Producing Non-toxic, High Bio-content Non-isocynate Polyurethanes from Lignin

(2020-026)

Safe, non-toxic polyurethane at both the manufacturing and customer-product level.

Market Overview

Polyurethane foams and plastics are widely used in the furniture, building, life sciences, and automotive markets due to their low-permeability, chemical resistance, and elasticity and toughness. Their production, however, involves numerous toxic additives and substances that pose a significant risk to workers and consumers. Compounds like phosgene and diisocyanates contain multiple health hazards and are classified as "Cancer Causing, Mutagenic and Reproductive Toxins". To combat this, Clemson University inventors have developed a synthesis of polyurethane that replaces the use of toxic compounds. Their protocol makes use of agricultural by-products, such as lignin, and non-toxic organic carbonates. The result is a polyurethane compound containing 100% bio-content. The lignin market in general is estimated at $7.6 billion in 2021, growing at a CAGR of 9.1%. The use of lignin is particularly innovative, given its ability to produce materials of high strength due to its unique chemical structure. Using a high level of biomass in the formulation and developing the conditions for its chemical recycling, this technology enables a sustainable polyurethane in a market dominated by the challenge of persistent plastic waste in the environment.

Technical Summary

The experimental protocol makes use of technical Kraft lignin without depolymerization or fractionation with organic carbonates to functionalize the lignin macromolecular structure with 5-membered cyclocarbonate groups. The technique makes use of glycerol carbonate at 150°C for 1.5 hours with Kraft lignin and a subsequent step using dimethyl carbonate at 75°C for 4 hours to produce cyclocarbonate groups on the backbone of lignin. The curing reaction makes use of a 100% biobased diamine derived from vegetable oil. The addition of curing agent to the cyclocarbonated precursors causes fast gel times enabling the curing and foaming reaction to occur on similar timescales. For the foaming reaction, a unique process developed in our lab called "delayed addition" (DA) makes use of polymethlyhydrosiloxane (PMHS) as foaming agent. The DA approach allows for a time interval before addition of the foaming agent allowing the crosslinking reaction to progress in the NIPU formulation.

Application

Automotive, Packaging, Insulation, Lignin, Sustainable and Biodegradable Plastic, Lightweight Materials

Development Stage

Proof of Concept

Advantages

- Creates reactive molecules from lignin using non-toxic and bio-based reagents
- Addresses the problems of environmental threats without contributing to the global crisis of plastic waster
- Present an entirely new concept of packaging materials using 100% biobased compounds

App Type	Country	Serial No.	Patent No.	CURF Ref. No.	Inventors
Provisional	United States	N/A	N/A	2020-026	Dr. Srikanth Pilla Dr. James Sternberg

About the Inventors

Dr. Srikanth Pilla

Robert Patrick Jenkins endowed Professor at Clemson University

Dr. Pilla earned his doctorate in mechanical engineering from University of Wisconsin-Milwaukee with postdoctoral training from Stanford University. Dr. Pilla's research interests are in the fundamentals and applications of sustainable and lightweight functional materials and manufacturing. Encompassing "Circular Economy" and "Sustainable Engineering" domains, Pilla has created Circular Engineering concept builds on the foundations of "Materials Genome Initiative", and "Hybrid and Intelligent Manufacturing Technologies". Specifically, Pilla's work enables informatics-driven materials and manufacturing discoveries of concepts that DRIVES (Driving Research and Innovation for Value-added Environmental Sustainability) the world on a true sustainable path. His research is supported by NSF, DOE, USDA, DOD, NIH, and NASA, in addition to a number of industries including automotive OEMs, and their suppliers.

Dr. James Sternberg

Dr. Sternberg completed his Ph.D. under Dr. Pilla's instruction where the idea for the sustainable polyurethane was born. Initially trained as a Chemist at Furman University and later at the University of Florida, Dr. Sternberg has continued his work with Dr. Pilla at the Clemson Composites Center as a Post Doctoral Fellow. His work centers on finding new synthetic routes to green plastics that have a molecular design for recycling. His work has been published in scientific journals and is patent-pending for two applications.

For more information on this technology contact:

Andy Bluvas
Technology Commercialization Officer
E: bluvasa@clemson.edu
P: (864) 656-0797