Streamlined Manufacturing of Biobased Chemicals for Performance Plastics

The success of the plastics industry has created a paradox. Demand for plastics continues to rise, yet there is growing consensus that their environmental burden is unsustainable. According to the Organization for Economic Cooperation and Development (OECD), in 2019, 460 million tons of plastic were produced, resulting in 1.8 billion tons of greenhouse gas emissions and 353 million tons of plastic waste. 22% of the waste was left in uncontrolled dumpsites, burned in open air, or released into the environment. Due to their chemically recalcitrant structures, the vast majority of plastics that end up in the environment are likely to persist for centuries. Environmentally benign alternatives have struggled to capture market share because of inferior performance and high manufacturing costs.

ReSource Chemical, a start-up in Oakland, CA, is commercializing the production of a biobased monomer that offers a possible solution: furan-2,5-dicarboxylic acid (FDCA). Polymers made using FDCA outperform conventional plastics while providing better end-of-use outcomes to avoid accumulation in the environment. ReSource's technology utilizes CO_2 in a novel way to streamline FDCA production, reducing the process complexity that has plagued competing technologies. With support from the U.S. National Science Foundation (NSF), ReSource is scaling its process from the multi-kilogram to multi-ton scale in an integrated pilot plant.

"Our goal is to unlock the plastics of the future — materials that are sustainably sourced, that outperform petrochemical incumbents, and do not cause harm to the environment," says Aanindeeta Banerjee, ReSource cofounder and CEO.

FDCA is a replacement for terephthalic acid, the petrochemical monomer used to make polyesters such as polyethylene terephthalate (PET). The FDCA analog polymer, polyethylene furanoate (PEF), has better gas barrier, thermal, and mechanical properties than PET, enabling higher performance with less material. PEF is fully recyclable and can be mixed with the PET recycling stream, and it has multifold faster degradation rates than PET under industrial composting conditions or if released in the environment.

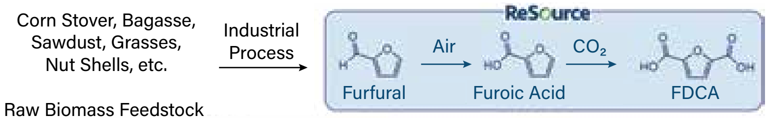
FDCA commercialization has been hampered by manufacturing challenges. Technologies developed over the past 20 years have used glucose from edible biomass as the feedstock. Converting glucose to FDCA requires multiple solvent systems, has moderate yields, and involves challenging purifications. The consequences are high process complexity and costs.

Instead of edible sugar, the feedstock for the ReSource process is furfural, a chemical made from inedible biomass. In ReSource's proprietary chemical process, furfural is first oxidized to furoic acid using air. Then, CO_2 is added to furoic acid to make FDCA using a novel, catalyst-free carboxylation reaction developed by Banerjee and her coworkers during her PhD at Stanford Univ. The only solvent used in the process is water. "Leveraging our core CO_2 utilization chemistry, we're able to reduce the overall process complexity by up to 70%," says Banerjee. The company has validated that its process generates polymer-grade product by providing multi-kg samples to multiple partners and customers.

While ReSource plans to use existing furfural suppliers for its first commercial plant, the ability to produce furfural from diverse biomass inputs provides opportunities to integrate furfural production with FDCA production in future plants. The U.S. currently produces more than 100 million tons of lignocellulosic biomass residues from agriculture and forestry and has the capacity to produce nearly a billion tons. The company sees these untapped resources as a source of low-cost feedstock to produce FDCA on the commodity scale.

Like terephthalic acid, FDCA is a platform chemical that has numerous applications. ReSource is pursuing the use of FDCA in other polymers beyond PEF as well as for specialty chemical markets such as adhesives, nontoxic plasticizers, and components of skincare products. The company is also developing production of other furanic products for chemical and material applications.

Banerjee sees endless possibilities for biobased chemicals. "With simple, scalable process technology, we see rich opportunities to leverage the unique chemical properties of these naturally occurring building blocks to create disruptive chemical and polymer product lines." CEP



▲ ReSource's chemical process converts furfural into furoic acid using air as the oxidant and produces furan-2,5-dicarboxylic acid (FDCA) using a C-H carboxylation reaction.

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