A microbial plastic factory for high-quality green plastic

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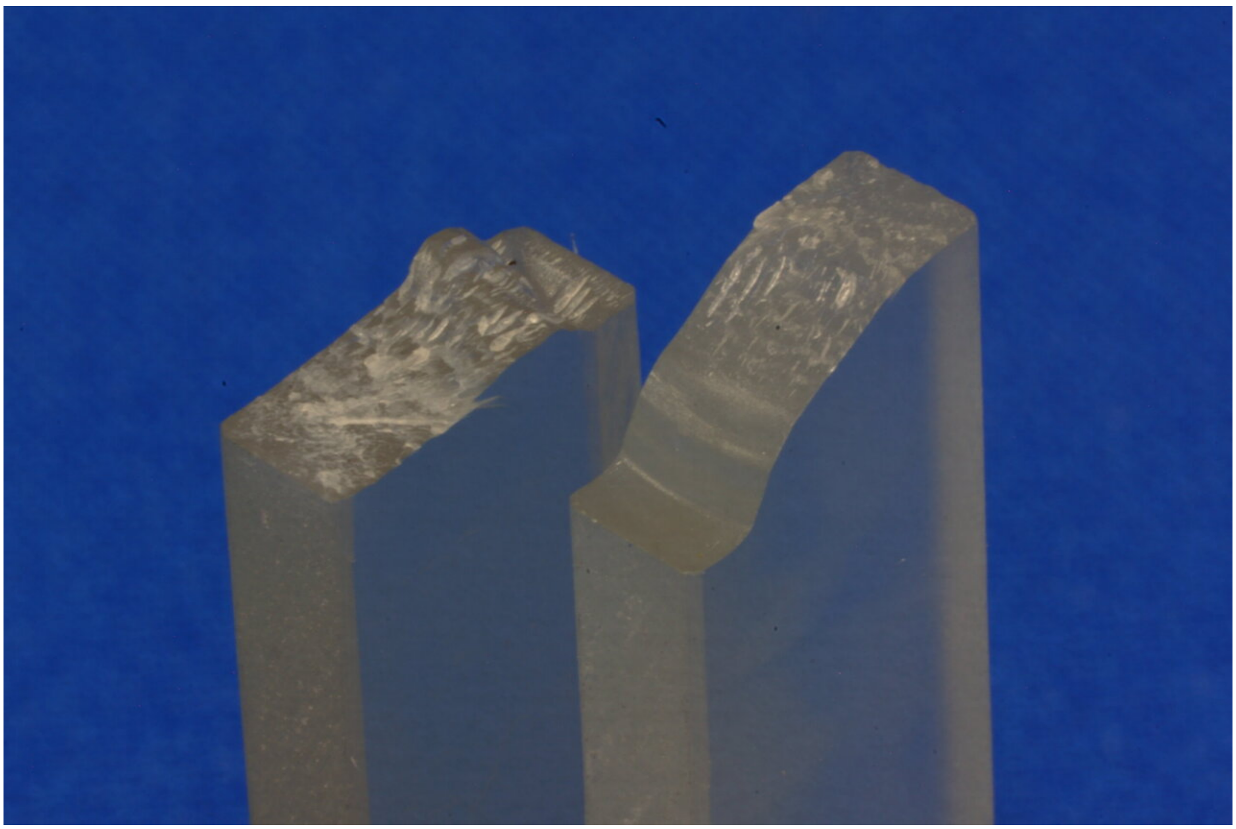


A fractured stick of lactic acid with added ultra-high molecular weight LAHB (left) exhibits obvious white discolorations at the fracture face, which is a sign of plastic deformation in toughened materials. On the other hand, pure polylactic acid (right) does not show such whitening, which is a sign of brittle materials. Credit: Koh Sangho

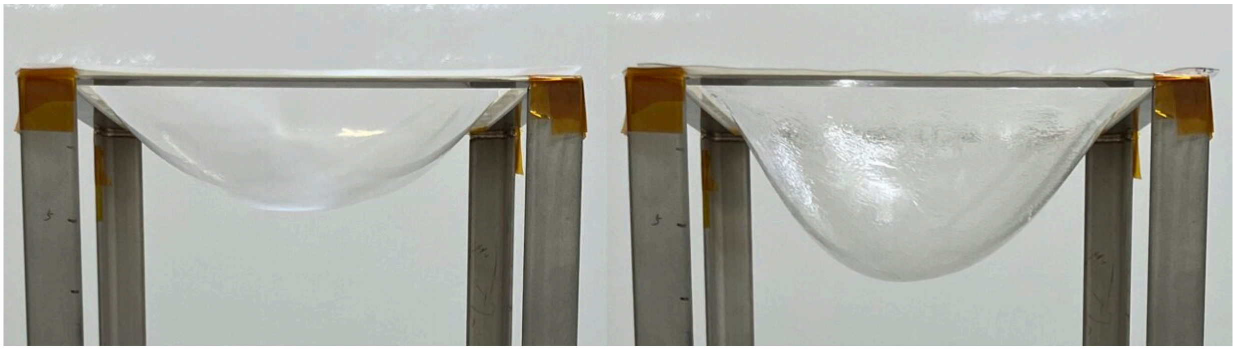
Engineered bacteria can produce a plastic modifier that makes renewably sourced plastic more processable, more fracture-resistant and highly biodegradable even in seawater. The Kobe University development provides a platform for the industrial-scale, tunable production of a material that holds great potential for turning the plastic industry green.

Plastic is a hallmark of our civilization. It is a family of highly formable (hence the name), versatile and durable materials, most of which are also persistent in nature and therefore a significant source of pollution. Moreover, many plastics are produced from crude oil, a non-renewable resource.

Engineers and researchers worldwide are searching for alternatives, but none have been found that exhibit the same advantages as conventional plastics while avoiding their problems. One of the most promising alternatives is polylactic acid, which can be produced from plants, but it is brittle and does not degrade well.

To overcome these difficulties, Kobe University bioengineers working with Taguchi Seiichi, together with the biodegradable polymer manufacturing company Kaneka Corporation, decided to mix polylactic acid with another bioplastic, called LAHB, which has a range of desirable properties.

Most of all, it is biodegradable and mixes well with polylactic acid. However, in order to produce LAHB, they needed to engineer a strain of bacteria that naturally produces a precursor, by systematically manipulating the organism's genome through the addition of new genes and the deletion of interfering ones.

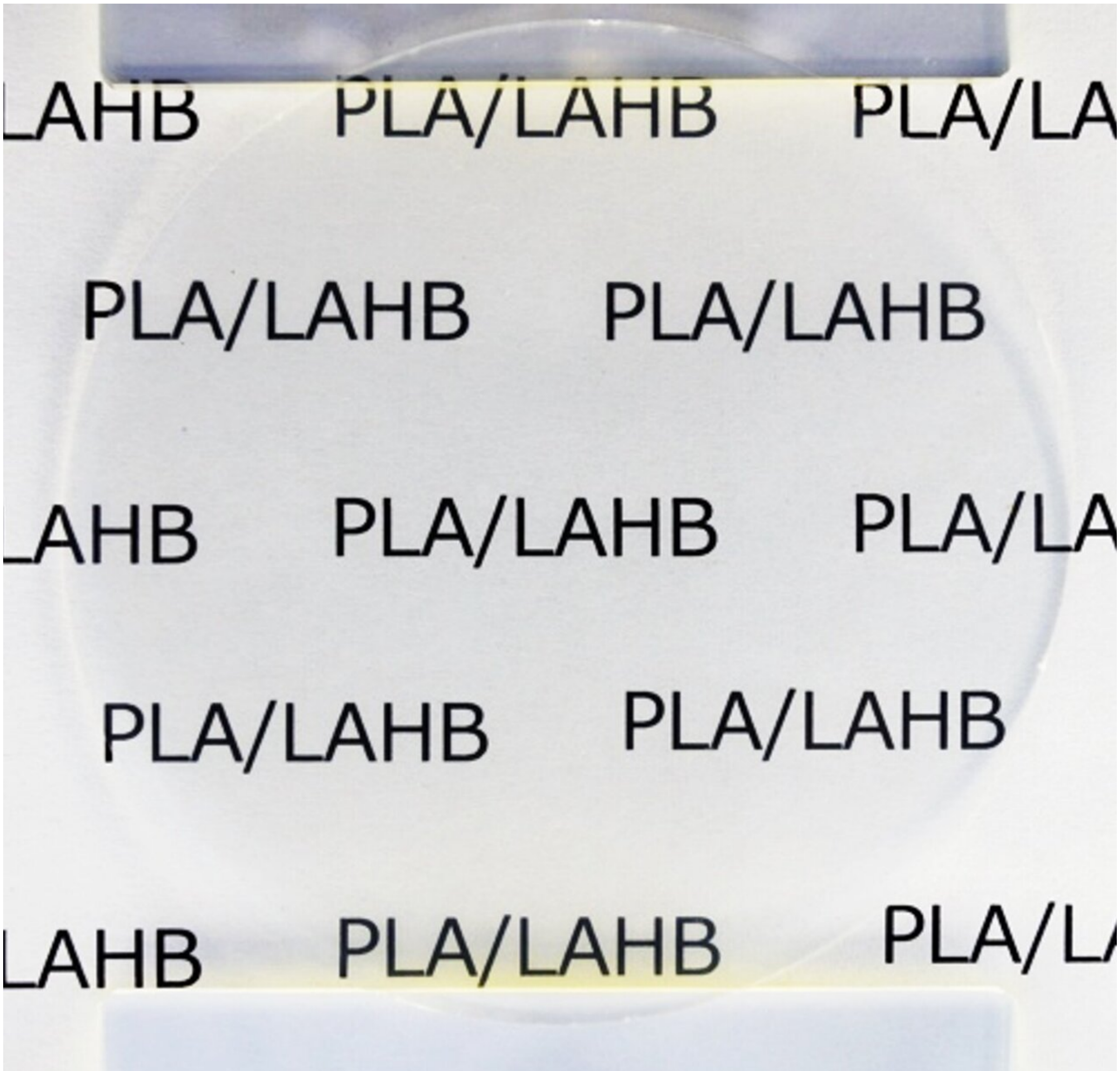


Industrial manufacturing requires a high degree of melt tension, which can be demonstrated by how little a material sags when being warmed up. LAHB-added polylactic acid (left) sags much less than pure polylactic acid (right), proving that it is a better processable material. Credit: Koh Sangho

In the journal *ACS Sustainable Chemistry & Engineering*, the researchers now report that they were able to create a bacterial plastic factory that produces chains of LAHB in high amounts, using just glucose as feedstock. In addition, they also show that by modifying the genome, they could control the length of the LAHB chain and thus the properties of the resulting plastic. They were thus able to produce LAHB chains up to ten times longer than with conventional methods, which they call "ultra-high molecular weight LAHB."

Most importantly, by adding LAHB of this unprecedented length to polylactic acid, the researchers were able to create a material that exhibits all the properties they had aimed for. The resulting highly transparent plastic is much better moldable and more shock resistant than pure polylactic acid, and also biodegrades in seawater within a week.

Taguchi comments on this achievement, saying, "By blending polylactic acid with LAHB, the multiple problems of polylactic acid can be overcome in one fell swoop, and the so modified material is expected to become an environmentally sustainable bioplastic that satisfies the conflicting needs of physical robustness and biodegradability."



The material resulting from adding ultra-high molecular weight LAHB to lactic is a highly transparent plastic: The circular disk is almost invisible in front of a sheet of paper that has "PLA/LAHB" printed on it. Credit: Koh Sangho

The researchers, however, dream bigger. The strain of bacteria they used in this work can in principle use CO_2 as a raw material. It should thus be possible to synthesize useful plastics directly from the greenhouse gas.

Taguchi explains, "Through the synergy of multiple projects, we aim to realize a biomanufacturing technology that effectively links microbial production and material development."

More information: Microbial platform for tailor-made production of biodegradable polylactide modifier: Ultra-high-molecular weight lactate-based polyester LAHB, *ACS Sustainable Chemistry & Engineering* (2024). DOI: 10.1021/acssuschemeng.3c07662

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