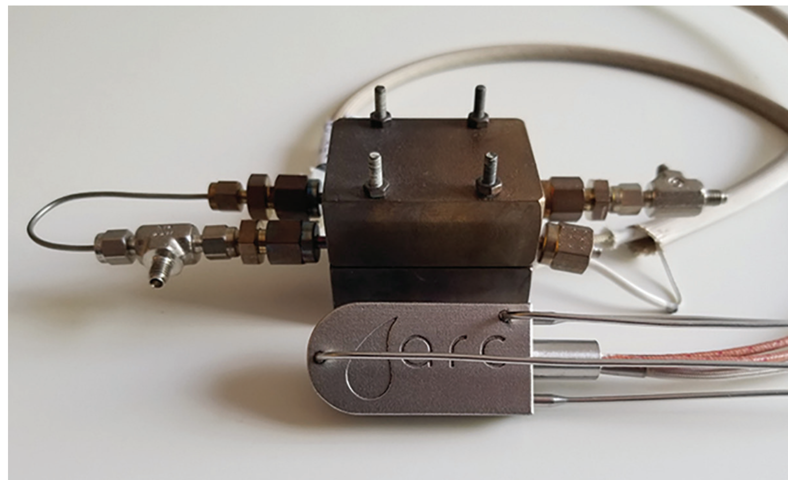
TRANSFORMING CHEMICAL ANALYSIS FOR SCIENCE AND FOR INDUSTRY

Biofuels and industrial chemicals made from renewable resources could help reduce use of the fossil fuels that contribute to climate change. That's one reason why the U.S. Department of Energy's Office of Science funded the Catalysis Center for Energy Innovation, an Energy Frontier Research Center (EFRC). The Center's research focused on new ways to process biofuels and to catalyze chemical reactions that could more efficiently make bio-oils or other products from crops such as corn, sugar cane, or algae.

Sometimes, though, fundamental research generates unexpected and important ideas that lead to valuable technologies, and that's what happened to one of the Center's principal investigators, Paul Dauenhauer of the University of Minnesota. He and his team were studying the products of biofuel processing reactions so they could fine-tune the process to produce more of the desired biofuel products. To do that, however, the

About the image: Algae being decomposed in a bioreactor in preparation for transformation into a biofuel. The decomposition leads to many different types of molecules, which a new analytical tool can help quantify. *(Chokniti Khongchum / Shutterstock)*



Top: Analytical chemistry labs test fuels, industrial chemicals, and ingredients in food or pharmaceuticals to ensure quality, or help to decipher the constituents of an unknown substance. This analysis requires testing multiple samples—such as those shown here—in an automated and standardized manner. *(Cergios / Shutterstock)*

Bottom: The Polyarc micro-reactor—shown here in its current form (foreground) along with an earlier prototype (background)—gives laboratories a novel tool to complement mass spectrometers, gas and liquid chromatographs, and other analytical devices because it can quickly determine the amount of each type of molecule present in a mixture. *(Activated Research Company)*

scientists had to repeatedly analyze mixtures of thousands of different molecules to sort out how much of each molecule was present in the reaction products. With then-available techniques, it was a tedious process, to say the least.

One day Dauenhauer and his team were discussing this challenge over coffee, and it occurred to them that if they could first separate the reaction products by type of molecule and then measure the amount of each type separately in some standardized way, then their work would flow much more easily. So they built a micro-reactor that could first separate the molecules, guiding each type down a separate tiny channel. (Ultimately, 3-D printing was used to construct the micro-channels precisely.) Then each stream of molecules was converted to a standardized form that could be automatically analyzed to measure the amount of carbon present. The result was a reliable, quantitative way to compare the relative amounts of all of the molecular types present in a mixture. The device and the overall analytical process required some fine-tuning, but it worked well.

Realizing that every analytical chemistry lab in the world—in universities and in industry—often faced similar problems, the team launched a startup company, Activated Research, to refine and commercialize the device. The resulting Polyarc micro-reactor is a lab-on-a-chip, about the size of a human thumb (see image). A mixture to be analyzed is fed to a mass spectrometer or a gas chromatograph (standard analytical tools that identify each molecular type present by comparing its signature to a library standard) and simultaneously to the micro-reactor. In the micro-reactor, each separate stream of molecules is first combusted to carbon dioxide, then converted to methane, then measured for the amount of carbon present—all in a few seconds. Comparison of the two data streams gives the amount of each unique molecular type present in a mixture.

The award-winning micro-reactor removes a huge burden for any laboratory responsible for analyzing fuels or industrial chemicals, testing ingredients in foods for purity, or even checking standard chemical mixtures received from suppliers. In effect, it automates a critical part of analytical chemistry, making research and testing more productive and improving the accuracy of routine tests required by health and safety regulations.

More recently, the micro-reactor has been integrated with another standard device, a liquid chromatograph, which can separate and identify the components of liquid mixtures while the micro-reactor measures the amount of each component present. This combination provides a powerful new toolset for molecular biology and the pharmaceutical industry.

None of this was contemplated in the EFRC proposal. But this technology development illustrates the potential of collaborative thinking over coffee—very much what the EFRC program intends to foster.

Catalysis Center for Energy Innovation (CCEI)
Winner — Technologies and Tools Award
www.science.osti.gov/bes/efrc/Centers/CCEI