agriculturalists, economists and other engineers to further research on improving sustainable energy practices. One of her roles is to facilitate groups of researchers to work together to develop solutions for large problems, such as how to produce energy from biomass in a sustainable manner.

Her matchmaking role continues as she helps potential participants appreciate the benefits they’ll receive if they enter the partnership. The center has been successful in developing several projects, including a multimillion dollar, multiyear project with funding from the National Science Foundation to train students in the interdisciplinary problems associated with the production of sustainable bioenergy. More information can be found at igert.ksu.edu.

Her success in her research would not be possible without the hard work of the many graduate students in her lab. She has mentored more than 30 graduate students who are now employed in a variety of industries from academia to pharmaceutical and petrochemical companies. Training the next generation of chemical engineers is one of her favorite parts of her job.

“I really get excited when my graduate students are successful,” Rezac said. “Maybe more so than when my own research activities are successful, because the impact of what I can do gets multiplied by the successes of the students I work with.”

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