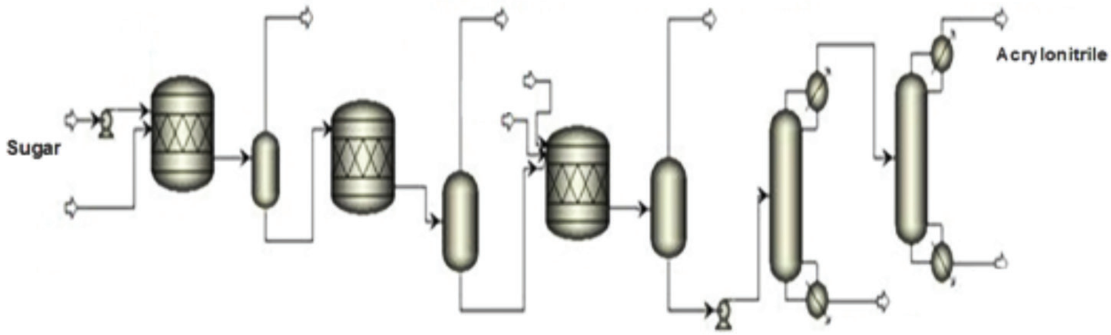
Biomass Conversion to Acrylonitrile Monomer-Precursor for Production of Carbon Fibers

Background

Micron-sized carbon fibers presently used are mostly produced by heat treatment or controlled pyrolysis of different precursor fibers. The most prevalent precursors are poly-acrylonitrile (PAN), cellulose fibers (such as viscose, rayon, and cotton), petroleum and coal tar pitch, and certain phenolic fibers. Synthesis process involves heat treatment, oxidative stabilization, carbonization and graphitization to achieve desired mechanical strength. Currently, carbon fibers which meet specifications (250ksi tensile strength and 25Msi Young's modulus) for automotive applications are made from PAN, obtained from acrylonitrile (ACN), which is synthesized using propylene and ammonia. World ACN production in 2010 was 5.7 million tons, and is highly dependent on volatility of propylene prices. Additionally, propylene production (a byproduct of naphtha cracking for ethylene) is reducing due to growth of the natural gas based process for production of ethylene. For reasons of price and lower GHG, alternate sources, most predominantly lignin, have been investigated thoroughly to make carbon fibers; however produced fiber falls short of required mechanical strength for automotive applications.

The US Department of Energy and the industrial sector anticipate an 11-18% annual increase in the market for carbon fiber, specifically driven by motivation to reduce weight for vehicles. To address these issues, The Bioenergy Technology office (BETO) a division of Office of Energy Efficiency and Renewable Energy (EERE) of Department of Energy (DOE) partnered with Southern Research to develop a process for biomass derived sugars conversion to acrylonitrile, along with Cytec Carbon Fiber, LLC as technology validator and New Jersey Institute of Technology for materials characterization.



Project Description

Southern Research biomass to acrylonitrile (B2ACN) process is a multi-step catalytic process for conversion of sugars from non-food biomass to acrylonitrile at mild conditions. Process utilizes known methods for recovery of sugars from any type of biomass. In the first reaction step, sugars are converted to oxygenates. Using a catalyst, oxygenates are then converted to an intermediate followed by conversion of the intermediate to acrylonitrile. The proposed technology circumvents many limitations; firstly it uses cheap sugars, secondly, the technology does not rely on glycerol, a byproduct obtained from transesterification of oils; thirdly, it utilizes industrially acceptable catalysts to convert an intermediate to acrylonitrile, thus reducing risk and shortening the number of catalytic steps to be developed. The product obtained from the proposed process will be validated by Cytec and compared with petroleum based acrylonitrile for it to be a carbon fiber ready monomer-precursor.

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PROJECT DURATION
Start Date
02/01/2015

End Date
05/30/2018

COST
Total Project Value
$ 6,815,879

DOE/ Non-DOE Share
$ 5,981,713 / $ 834,166

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Goals and Objectives

The overall goal of this project is to utilize biomass derived sugars, catalysts, and process intensification approaches to produce carbon fiber ready bio-ACN at a cost $1.00/lb. The project will demonstrate the B2ACN process at lab scale in Phase I followed by large bench-scale in Phase II with the goal to be ready for fully integrated pilot /demo scale at the end of Phase II. Specific project objectives are: (1) to develop catalysts and a prototype biomass to ACN process during Phase I and validate the quality of product against conventional ACN and (2) to scale up the prototype method during Phase II to a bench scale unit for production of 500 kg bio-ACN for validation of process and observing the quality of bio-ACN produced.

Accomplishments

The B2ACN process has been demonstrated at proof of concept stage; key catalysts verifying process chemistry have been identified. Under Phase I of the project, the process will be optimized and the product will be validated. Initial techno-economic analysis and life cycle assessment show significant economic ($ 0.70/lb - 22% reduction) and GHG benefits (37%)

Petroleum ACN	GHG Emissions *(kg GHG / kg ACN)*	Biomass to ACN	GHG Emissions *(kg GHG / kg ACN)*
Crude to Propylene[34]	0.16	Sugars to Oxygenates	0.91
Propylene to ACN[35]	2.86	Oxygenates to intermediate	0.42
		Intermediate to bio-ACN	0.56
	3.02		**1.90**

Conclusions

The potential advantages of the B2ACN technology are summarized below:

- Significant reduction of lifecycle GHG emissions below conventional petroleum-based counterpart
- Use of industrially relevant catalysts resulting in low operating costs.
- Process intensification for converting sugars to chemicals leading to significant energy and catalyst savings Simple separation and process integration resulting in reduced capital costs
- Utilization of maximum carbon with high selectivity for desired product
- Utilization of known technologies for sugar production and industrially accepted reactor designs.