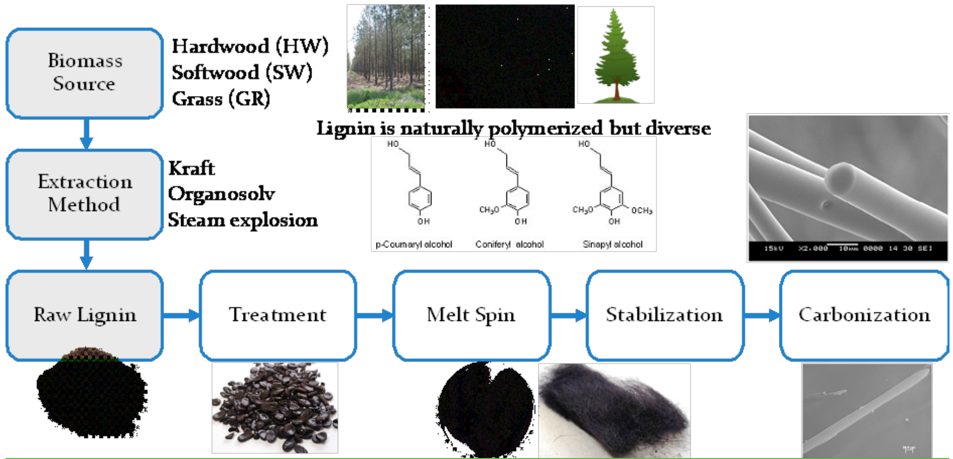
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Lignin-based Carbon Fibers for Clean Energy—Low-Cost Bio-Based Carbon Fibers for High-Temperature Processing

Developing a renewable, domestic supply of affordable carbon fibers for use in clean energy applications



Process flow diagram for production of high-performance carbon fibers from lignin sources. *Graphic image courtesy of GrafTech International Holdings.*

Carbon fibers derived from petroleum intermediates are used in a variety of high-temperature insulation products and manufacturing applications. U.S. manufacturers currently purchase these materials from foreign supply chains that may be vulnerable to price volatility. Domestic production of carbon fibers from woody plants (lignin) could stabilize and reduce costs while meeting all performance requirements. Developing a reliable supply chain and economical manufacturing process for these bio-based fibers could pave the way for their use in solar and other clean energy markets.

The composites industry has primarily exploited the structural properties of carbon fiber to reinforce or strengthen materials; however, carbon fiber also has useful thermal and electrical properties. Carbon fiber is a unique material that is capable of withstanding 3,000°C or more in an inert environment. Its electrical properties can enhance performance in virtually any synthetic graphite.

The goal of this project was to demonstrate that bio-based carbon fibers can serve as economical drop-in replacements for the pitch or rayon fibers used for insulation during the manufacture of photovoltaic materials.

The research planned to focus on identifying appropriate lignin supplies/precursors and melt blowing them into the carbon fiber mat and continuous fiber needed for non-structural, high-temperature insulation materials.

Benefits for Our Industry and Our Nation

Lignin-based carbon fibers could directly replace high-cost, foreign-sourced pitch and rayon carbon fibers currently used in some commercial, high-temperature insulation products. Key benefits include the following:

- Lignin-based carbon fibers could potentially cost half as much as pitch and rayon fibers derived from petroleum products.
- Developing lignin-based carbon fibers to cost-effectively deliver the thermal efficiency required in high-temperature applications (e.g., production of photovoltaic materials) or to conduct current (as in graphite electrode assemblies) could help boost U.S. competitiveness in world markets.
- Products from sustainable sources like biomass can help meet a number of sustainability goals.

Applications in Our Nation's Industry

Although this project was to initially focus on insulation products used in the manufacture of photovoltaics, the plan was to evaluate lignin-based carbon fibers for two additional market applications.

One application was to reinforce the graphite electrodes and connecting pins used in high-temperature electric arc furnace (EAF) steelmaking. A low-cost lignin-based carbon fiber (less than $5 per pound) would be attractive for steel manufacturers.

The research also planned to evaluate the use of activated lignin-based carbon fibers in filtration products, which could be a major market opportunity if coupled with a low-cost activation process. Establishing a reliable supply chain for the lignin could pave the way for use of renewable carbon fibers in other applications such as automotive applications.

Project Description

Project partners were to leverage their carbon materials science and manufacturing expertise to break through current barriers and take lignin-based carbon fibers to the next level. The project team began by developing a low-cost carbon fiber precursor derived from lignin, a by-product of the wood/paper/forest products and biorefining industries. The work entailed selecting the most promising lignin sources from among hardwood, softwood, and grass samples.

The team then planned to develop an innovative melt-spin process to reliably and rapidly transform the selected precursors into a stable fiber mat or continuous fiber at the lab scale. This process was to be scaled up and used to produce lignin-based carbon fiber for use in prototype products for testing and evaluation.

Barriers

- Currently, no supply chain exists for lignin-based carbon fibers. There are no detailed specifications, validated lignin suppliers, or qualified applications.
- The specific type of biomass and the extraction method will affect lignin purity, molecular weight, and how well it flows. High purity is necessary for the melt spinning process, while the molecular weight must be controlled to achieve the desired stability and yield.
- Melt spinning of lignin precursors represents a major technical challenge.
- Minimizing the time required to stabilize the lignin is another key challenge. To date, only organosolv hardwood has been melt spun without treatment, but stabilization time still takes too long.

Pathways

Project partners obtained lignin samples from various hardwood, softwood, and grass sources. After analyzing and characterizing the samples, the researchers conducted laboratory-scale fiber spinning trials to ascertain lignin suitability. Using the results of this process, the team identified four promising lignin sources and began cost modeling.

The most suitable lignin was to be selected for scale-up to produce lignin-based carbon fibers for prototypes. Scalability of the production processes were to be demonstrated in Oak Ridge National Laboratory's Carbon Fiber Technology Facility. Before this phase of the project began, however, Graftech International planned to divest a portion of the company critical to the project. DOE and research partners therefore agreed to terminate the project early.

Milestones

This three-year project began in December 2014 but terminated early in 2016.

- Select at least four lignin sources that show promise for scaling up to enable the production of carbon fiber (Completed).
- Produce lignin-based carbon fibers for initial evaluation (Unmet).
- Demonstrate use of qualified products containing lignin-based carbon fibers through end-use trials of insulation and graphite electrodes (Unmet).

Technology Transition

Transitioning this technology towards commercialization requires the establishment of multiple, qualified lignin sources to avoid manufacturing bottlenecks. Four lignin samples were identified as candidates for reliable supply chains but activities to scale-up production were halted. The completed research does confirm, however, that the future of lignin-based carbon fiber needs collaboration between lignin producers, product manufacturers, and end users in order to establish a supply chain that validates lignin viable for specific commercial applications.

The final report for the project focusing on the research activities conducted in collaboration with Oak Ridge National Laboratory is available at: http://info.ornl.gov/sites/publications/files/Pub72969.pdf

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