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Wind Energy Initiative (WEI)

Analysis of biorenewable precursor fibers formed from blending polylactic acid, butyrated lignin, and grafted lignin

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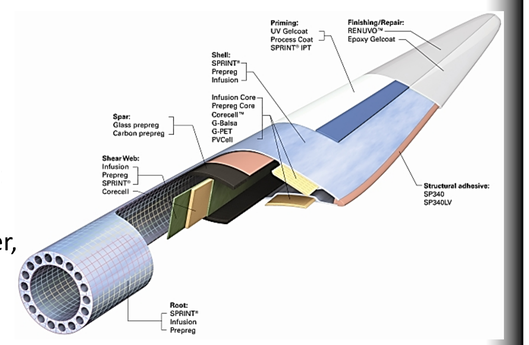
Motivation and Objectives

Motivation:

Developing bio-renewable and low-cost carbon fibers for wind turbine blade application.

- Fiber-reinforced polymer matrix composites (PMC) are currently the materials of choice for wind turbine blades.
- E-glass fibers are widely used in wind turbine blade PMC's due to low cost, adequate strength, stiffness, and high failure strain.
- Replacing E-glass with Carbon fibers can provide excellent mechanical properties, low overall densities, and high fatigue ratio but the high costs of conventional carbon fiber, which starts with expensive polyacrylonitrile (PAN) polymer has limited their use in wind turbine blades.



The ability to derive carbon fibers from lignin would lead to great economic benefits, environmental benefits, since lignin is a cheap, readily available bio-renewable precursor material.

Advantages of Lignin

- Sustainable, renewable material
- Second most abundant organic substance (polymer) on earth after cellulose
- Readily available
- Low cost: the price of lignin is about $150-200 / Ton, versus the main precursor of conventional carbon fibers, is $10,000 - 30,000 / Ton

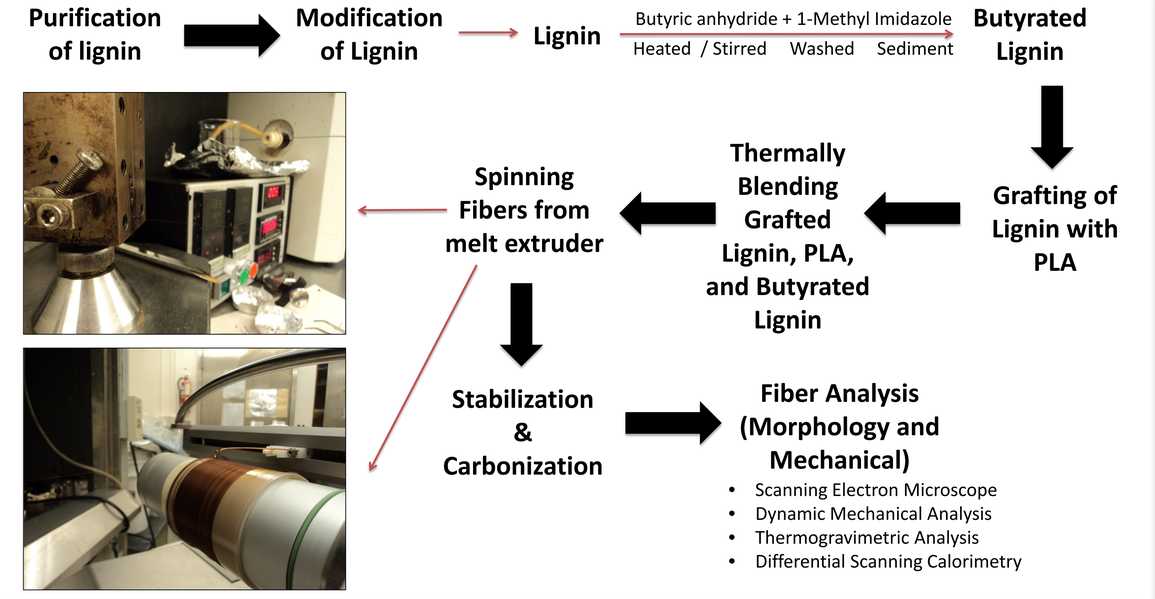
Objectives:

1. Provide melt spinnablity for lignin by graft copolymerization with polylactic acid (PLA), and blending with PLA in a microcompounder.

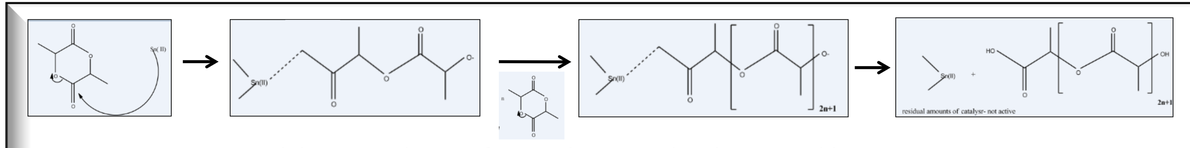
2. Enhance the miscibility of lignin with PLA by chemical modification

3. Optimize the grafted lignin/PLA blend composition to yield required mechanical and thermal properties of final fibers.

Technical Approach



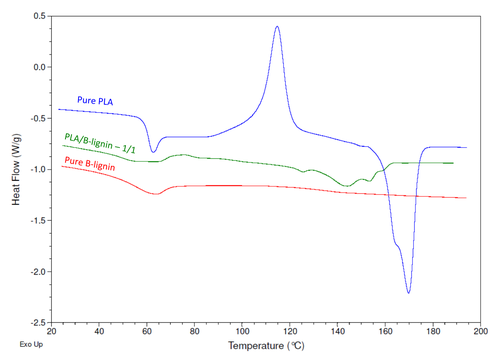
Copolymerization of PLA/Lignin



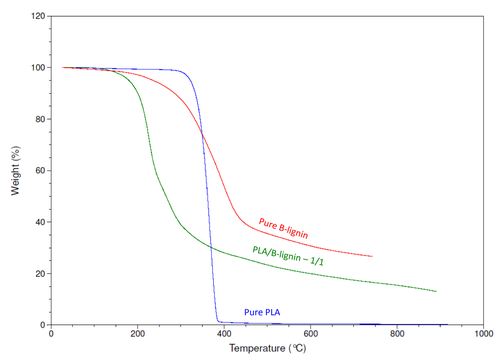
Polylactic acid is graft copolymerized to butyrated lignin hydroxyl group, increasing lignin/PLA miscibility

Thermomechanical Analysis Data

Differential Scanning Calorimetry

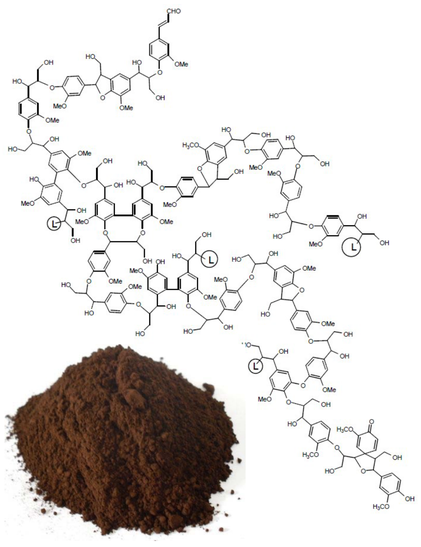


Thermogravimetric Analysis



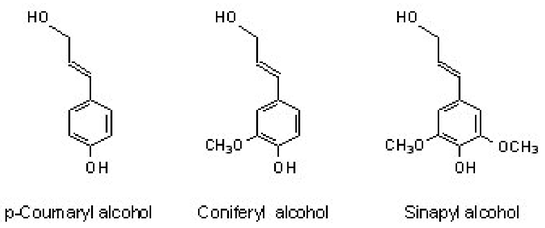
Materials

Softwood Lignin



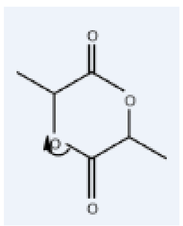
- Lignin is a highly aromatic biopolymer extracted as a bi-product from paper industry wood pulping.
- Softwood lignin contains three types of phenylpropane units and is linked by different ether linkage and carbon-carbon bonds.

Monolignols



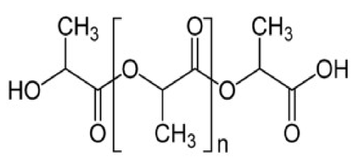
L - Lactide

- Cyclic di-ester of lactic acid.



Poly(lactic acid) biopolymer

- Thermoplastic aliphatic polyester
- Derived from renewable resources, such as corn starch
- Biodegradable



Analysis/Summary

- The B-lignin added to the PLA serves to lower its T_g and broaden the T_g peak on the DSC plot. This indicates a good level of miscibility between the B-Lignin and PLA. This indicates graft copolymerization was successful.
- The TGA plot shows that PLA serves to thermally stabilize the butyrated lignin about 200° C.
- Further work includes testing different ratios of B-lignin to PLA. SEM must be done to characterize morphology. Stabilization and carbonization will then convert the samples to carbon fibers, which will be analyzed for purity and mechanical properties.

References

- K. Chen, "Bio-renewable fibers extracted from lignin/polylactide (PLA) blend," M. S. Thesis, Materials Science and Engineering, Iowa State University, Ames, IA, 2012.
- J. F. Kadla , S. Kubo, R. D. Gilbert, R. A. Venditti, "Lignin based carbon fibers," in *Chemical Modification, Properties, and Usage of Lignin*. Boston: Kluwer Academic/Plenum Publishers, 2002, ch. 7, pp 121-138.

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