Treeing it up: Research team documents design of wood-based polymers

March 7 2016, by Diane Kukich

A paper in Macromolecules co-authored by the University of Delaware's Thomas H. Epps, III, documents the design of low-cost, high-performance lignin-based polymers.

Richard Wool was a pioneer in green engineering and author of the first book to systematically describe the chemistry and manufacture of bio-based polymers and composites derived from plants.

Although the University of Delaware chemical engineering professor died in 2015, his legacy lives on, not only in the book but also in the inspiration he provided to others.

Thomas H. Epps, III, the Thomas and Kipp Gutshall Associate Professor of Chemical and Biomolecular Engineering at UD, credits Wool with piquing his interest in using trees—specifically, waste from the pulp and paper industry—as a source for new polymers and plastics with "tunable" thermal and flow properties.

Epps, who is also an associate professor of materials science and engineering, along with several co-authors recently demonstrated the design of softwood lignin-based polymers with potential application as alternatives to petroleum-based polystyrene. These softwood materials can be obtained from sources such as pine, cedar, spruce, and cypress trees.

The work is documented in a paper in *Macromolecules*, a journal of the American Chemical Society, that appeared on Feb. 4.

"The two key drivers in the adoption of bio-based materials as replacements for petroleum-derived polymers are cost and properties," Epps says. "The cost of the bio-based alternatives has to be the same or less, and the properties have to be the same or better."

Waste from the pulp and paper business definitely ticks the cost box—the industry is eager to get rid of this plentiful waste product.

Softwood lignin-based polymers also come up big in terms of properties, exhibiting excellent glass transition temperatures and desirable thermal stabilities.

This means that the materials hit a "sweet spot" similar to that of polystyrene, with use temperatures that are not too low (that is, useable for boiling water and lower pressure steam applications) and processing temperatures that are not too high (that is, enabling low-energy materials fabrication and reducing polymer degradation).

The lignin-based polymers developed in the study are components of viscoelastic materials—like Silly Putty, they combine the characteristics of a viscous fluid and an elastic solid, offering some "give" and cushioning while also holding their shape. Such materials have potential use in applications in tires, running shoes, gaskets, seals, and O-rings.

Epps points out that previous efforts to polymerize lignin-based bio-oils have generally employed only one or two chemically distinct monomers. His team discovered that by building multicomponent polymers from mixtures of various bio-based molecules, they could eliminate separation costs while also unlocking the ability to tailor the polymer properties.

"The diversity of molecules that come from trees—not only from different types of trees but even from the same type of tree grown in two different locations—offers the opportunity for a 'mix-and-match' approach to designing low-cost, high-performance bio-based viscoelastic materials tailored to specific uses," Epps says.

About the research

Angela Holmberg, who completed her doctorate in January as a member of the Epps research group, contributed to the research by leading the design and synthesis of a library of monomers from lignin and fatty acids as potentially cost-effective and sustainable building-blocks for thermoplastic elastomers and pressure-sensitive adhesives. Holmberg performed the majority of the experiments for the paper and is the first author on the *Macromolecules* article.

In addition to the late Prof. Wool, Epps credits Wool's former Ph.D. student Joe Stanzione with engaging in initial discussions regarding the utility of lignin-based monomers and polymers. Stanzione, who earned his doctoral degree in 2013, is now an assistant professor in the Henry M. Rowan College of Engineering at Rowan University in New Jersey.

More information: Angela L. Holmberg et al. Softwood Lignin-Based Methacrylate Polymers with Tunable Thermal and Viscoelastic Properties, *Macromolecules* (2016). DOI: 10.1021/acs.macromol.5b02316

Provided by University of Delaware