Sifting the Garbage for a Green Polymer

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Published: June 19, 2007

Carbon dioxide. Orange peels. Chicken feathers. Olive oil. Potato peels. E. coli bacteria. It is as if chemists have gone Dumpster diving in their hunt to make biodegradable, sustainable and renewable plastics. Most bioplastics are made from plants like corn, soy, sugar cane and switch grass, but scientists have recently turned to trash in an effort to make so-called green polymers, essentially plastics from garbage.

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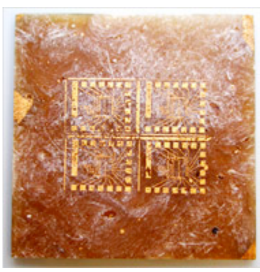

Dawn Marie Fiore/University of Delaware

REUSE, RECYCLE A circuit board, made from a polymer consisting partly of chicken feathers.

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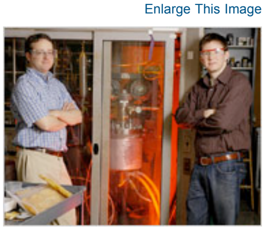

Kevin Rivoli for The New York Times

Geoff Coates, left, and Scott Allen, with the polymer reactor at Cornell, have started a company to develop bioplastics.

Geoff Coates, a chemist at Cornell, one of the leaders in the creation of green polymers, pointed to a golden brown square of plastic in a drying chamber.

"It kind of looks like focaccia baking, doesn't it?" Dr. Coates said. "That's almost 50 percent carbon dioxide by weight."

Dr. Coates's laboratories occupy almost the entire fifth floor of the Spencer T. Olin Laboratory at Cornell, and have a view not only of Cayuga Lake and the hills surrounding Cornell, but of a coal power plant that has served as a kind of inspiration. It was here that Dr. Coates discovered the catalyst needed to turn CO_2 into a polymer.

With Scott Allen, a former graduate student, Dr. Coates has started a company called Novomer, which has partnered with several companies, including Kodak, on joint projects. Novomer has received money from the Department of Energy, New York State and the National Science Foundation. Dr. Coates imagines CO_2 being diverted from factory emissions into an adjacent facility and turned into plastic.

The search for biocomposite materials dates from 1913, when both a French and a British scientist filed for patents on soy-based plastic.

"There was intense competition between agricultural and petrochemical industries to win the market on polymers," said Bernard Tao, a professor of agricultural and biological engineering at Purdue. Much of the early research on bioplastics was supported by Henry Ford, who believed strongly in the potential of the soybean. One famous 1941 photo shows Ford swinging an ax head into the rear of a car to demonstrate the strength of the soy-based biocomposite used to make the auto body. But soy quickly lost out to petrochemical plastics.

"In those days you had a lot more oil around, and you could dig it up all year round," Dr. Tao said. "You didn't have to wait until the growing season."

And there was another problem: permeability. The soy plastic was not waterproof. "Petroleum is biologically and relatively chemically inert, " explained Dr. Tao. "Most living systems require water."

Fossil fuels — inexpensive, abundant and water resistant — quickly dominated the plastics market. Now, agriculture-based plastics are back in the running, and with the type of catalysts developed by Dr. Coates and others, a whole new array of polymers has become commercially viable.

Choosing carbon dioxide as a feedstock for a polymer was not an obvious choice. It was what Dr. Coates called "a dead molecule."

"CO_2 has almost no reactivity," he said, "and that's why it's used in fire extinguishers." So what made him choose carbon dioxide? "It's highly abundant and really cheap. We picked it for environmental and economic reasons, not for its reactivity."

Mix carbon dioxide with an epoxide, he explained, "and the two would just stare at each other for a hundred years." This despite the fact that epoxides are the base derivative for sticky epoxy resins and glues. The key is in finding the right catalyst to open a pathway for the carbon dioxide and the epoxide to bond.

"Catalysts are like a matchmaker who make a marriage and then can go off and make other marriages, Dr. Coates said. "They accelerate a reaction without being consumed by that reaction." His catalyst — beta-diiminate zinc acetate, or "zinc-based pixie dust," in Dr. Coates's words — was designed to speed "a reaction from a geological time scale to the laboratory time scale."

Dr. Coates is creative with these matchmakers, having developed a catalyst to turn orange peels into a type of Styrofoam.

At a meeting of the American Chemical Society in Boston this summer, Dr. Coates will be co-chairman of a symposium on sustainability, "Polymers from Renewable Resources." One of the speakers is Richard Wool, a University of Delaware chemist who works with a material even less glamorous than orange peels: chicken feathers.

Professor Wool and his graduate students designed a composite made from soybeans and the down of chicken feathers — two agricultural products in abundance in Delaware — as an exhibition for the state fair. After seeing the composite, a Tyson Foods engineer approached Professor Wool, offered him two billion pounds of chicken feathers, and an unlikely partnership was born. Despite the madcap premise, Professor Wool used the material to design a circuit board he said is a lighter, stronger, cheaper product with high-speed electronic properties. In short, the feathers allow extra air flow and do not expand like plastic when heated, so the hotter temperatures that come with higher speeds are less problematic.

Professor Wool is also working with olive oil and other high-oleic oils to create rubber, paint and what he calls biocompatible adhesives; he envisions making bandages that would work more like skin.

His prototypes have been shown at the London Science Museum, and the federal Department of Agriculture has given him a half-million dollars to support his research. Recently, his company, Cara Plastics, started working with DynaChem to mass produce his soy-based resin.

Green polymer businesses seem to be springing up everywhere. Rodenburg BioPolymers, a Dutch company, makes plastic from potato waste. Metabolix, based in Boston, grows a natural form of polyester inside genetically modified E. coli bacteria.

Dr. Tao, of Purdue, said history was repeating itself, in a way. "Its almost like we're seeing the same competition over who will dominate the plastic market as we did a hundred years ago," he said. "But this time it is a very different race."

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