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 PMCs 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 ratios but the high costs of conventional carbon fibers, which start with expensive polyacrylonitrile (PAN) polymer, have 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 spinnability 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**

**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.

**Poly(lactic acid) biopolymer**
- Thermoplastic aliphatic polyester
- Derived from renewable resources, such as corn starch
- Biodegradable

**Monolignols**
- p-Coumaryl alcohol
- Coniferyl alcohol
- Sinapyl alcohol

**L - Lactide**
- Cyclic di-ester of lactic acid.

**Technical Approach**

**Copolymerization of PLA/Lignin**
- Polylactic acid is graft copolymerized to butyrated lignin hydroxyl group, increasing lignin/PLA miscibility

**Thermomechanical Analysis Data**

**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**