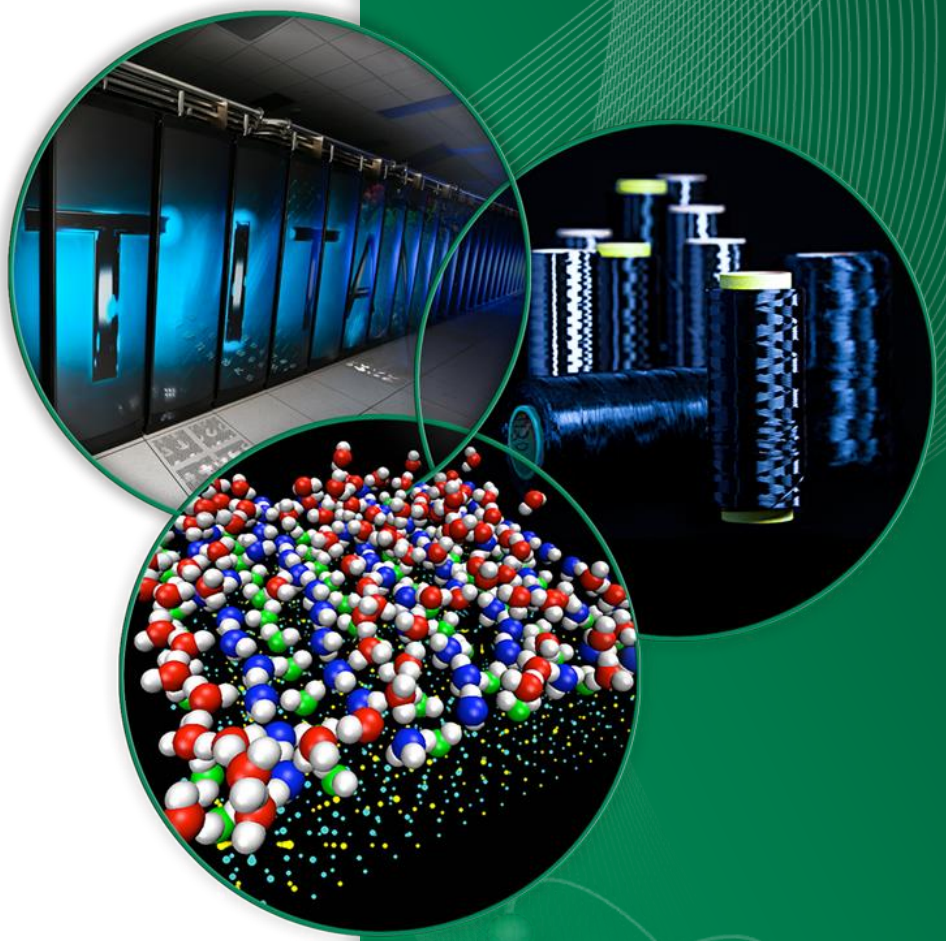
Biomass Waste Stream to Carbon and Composite Product R&D: Case Studies



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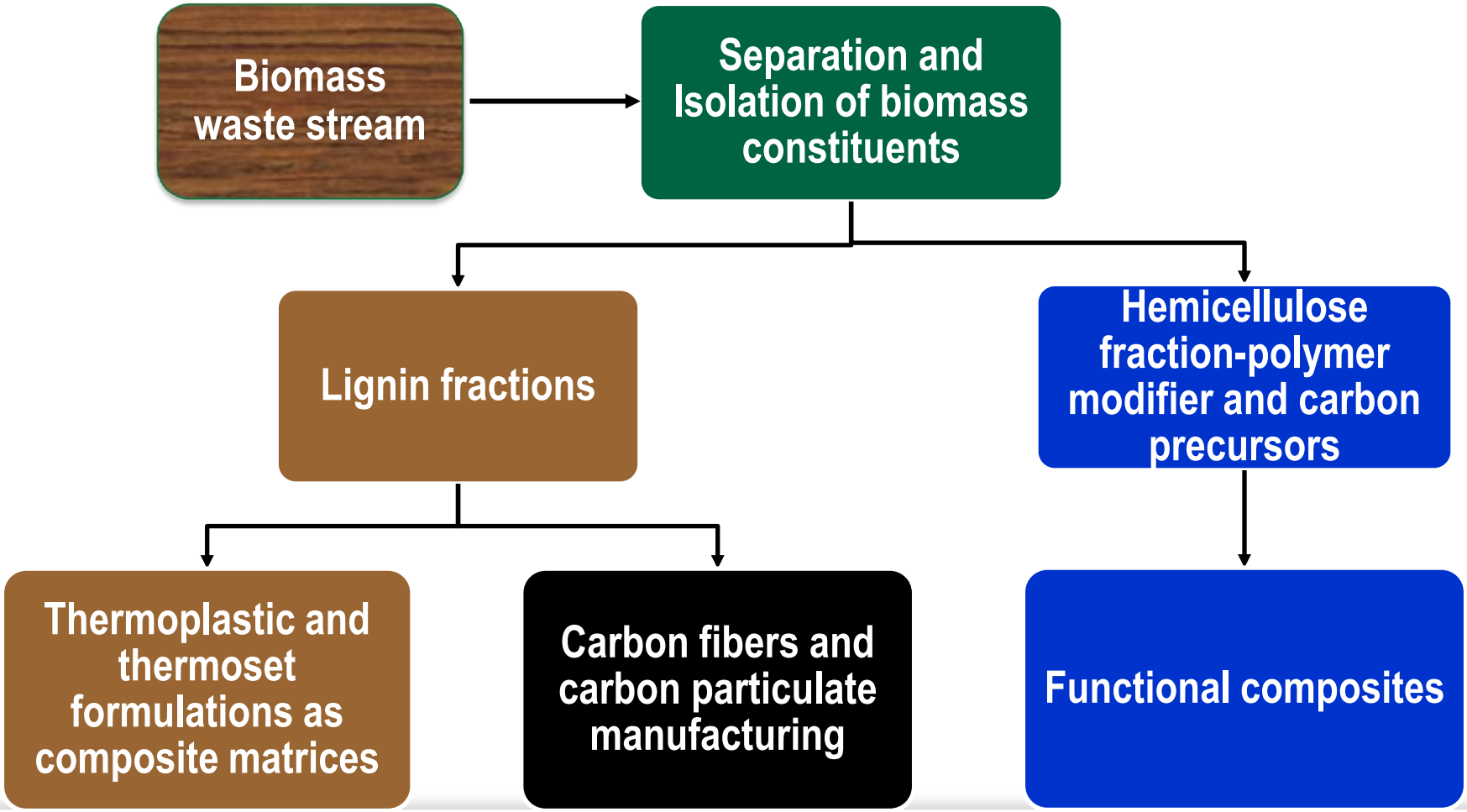
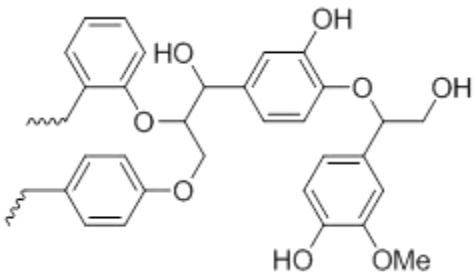
Vision

Produce and commercialize biomass waste stream-derived industrial-grade fibers, polymers, and their composites, with properties rivaling current petroleum-derived alternatives.



Spinning neat or modified lignin to fibers

Lignin formulation



Melt extruder

Drying

1. Oxidation or stablization
2. Carbonization

Melt-blown lignin web production was demonstrated at ORNL

- ORNL demonstrated hardwood lignin web production
- First reported semi-production scale web forming with softwood lignin (~20 lb quantity).
- Process modification and subsequent stabilization/carbonization protocols are being developed.

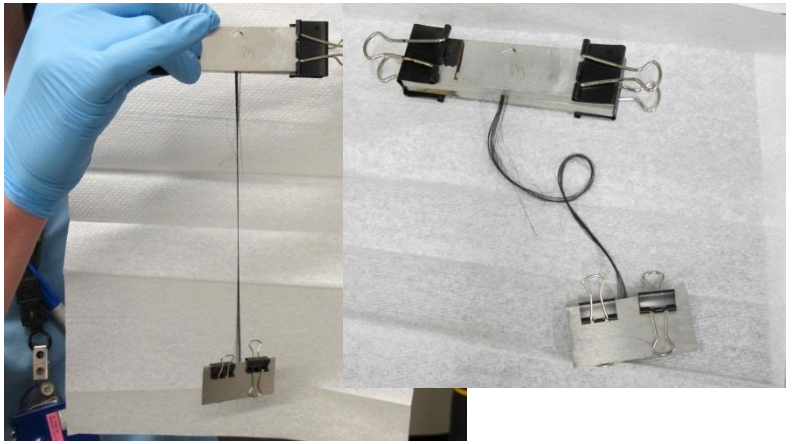
Lignin fiber web formation by melt-blowing at CFTF

Project supported by EERE-Advanced Manufacturing Office

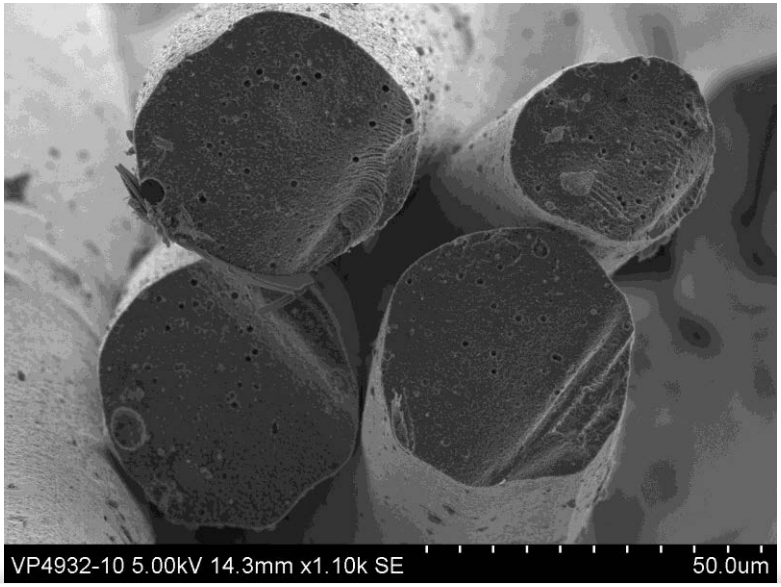
Oxidation of lignin fibers produce infusible carbon precursor filaments

Melt-spun lignin fiber

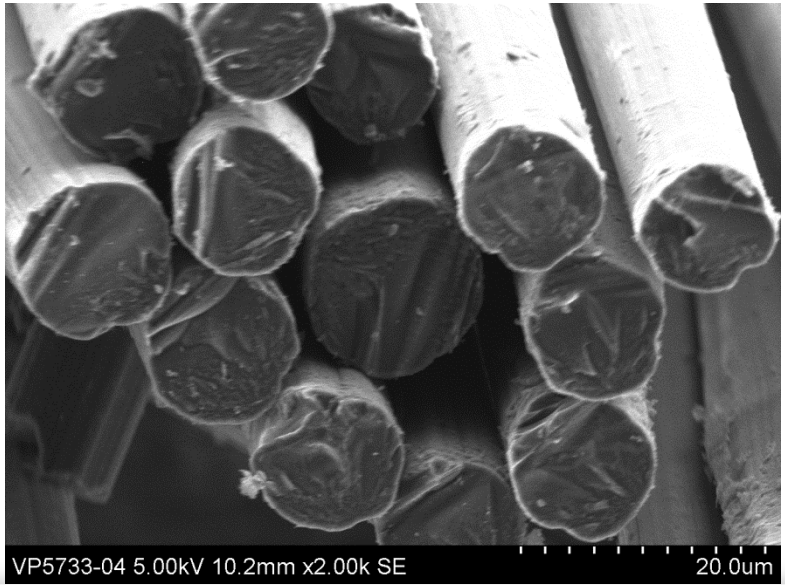
Tension is applied during oxidation and the tow was stretched



Processed & carbonized without tension



Carbonized with tension

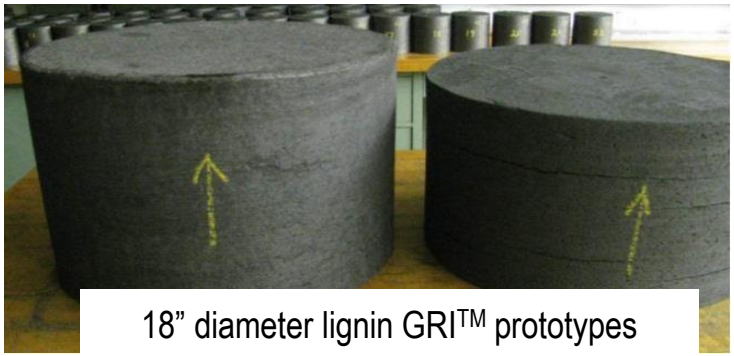


Mays, Naskar et al. POLY Symposium (2013)

Immediate FUNCTIONAL applications of lignin-derived carbon fibers

- **Lignin-derived CF is a "drop-in" replacement for commercial isotropic pitch CF used in GrafTech's commercial GRI™ product**

  Eberle et al. *ORNL Report* (2013).

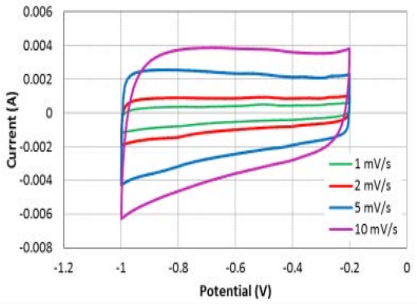


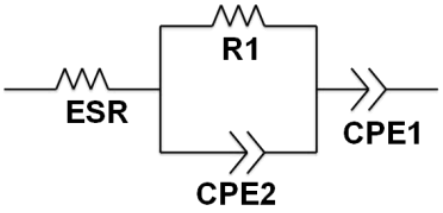
18" diameter lignin GRI™ prototypes

- **High performance battery electrodes and supercapacitor with potential for low cost were made from lignin-derived CF at laboratory scale**

  Tenhaeff et al. *Adv. Funct. Mat.* (2014).

  Saha et al, *Langmuir*, (2014)





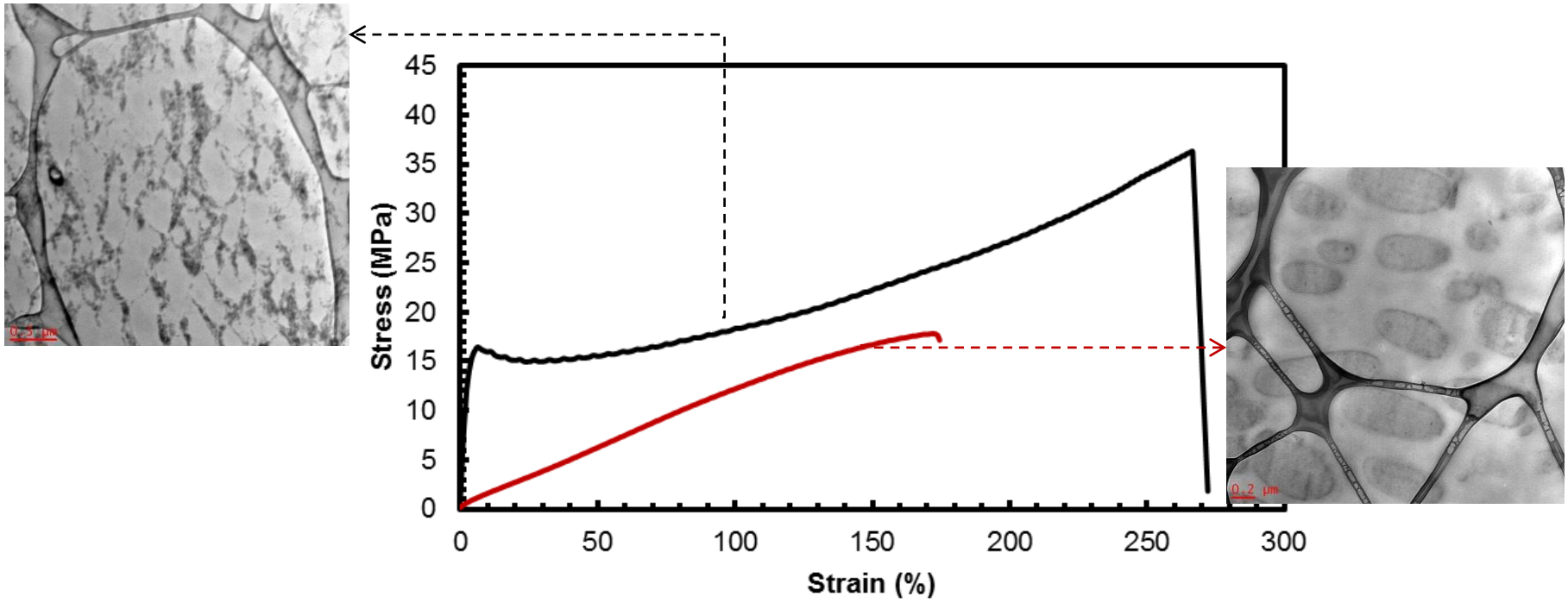
Grand Challenge

Both the biorefineries and pulping industries are keenly interested in developing new revenue streams ….

……and automotive part manufacturers are also extremely interested in gaining access to thermally and hydrolytically stable, uv-resistant, and renewable polymers. Such an economically advantageous technology is yet to develop mainly due to the lack of integrated knowledgebase and interdisciplinary research approach involving:

1. ***lignin feedstock consistency,***
2. ***ability to control lignin self-assembly in soft polymer matrix,***
3. ***understanding chemistry and physics of lignin-derived polymers,***
4. ***process engineering, and***
5. ***melt-rheology of the polymeric products***

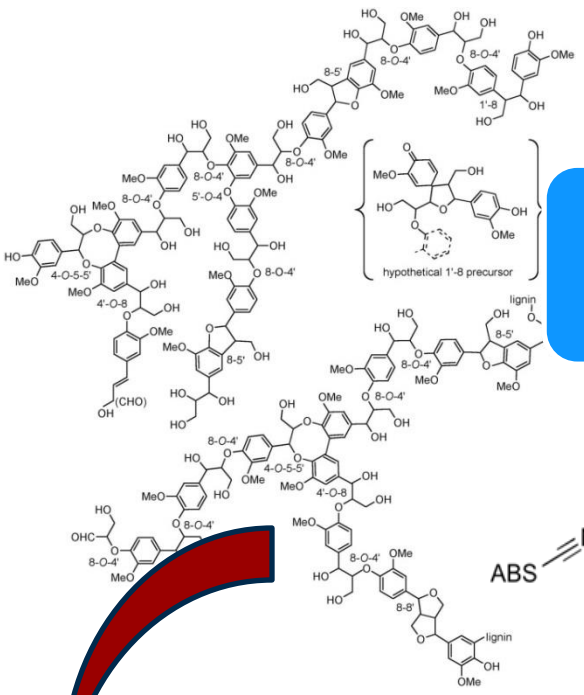
A new methodology of extruding reactive lignin with soft matrices exhibits outstanding performance in the product (Exceeds performance by ABS)



Tensile stress-strain profile of lignin-polymer materials synthesized by state-of-the-art method vs. newly developed method that shows dramatic improvement in modulus, a yield stress, and extraordinary toughness mainly due to our ability to tailor the phase morphology and interface of the multiphase material.

Tran, Chen, Keum, and Naskar. ***Advanced Functional Materials*** (2016)

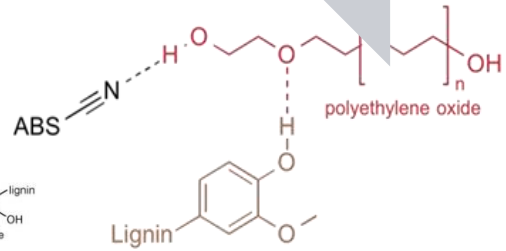
Lignin-extended high performance thermoplastics: composites applications



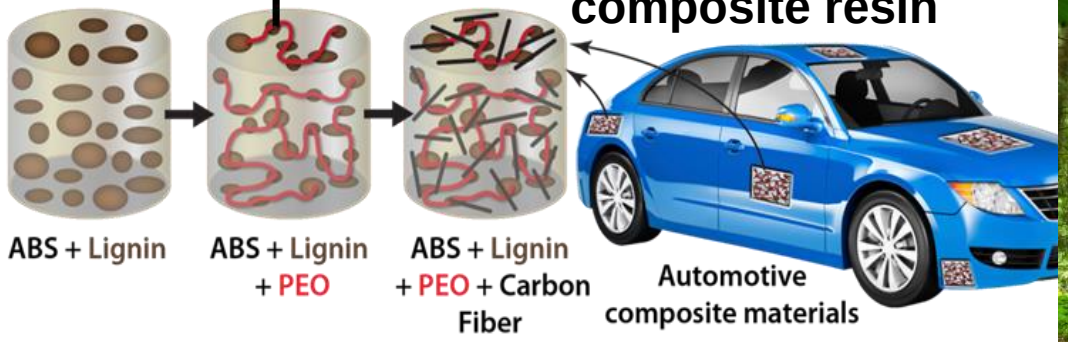
Lignin (residue)

Cellulose (sugar and biofuel)

Hemicellulose (C5 sugars & chemicals)



High performance thermoplastics are being made as substitute for ABS, a automotive composite resin



Akato, Tran, Chen, Naskar, ***ACS Sustainable Chemistry & Engineering*** 3(12), 3070–3076 (2015).

Conclusions

Our results demonstrate feasibility of i) functional carbon manufacturing from lignin, and ii) synthesizing a new class of elastomers, prepared by nanoscale dispersion of lignin, a renewable phenolic oligomer, in rubber.