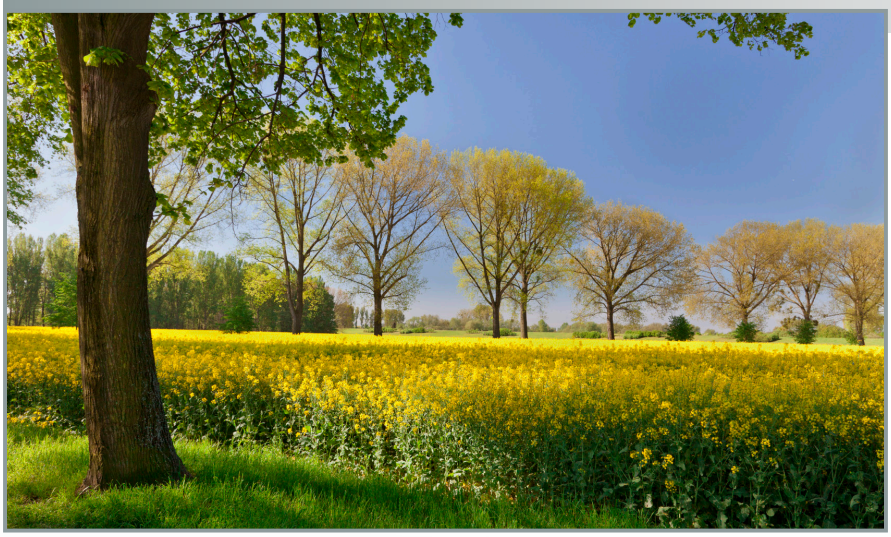
Nanoporous Membranes for Pretreatment of Lignocellulose and Other Applications

UT-B ID 201002406



Technology Summary

Researchers at ORNL have developed an inorganic membrane element and a flow-through recycle (FTR) process for pretreating lignocellulosic biomass to produce a high-quality ethanol feedstock more amenable to hydrolysis and fermentation than other pretreatment methods. The ORNL process minimizes carbohydrate and lignin degradation while providing a clean sugar stream for further processing.

Producing ethanol from inedible plant matter such as wood and agricultural or forest residues is an attractive alternative to using corn or sugar cane because the source biomass not only is renewable and abundant, but also does not impact food supplies or prices. However, hydrolysis of lignocellulose from inedible plant matter is more difficult than with other biofuel precursors—the "recalcitrance" factor often referred to—requiring more preprocessing than corn or sugar cane to make sugar molecules available for ethanol production. In recent years numerous physical, chemical, and biological pretreatment methods have been developed; however, they all have disadvantages, including degradation or destruction of some of the polysaccharides, impacting final sugar (and ethanol) yields; production of toxic byproducts that interfere with later processing; and expense.

ORNL's FTR process consists of a pretreatment reactor containing a stationary bed for the lignocellulosic biomass and a layered inorganic membrane configured in a tubular design for selective separation of solubilized organic compounds from the reactor. Pressurized water heated to 170°C–210°C is passed through the reactor, and the exit stream, which contains solubilized organics such as glucose, xylose, pentose, and lignin, is pressurized to between 200 and 550 psi and directed through the nanoporous inorganic membrane to generate a retentate with an increased concentration of reactive solids. The process also selectively removes inhibitors such as monolignols and phenolic acids. The water can be recirculated to the reactor for reuse, and the retentate, enriched in sugars, can be fractionated and fermented to produce ethanol. By using step-wise temperature increases in the flow-through process, organic fractions that solubilize at different temperatures can be separated. Testing has confirmed high levels of carbohydrate retention (> 98%) for various biomass feedstocks.

Advantages

- Produces highly reactive solids
- Energy efficient selective separations
- Direct separations at pretreatment conditions compared to reverse osmosis membranes that are limited to low temperature processing
- Achieves high cellulose and hemicellulose extraction levels
- Does not use or produce toxic substances/ chemicals
- Less prone to fouling than reverse osmosis membranes

Potential Applications

- Biomass pretreatment
- Extraction of various organic compounds from biomass
- Extraction of low molecular weight organics (e.g., from waste streams)

Patents

Ramesh R. Bhave. *Inorganic Nanoporous Membranes for High Temperature Pretreatment of Lignocellulosic Biomass,* U.S. Provisional Patent Application 61/553,419, filed October 31, 2011.

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