Polymer researcher's latest development results in novel cup that withstands boiling liquids

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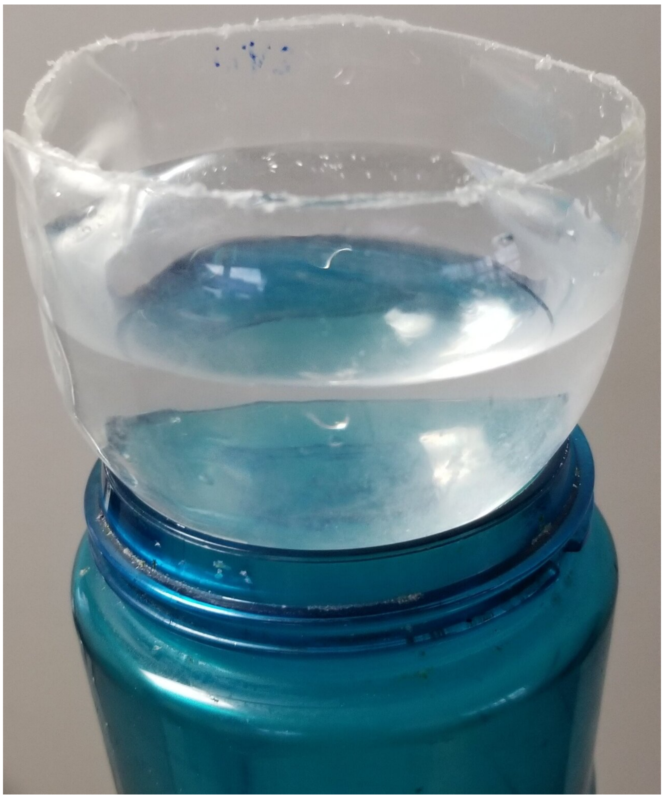

The prototype PLA cup developed by Kumho Polymer Science Professor Shi-Qing Wang, Ph.D., is transparent and super tough, and does not shrink when filled with boiling water. Credit: University of Akron

A University of Akron (UA) professor's latest development in bioplastics has the potential to make important strides in sustainability for future plastics.

In the lab of Dr. Shi-Qing Wang in UA's School of Polymer Science and Polymer Engineering, the team is focusing on research that showcases effective strategies for turning brittle polymers into tough and flexible materials. For example, the group has recently produced a prototype poly(lactic acid) (PLA) cup that is transparent, super tough and does not shrink when filled with boiling water.

"Plastics have become an essential part of our daily lives, though most cannot be recycled and therefore accumulate in landfills," says Wang, who currently serves as the Kumho Polymer Science Professor. "Some promising biodegradable/compostable alternatives, such as PLA, are typically not strong enough to replace traditional fossil-fuel based polymers like poly(ethylene terephthalate) (PET) because these sustainable materials are brittle."

Dr. Ramani Narayan, distinguished professor in Michigan State University's Department of Chemical Engineering and Materials Science, and renowned scientist in the bioplastics space, says Wang's research has the potential to be a breakthrough in the PLA market.

"PLA is the world's foremost 100% biobased and fully compostable polymer," says Narayan. "But it has low toughness and a low heat distortion temperature. It softens and structurally collapses around 140 degrees Fahrenheit, making it unusable in many hot food packing applications and disposable containers. Dr. Wang's research could be disruptive technology because his prototype PLA cup is tough, transparent, and yet rigid to hold boiling water."

Wang, who has taught at UA for 20 years, has been trying to establish a knowledge base for understanding the processing-structure-property relationship for various plastics and applying the latest understanding to deal with the notorious brittleness of PLA.

To explain the science behind how his prototype

PLA cup is able to gain ductility and achieve heat resistance, Wang uses the analogy of cooked spaghetti. If the molten PLA is magnified by a million times, each chainlike molecule would look like a strand of spaghetti, many meters in length. For thermoplastics (including PLA) to be tough, it is important that crystallization does not remove or disrupt the intertwining of "spaghetti strands."

Wang calls this interwoven structure the "chain network." It is through such a structure that anyone can pick up nearly all of the spaghetti strands out of a bowl with a pair of chopsticks. This chain network, when properly manipulated, ensures that the PLA beverage cup is mechanically strong without crystallization. But such a commercial cup collapses when boiling water is poured into it. "Cups made from normally crystallized PLA can hold boiling water but are terribly brittle and opaque," said Wang.

By investigating the origin of ductility in semicrystalline polymers, Wang's research group discovered a way to limit crystals to nanoscopic scales in PLA while preserving the network, resulting in the clear, tough and heat resistant cup. Such a transparent cup can hold hot tea and coffee and could replace most plastic beverage cups on the market.

"The impact of our new understanding could finally stimulate the PLA market to grow exponentially," says Wang.

More information: Masoud Razavi et al. Why Is Crystalline Poly(lactic acid) Brittle at Room Temperature?, *Macromolecules* (2019). DOI: 10.1021/acs.macromol.9b00595

Provided by University of Akron
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