

# Nanofabrication of Electrospun PAN-Derived High Surface Area Activated Carbon Nanofibers for Energy Storage

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At present, batteries, fuel cells, and supercapacitors (SCs) are the primary electrochemical energy storage systems employed for meeting modern energy demands. SCs exhibit fast charge/discharge capabilities and high specific capacitance and are particularly appealing due to minimized degradation over repeated cycling which results in extended lifetimes. Further, in the absence of chemical reactions that degrade batteries over time, SCs also boast a longer shelf-life without use.<sup>1</sup> Notwithstanding, these benefits are slightly contrasted by lower energy storage densities and high cost for production. In this work, we aim to address these issues by producing hollow nanofiber SCs that not only provide high surface area to volume ratios due to size scale, but that enhance surface area for energy storage further through hollowing of the individual fibers.

In this work, we aim to provide hollow, activated carbon nanofiber electrodes with ultrahigh surface area for efficient energy storage in cold temperatures. In our design, we plan to utilize modified methods<sup>2</sup> to electrospin and process polyacrylonitrile (PAN) nanofibers to form stabilized and activated carbon fibers. Thus far, we have synthesized an activated PAN framework. Based on our past work fabricating nanofiber SCs materials<sup>3</sup> and liquid-core fibers<sup>4</sup> (**Fig 1-2**), we are working to use coaxial (core-shell) electrospinning (ES) to produce hollow fibers with significantly increased surface area for energy storage. The core of the fibers will be filled with electrolyte (tetraethyl ammonium tetrafluoroborate in acetonitrile and propylene carbonate) that has been previously established to enable capacitance at extremely low temperatures ( $-40^{\circ}\text{C}$ )<sup>5</sup>, and fibers will be reinforced with cellulose nanocrystals to prevent ice formation and improve fiber integrity.<sup>2</sup> Fiber morphologies will be characterized on transmission and scanning electron microscopy and atomic force microscopy. Electrochemical characterization will include cyclic voltammetry (CV), galvanostatic charge–discharge (GCD), and electrochemical impedance spectroscopy (EIS) at room temperature and at extremely low temperatures. Long-term cycling stability will also be evaluated using a flat test cell under both conditions to investigate the effect of temperature on overall device performance. Electrochemical testing in cold temperatures will be carried out using an alcohol based circulating cooling system.

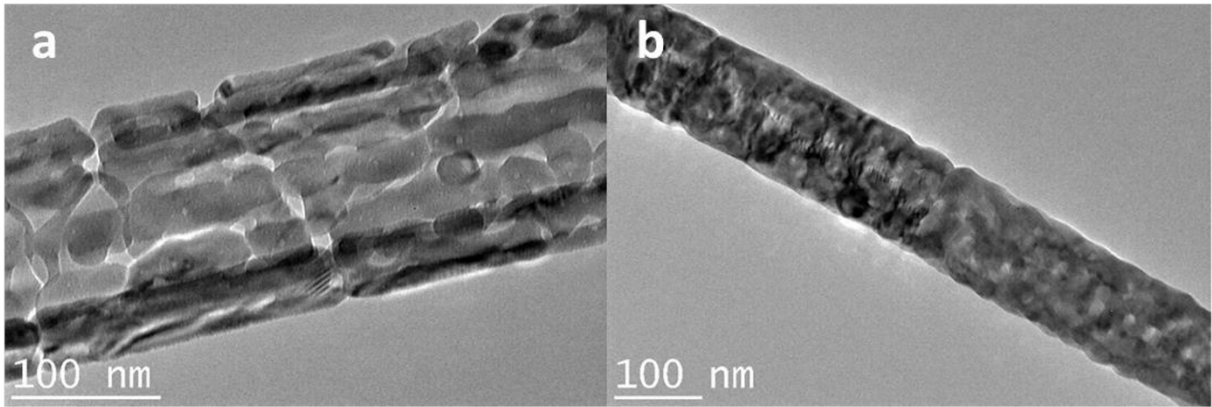
<sup>1</sup>Khan et al., Journal of Industrial and Engineering Chemistry, 2024, [doi.org/10.1016/j.jiec.2024.07.014](https://doi.org/10.1016/j.jiec.2024.07.014)

<sup>2</sup>Awad et al., Chemical Engineering Journal, 2021, [doi.org/10.1016/j.cej.2021.128412](https://doi.org/10.1016/j.cej.2021.128412)Get rights and content

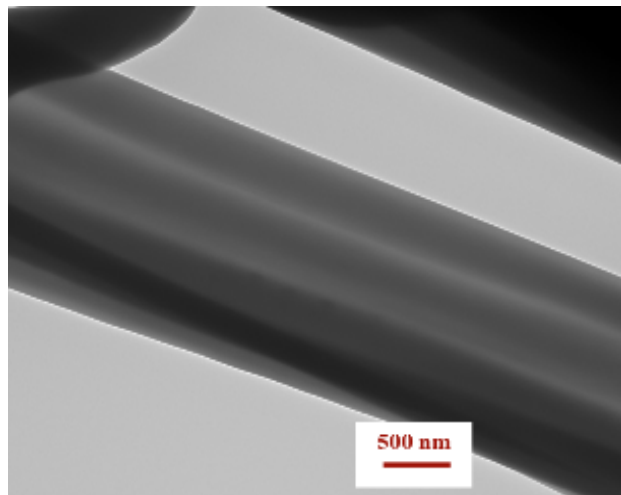
<sup>3</sup>Brockway et al., Journal of Vacuum Science and Technology B, 2020, <https://doi.org/10.1116/6.0000553>

<sup>4</sup>Andriolo et al., MRS Advances, 2017, <https://doi.org/10.1557/adv.2017.416>

<sup>5</sup>Hung et al., Journal of Power Sources, 2009, <https://doi.org/10.1016/j.jpowsour.2009.01.083>



**Fig 1.** TEM micrographs of electrospun  $Mn_2O_3$  electrodes fibers calcined at 600 °C for (a) 120 min and (b) 240 min. The fibers calcined for 120 min (Figure 1a) have a nearly hollow structure, indicated by dark exterior walls and a lighter fiber interior.<sup>3</sup>



**Figure 2.** Core-shell electrospun fibers consisting of a PCL-PEG shell and liquid core with bacteriophage for controlled-release of antibacterial therapy.<sup>4</sup>