Low-Cost Bio-Based Carbon Fibers for High-Temperature Processing

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GrafTech International Holdings Inc. / Oak Ridge National Laboratory

12/22/2014 – 12/21/2017

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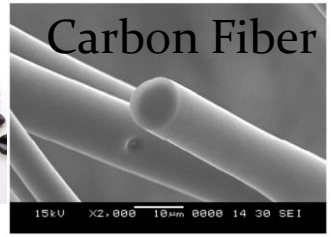
Project Objective

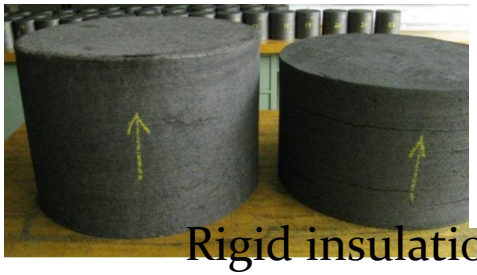
- Demonstrate that bio-based carbon fibers from lignin can be a drop-in replacement for pitch or rayon fibers in high-temperature insulation. TRL is currently 4. At project end the TRL will be 6.

Supporting Objectives

- Develop lignin-based carbon fiber technology (LBCF), focusing on melt blowing carbon fiber mat.
- Evaluate the scale-up potential of LBCF technology for melt blowing carbon fiber mat in ORNL Carbon Fiber Technology Facility (CFTF).
- Evaluate LBCF in GrafTech's high-temperature products, including insulation, graphite electrodes, and activated filters.
- Show progress towards LBCF supply chain, from raw lignin to carbon fiber to products.

Lignin





Rigid insulation

Technical Approach

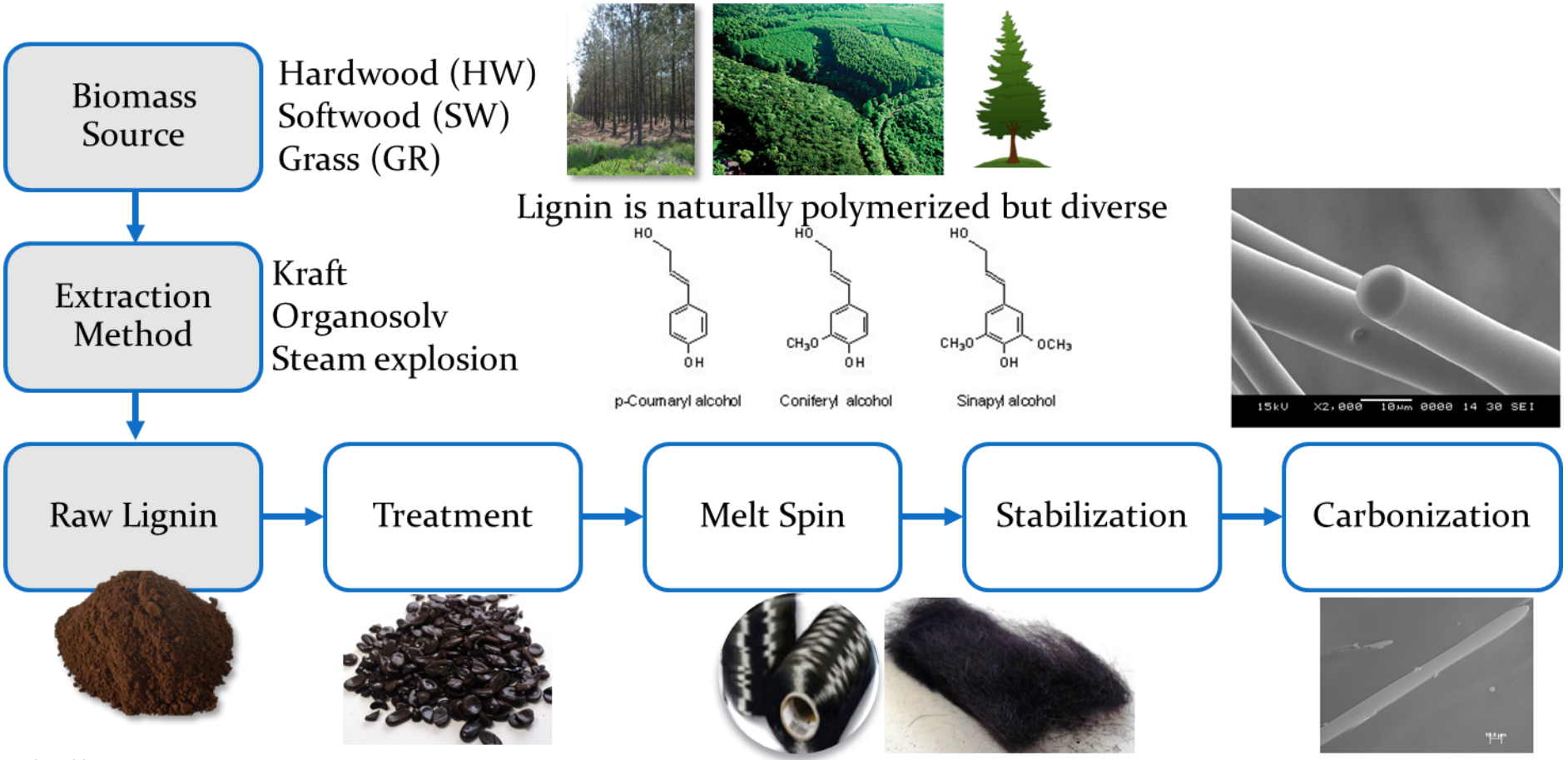
Team

- GrafTech is a leader in graphite materials science solutions, including high-temperature products, with over 125 years of experience.
- ORNL is a leader in carbon fiber precursor materials science and stewards resources such as Carbon Fiber Technology Facility (CFTF).

Approach

- Lignin, a biopolymer, has potential to be a low-cost carbon fiber precursor if certain technical challenges are overcome.
- LBCF could have lower cost, lower energy demand, and higher performance than current fibers used by GrafTech.
- Currently there are no commercially available LBCF. Supply chain does not exist. No detailed LBCF specifications, validated lignin suppliers, or qualified applications.
- Team is taking a fresh look and evaluating multiple lignin sources.
- Focus on high-temp insulation as commercialization entry point.

Technical Approach



Challenges

- Lignin purity, molecular weight (MW), rheology depend on biomass and extraction method.
- Supply chain requires multiple qualified lignin sources and no manufacturing bottlenecks.
- To date only organosolv HW was melt spun without treatment but stabilization time too long.
- High purity needed to melt spin while control of MW needed for stabilization and high yield.

Transition and Deployment

- Demand exists for lower-cost carbon fiber for industrial applications, especially functional (non-structural). Precursor should be abundant, renewable, and decoupled from oil supply chain.

- GrafTech could use lignin-based carbon fiber in the production of functional products such as high-temperature rigid and felt insulation, filtration, and/or energy storage applications. LBCF could be lower cost and higher performance.

- Commercialization Approach: (1) Evaluate lignin suitability at lab scale. (2) Scale-up to produce LBCF for prototypes. (3) Evaluate LBCF in products in actual end-use application. Show progress towards supply chain (raw lignin => fiber => products).

- Technology Sustainment Model: Lignin is an underutilized renewable resource. Validated/qualified uses of lignin are sought.

Measure of Success

- A successful outcome will show that lignin-based carbon fibers are a drop-in replacement for the rayon or pitch carbon fibers currently used in high-temperature insulation.
- Success will also demonstrate LBCF technology, scale-up potential, and qualified products, and show progress towards a supply chain.
- It is expected paths will be identified towards semi-structural properties for LBCF, which will open new applications.

- Initial commercialization opportunities are high-temperature insulation, filtration, and fillers for high-temperature products.

- LBCF are expected to have a lower energy demand for production versus standard carbon fiber precursors.

Project Management & Budget

- Project is planned for 3 years. 12/22/2014 – 12/21/2017.

Budget Period	Task	Subtasks	Expected Outcome
Budget Period 1 12/22/2014 to 12/21/2015	Task 1 Task 2 Task 3	Lignin Procurement, Testing, Melt spinning, Modification Fiber Stabilization Fiber Carbonization and testing	Evaluate 10 lignin sources or suppliers and select 4 that show promise to scale-up and produce carbon fiber mat in CFTF. Cost modeling shows estimated cost < $5/lb.
Budget Period 2 12/22/2015 to 12/21/2016	Task 4 Task 5 Task 6 Task 7 Task 8	Lignin Procurement and Preparation Melt Blowing of 500 Pounds of LBCF at CFTF Evaluate LBCF in Insulation Prototypes Evaluate LBCF in EAF Electrodes and Pins Evaluate LBCF in Filters	Scale-up 4 lignin sources or suppliers in ORNL CFTF. Produce 500 pounds of LBCF and evaluate in insulation prototypes, graphite electrodes, and filters.
Budget Period 3 12/22/2016 to 12/21/2017	Task 9 Task 10 Task 11 Task 12	Lignin Procurement and Preparation Melt Blowing of 5000 Pounds of LBCF at CFTF LBCF Insulation Product and Customer Trial LBCF Electrodes Product and Customer Trial	Scale-up 2 lignin sources or suppliers in ORNL CFTF. Produce 5000 pounds of LBCF and evaluate in insulation and graphite electrodes in end-use trial.

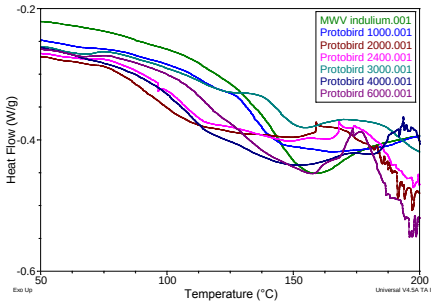
Total Project Budget	
DOE Investment	$4,500,000
GrafTech Cost Share	$1,900,443
Project Total	$6.400,443

ORNL $3,250,000
GrafTech $1,250,000

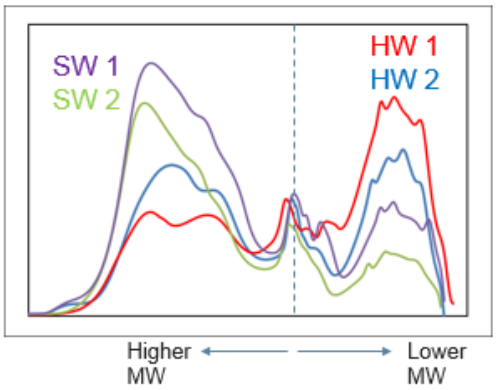
Results and Accomplishments

- Project is in Task 1, Subtask 1.2 and Subtask 1.3, out of 12 Tasks
- Completed Subtask 1.1 and Milestone 1.1.1 on time (lignin procurement)
- Obtained various hardwood, softwood, and grass samples. Only 1 type of lignin was tested in previous work.
- Performing analytical and physical characterization, as well as melt spinning of initial as-received lignin. Beginning cost modeling.

Initial 10 Lignin Samples



Thermal Testing



Lignin Molecular Weight Distribution by Gel Permeation Chromatography (GPC)

Initial Lab Scale Fiber Spinning Trials