Lignin-Derived High-Performance Plastics

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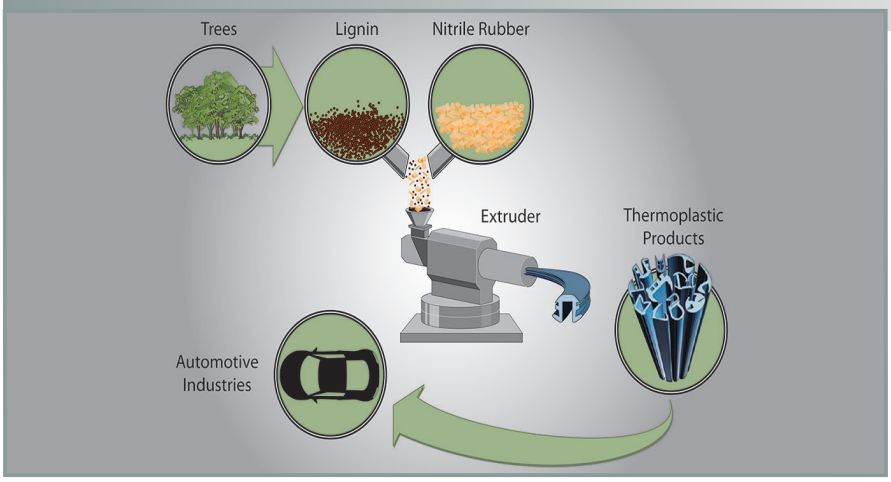

Technology Summary

Lignin, a complex polyphenol found in lignocellulosic biomass, is the third most abundant natural polymer and accounts for up to 30% by weight of wood. This valuable by-product of the biorefinery and pulp and paper industries is produced in quantities exceeding 200 million metric tons annually. Significant commercial potential exists for the conversion of lignin to high-value end products (i.e., functional materials), but lignin remains a difficult material to convert into useful products that have adequate plasticity, elasticity, strength, and toughness for industrial and commercial applications. The challenges associated with converting lignin to finished polymeric products require understanding lignin molecular architecture and the ability to control its morphology. Furthermore, traditional lignin-based thermoset plastics are not recyclable. A successful manufacturing process for novel lignin-based thermoplastics would open a new pathway to biomass utilization and help conserve petrochemicals.

Researchers at Oak Ridge National Laboratory have developed a high-performance lignin-based thermoplastic that will be useful for industrial plastic resins and commercial materials. The thermoplastic product is an unmodified solvent-extracted melt-stable lignin combined with non-lignin thermoplastic polymer segments.

By integrating networked lignin with its thermoplastic derivative, the method developed by the researchers has resulted in a product with the advantageous properties of both materials, including moldability, elasticity, ductility, strength, durability, and toughness. The sustainable product has unprecedented yield stress (15–45 MPa), strain hardens at large deformation, and has outstanding recyclability. By fine-tuning the components in the lignin formulations, molar ratios, and other variables, the ORNL researchers can adjust the final thermoplastic material's characteristics to meet specific needs or purposes, such as tensile strength, tensile yield stress, elastic modulus, and elongation properties. The method is unique due to the ease of forming different kind of materials—elastomers, thermoplastics, and thermoplastic elastomers. More than 50% of the polymer composites is lignin, which further confirms the success of the method compared to other known processes. In addition, no chemical functionalization of lignin is required prior to melt-extrusion-based processing. The team also developed a composite fabrication protocol using lignin-based resin as the matrix.

Advantages

- Superior physical properties of polymeric material (good mechanical strength and elongation)
- No chemical functionalization of lignin
- Potential pathway for reducing the carbon footprint
- Ability to tune the material's morphology and performance

Potential Applications

- Conversion of lignin into lightweight materials for vehicles without reducing crash-worthiness
- Greater fuel economy and reduced CO_2 emissions of vehicles
- Replacement of fossil-based resins in polymer applications with eco-friendly material
- Improved economics of the paper and biofuels industries

Patent

Amit K. Naskar and Chau D. Tran. *High Performance Lignin-Acrylonitrile Polymer Blend Materials,* Provisional US Patent Application 14/798,729, filed July 14, 2015.

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