Polyurethane (PU) is an important class of thermoset polymer with a \$70 billion/yr market, providing materials for the construction, transportation, furniture, and packaging industries. PU materials are composed of two main components: an isocyanate and a polyol. Both of these product classes are currently obtained from non-renewable petroleum resources, suggesting that the development of biobased alternatives is of utmost importance for the national goal of net zero carbon emissions by 2050.

Lignin, a major constituent of lignocellulosic biomass, is one of the most abundant natural biopolymers on Earth and is currently produced in large quantities as a byproduct in the pulp and paper industry. As a renewable aromatic macropolyol, lignin is a promising substitute for fossil-derived feedstocks for PU synthesis. A considerable amount of previous work has been performed to develop lignin-based PU. Due to the heterogenous and complex structural properties of lignin, it remains a grand challenge to incorporate a high lignin content into a semi-flexible foam. There is an increasing push in the automotive industry to replace traditional PU foams with bio-derived polyurethane (BPU) foams.

Washington State Univ. (WSU) researchers, part of the NSF-supported Industry-University Cooperative Research Center for Bioplastics and Biocomposites (CB^2), recently developed a novel deep eutectic solvent (DES) extraction process that generates oligomeric lignin at high yield and nanoscale dimensions from plant biomass. These nanolignin oligomers, which the researchers have dubbed nanoDESL, exhibit a narrower molecular size distribution and more controlled structural properties than traditional lignin materials.

The WSU researchers also optimized the oxypropylation of lignin, a process by which an alkyl chain of poly(propylene oxide) is grafted onto the lignin backbone to increase its reactivity and processability. In the past, researchers have tried to use oxypropylated lignin to make PU foams. However, it has been a challenge to maintain the desired flexibility characteristics of the resulting PU foams. In this project, the WSU team discovered that the introduction of polar aprotic solvents to the oxypropylation process, coupled with the appealing features of nanoDESL, significantly promote the oxypropylation reaction toward the synthesis of semi-flexible PU.

The team investigated the feasibility of producing semi-flexible PU foams with oxypropylated nanoDESL. The objective was to replace a significant amount of polyol with lignin while maintaining the key structural and mechanical characteristics of the PU. This lignin-based PU contains ~20 wt% nanoDESL-derived polyol and has a comparable density and compressive force deflection value (CFDV) to the PU foam prepared using a standard formulation.

Alper Kiziltas, Technical Expert at Ford Motor Company, commented: “Cost- and performance-competitive lignin-based polyol from forest sources