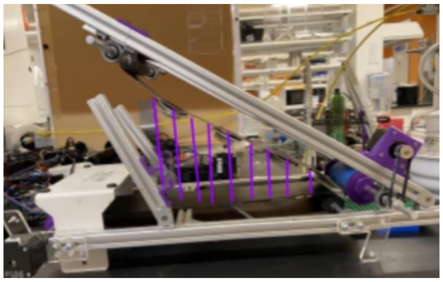
Carbonized Lignin Nanofibers for Sustainable Biomedical Applications

Abigail Heinz, Dave Jao, Dr. Vince Beachley
Rowan University

Statement of Purpose: Carbon fiber has been a commonly favored material in many industries for its lightweight yet strong composition. Carbon nanofibers have additional advantages due to their increased surface area, conductivity, and potentially porous structures (1). Creating these carbon nanofibers from lignin, a complex organic polymer derived from plant support tissues, could create a sustainable biomaterial suitable for use in biomedical device applications. Lignin nanofibers (LNFs) cannot be created with typical fiber production methods due to the high viscosity and slow evaporation rate when lignin is dissolved, however the novel track spinning method detailed in this paper can accommodate these characteristics and has potential to work with a variety of other solutions. Some possible applications of these nanofibers after carbonization include implantable electronic devices, wound coverings, or mesh for tissue reconstruction or scaffolding (2,4). Each of these applications depends on one or more of the important characteristics of carbon fiber and would benefit from the highly aligned nanostructures created by lignin carbon nanofibers (LCNFs).

Methods: LNFs for this application are manufactured using a lignin-based solution in conjunction with a novel manufacturing device known as a track spinner. This device, shown in Figure 1, is capable of producing nanoscale fibers without the application of electromagnetic forces commonly found in other fiber production techniques.

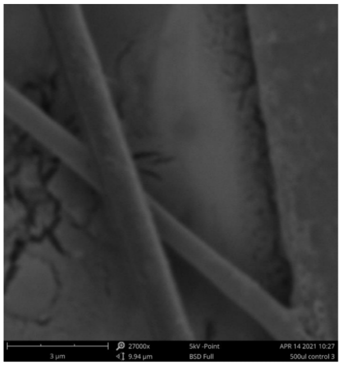


(Figure 1**:** This is a photo of the track spinning device and the area where fibers are drawn between the surfaces of the device.)

This track spinning device is also capable of continuously creating fibers with high throughput in comparison to other techniques. Fibers are subjected to multiple drawing regions to reach final fiber diameters within the nanoscale, as shown by the purple lines in Figure 1. After production, the fibers are collected and can be analyzed or prepared for carbonization. For proposed carbonization research, the fibers would be first washed with water. Then, the fibers would be adhered to a graphite sheet using cement paste and heat treated using a tube furnace at a variety of temperatures to estimate the ideal carbonization temperature based on temperatures established by previous research (3). The LCNFs can then be removed from the graphite for further evaluation.

Results: We expect the nanofibers to be carbonized at previously established carbonization temperatures exceeding 400 C. Preliminary results have proven these nanofibers are able to withstand drying processes and can remain intact for long periods of time at standard room temperature and pressure conditions. In non-carbonized mechanical testing, fibers have been able to withstand a maximum of 2 N of tensile force. We expect the mechanical properties to be similarly high in comparison to other CNFs and LCNFs.

Non-carbonized samples have been observed to reach diameters as low as 700 nm as shown in Figure 2.



(Figure 2**:** This is an SEM image of a 700 nm LNF.)

We expect the fiber diameters to decrease significantly post-carbonization, putting the fiber diameters much further into the nanoscale and increasing their surface area.

References:

1.Zhou X. Mat Adv. 2020; 7, 2141-2546. https://doi.org/10.1039/D0MA00492H 2. Kumar N. Recent Dev. In CNF. 2018. https://doi.org/10.5772/intechopen.75826 3. Bengtsson A. Sustainable Chem. Eng. 2020; 8, 17, 6826–6833. https://doi.org/10.1021/acssuschemeng.0c01734 4. Petersen, R. CF Biocomp. for Implants. Fibers 2016; 4, 1. https://doi.org/10.3390/fib4010001

Acknowledgments:
Army Research Laboratory W911NF-17-2-0227
National Science Foundation NSF1653329