New patent for bio-based polymer to be used in piezoelectric devices

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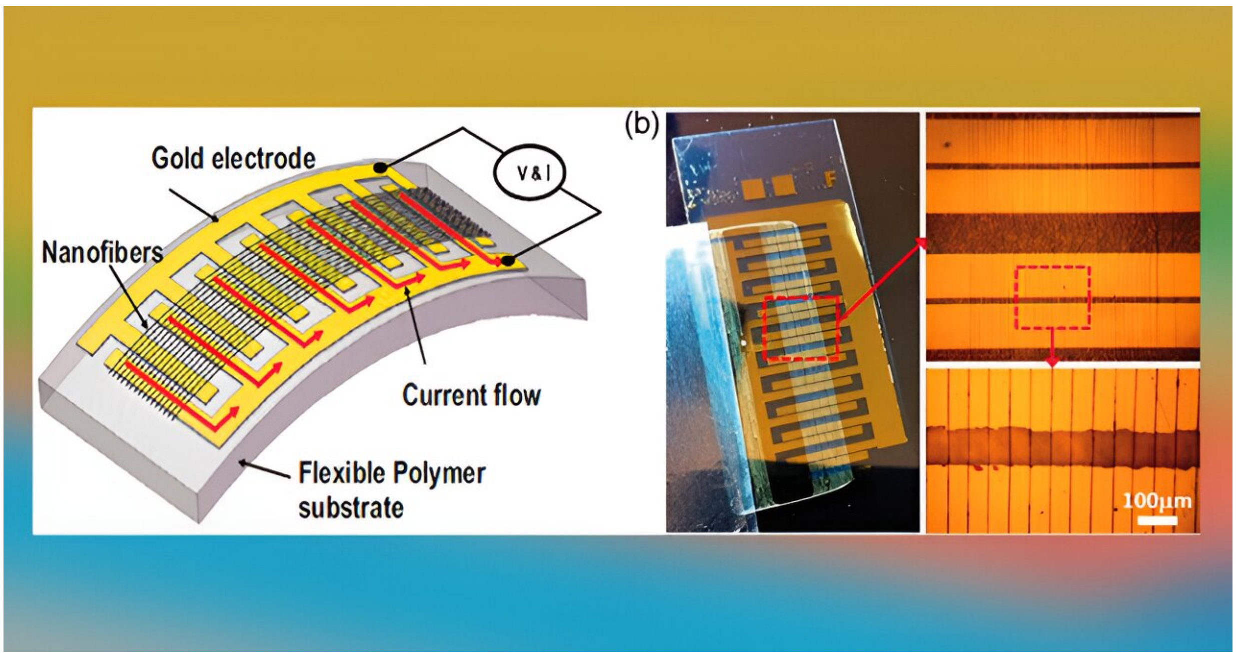


A schematic (left) and photograph (right) of an organic piezoelectric material, demonstrating how these materials can be used to guide the flow of electric current. Credit: University of Delaware

UD engineers are the lead inventors on a new patent for making piezoelectric devices, such as sensors and actuators, using Nodax, a biodegradable, bio-based polymer.

Every year, more than 400 million tons of plastic are manufactured, including single-use items such as shopping bags and drinking cups. Because these materials can reach the environment without degrading for a long time, researchers and companies are looking for materials that offer similar physical properties as conventional plastics but will quickly biodegrade and won't cause harm to plants and animals.

A polymer invented, designed, and chemically synthesized by Isao Noda, an affiliated professor with the Department of Materials Science and Engineering in UD's College of Engineering, is one such alternative material that is bio-based and biodegradable. Enabled by an ongoing collaboration with John Rabolt, the Karl W. and Renate Böer Professor in Materials Science and Engineering, this polymer was found to have surprisingly high piezoelectric properties, meaning that it's capable of producing electricity when bent or deformed.

Now, the UD-based research team has been awarded a U.S. patent for the use of this innovative material to produce piezoelectric devices. Along with patents already awarded in several other countries, this achievement paves the way for a wide range of potential applications and commercialization opportunities.

Making naturally occurring polymers at industrial scale

While working as an industrial scientist at Procter & Gamble, Noda was tasked with finding a new type of biodegradable material for disposable diapers and packages. He started looking into a class of polymers called polyhydroxyalkanoates (PHAs), a type of naturally occurring polyester made by bacteria and other microorganisms and plants.

The problem, Noda explained, was that the PHAs that were known at the time were too hard and brittle to be useful in most practical applications.

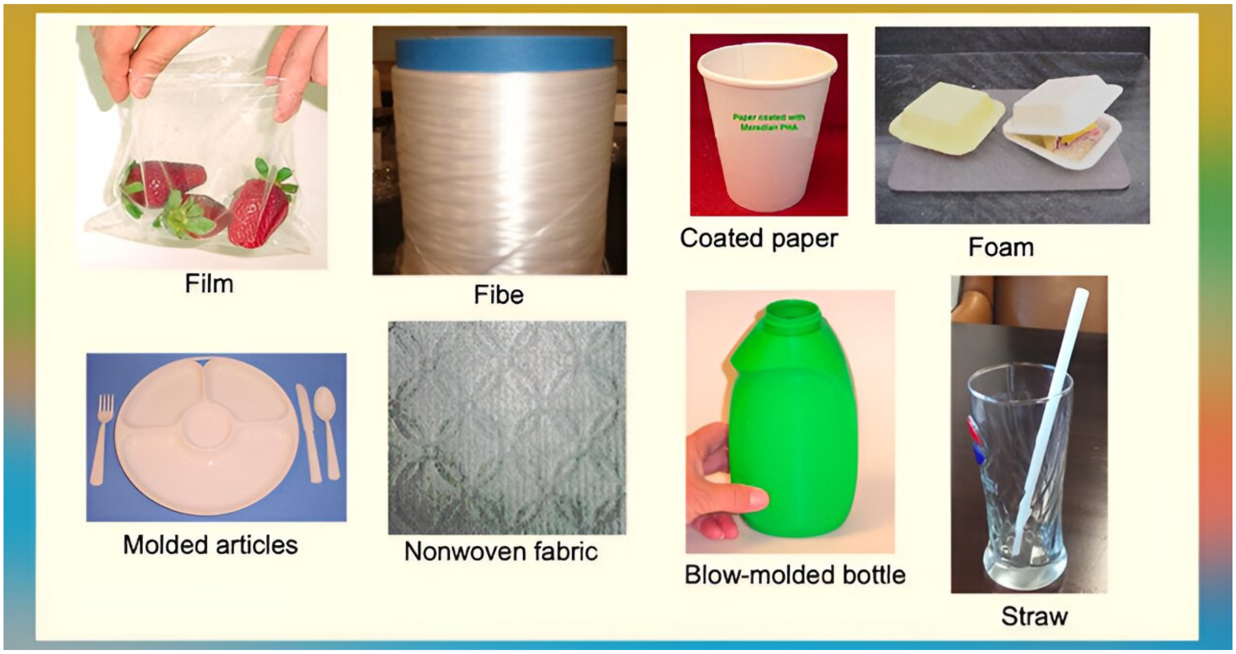
"I was doing a lot of spectroscopic characterization, and realized that we should be able to find bacteria that could modify PHAs' molecular structure in a particular way," explained Noda, referring to the chain length of the polymer's alkyl side group.

"These branches can be methyl or ethyl, which cannot easily be melted or processed. But, when you extend this branch to three carbons, i.e., propyl, or even longer, suddenly the material is able to be more easily processed and becomes a ductile, tough, and useful polymer."

This biodegradable polymer, with the trade name Nodax, is manufactured today at industrial scale by Danimer Scientific, a biotechnology company focused on creating sustainable alternative materials to replace conventional plastics. UD also has an ongoing partnership with Danimer, who supported the recent patent application efforts.

In contrast to how standard plastics are fabricated, Nodax is made in large tanks by bacteria using plant-based feedstocks. The formulated Nodax polymers are then purchased by other companies to make a variety of end use products, with biodegradation rates similar to that of cellulose or food waste.

"Danimer Scientific has pioneered the commercial production of naturally occurring PHAs, offering renewable and fully certified biodegradable and compostable materials for many different food service and packaging applications, such as straws, cutlery, paper coatings, coffee pods and flexible films," said Keith A. Edwards, vice president of business development at Danimer.



Nodax polymers are used to make a variety of end use products, with biodegradation rates similar to that of cellulose or food waste. Credit: University of Delaware

Discovering new properties through fundamental research

But the work didn't stop once Nodax biopolymers were being produced at scale. After giving an invited talk at UD in 2012, Noda met with long-time colleague Rabolt and decided to transfer some of the material he'd accumulated over the years to support new avenues of fundamental research. Noda, who also served as the Danimer Scientific senior vice president from 2013 until 2019 and still sits on its Board of Directors, joined UD as an affiliated faculty member in 2012.

With efforts led by Ph.D. alumni Liang Gong (now at 3M), Brian Sobieski (now at FXI), Changhao Liu (now at A123 systems), and materials science and engineering research professor Bruce Chase, in addition to Noda and Rabolt, the UD-based research team discovered even more unique properties of PHAs. This included the discovery that one of the material's forms was highly piezoelectric, meaning that it holds an electrical charge after a mechanical force is applied.

"It was a great collaboration—we had chemists, rheologists, physicists, the right mix of skillsets to be able to understand and do different things with this unique material," said Rabolt.

This finding led UD's Office of Economic Innovation and Partnerships (OEIP) to apply for a patent using Nodax as a biodegradable polymer to make piezoelectric devices in 2019; that patent was allowed and issued earlier this year, with named inventors including Chase, Noda and Rabolt.

"It's exciting to see the results of this collaboration between the University of Delaware and Danimer Scientific, which has the potential to spark a chain reaction of benefits," said Julius Korley, associate vice president of OEIP.

"As companies incorporate Nodax into devices useful to the public, patent royalties will come back to the University to reward our inventors and to further the investment in research and innovation, with our students learning to become innovators along the way."

Unlocking the potential of a new piezoelectric polymer

The finding that Nodax has high piezoelectric properties means that it could potentially be used in sensors or actuators. Nodax could also serve as a possible replacement for polyvinylidene fluoride (PVDF), a common piezoelectric material that is made from per- and polyfluoroalkyl substances (PFAS), a class of "forever chemicals" that have been linked to negative health outcomes.

While this material is still in the early developmental stages, the possibilities for further work, in terms of both fundamental research and potential applications, excites Noda. "We want to discover additional properties that haven't yet been explored, understand how to make the material better and adapt the processing for industrial scales, and overall keep doing fundamental research that will help other companies with their future applications," he said.

"The fun part is just being able to try different things over time—maybe develop the material's ferroelectric or pyroelectric capacity, things like that," added Rabolt. "We're really just at the tip of the iceberg with this new material."

Danimer has already worked with partners to produce textile fibers using Nodax to replace conventional materials such as PET and polypropylene. The opportunity to now expand into piezoelectric fiber applications is an exciting development.

"The future of PHAs as a more perfect polymer in many applications is now, and Danimer is again pioneering new biotechnology solutions with great partners like UD," said Edwards.

Provided by University of Delaware

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