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Electrospun Lignin-based Carbon Nanofibers and Their Application in Water Treatment

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Nano-sized carbon fibers have wide range of applications in composites, fuel cells, sensors, filtration, and nano energy systems. In response to the growing demand for lightweight high-performance carbon nanofibers that can be used in multifunctional fields, seeking low-cost precursors becomes a focal point of research. Lignin, the most abundant aromatic biopolymer with high carbon content and often an industrial byproduct, is considered a promising substitution for traditional carbon fiber precursors such as polyacrylonitrile or pitch. Using lignin as a carbon nanofiber precursor not only presents an effective strategy for overcoming the cost barrier, but also makes carbon nanofibers more eco-friendly as lignin is a sustainable resource. In this work, lignin-based carbon nanofibers precursors were produced via electrospinning, followed by thermostabilization and carbonization. Two Alberta-based lignin samples, KLA and KLB, were cleaved from cellulose, hemicellulose, and ash with *Pseudomonas fluorescens* to explore the influence of bio-cleaning on the processability, carbonization and mechanical properties of produced precursors and carbon nanofibers. The electrospinning process was optimized using Design of Experiment methods with PEO as a spinning aid. For untreated KLA electrospun fibers, smallest fiber diameter, highest elastic modulus and tensile strength, uniform, and defect-free morphology were obtained at the optimal condition of lignin/PEO ratio of 95/5, PEO molecular weight of 1000 kDa, and electric field of 50 kV/m. Using the same optimal parameters, bio-cleaned KLA (Bio-KLA) fibers yielded 41% decrement in fiber diameter and higher than 2-fold increase in mechanical properties. Bio-KLA carbon nanofibers achieved an average diameter of 465 nm, tensile strength of 9.3 MPa, and elastic modulus of 1.9 GPa. The significant improvement in mechanical properties illustrated the effectiveness of impurity and defect reduction by bio-cleaning. For KLB, bio-cleaning converted the highly viscous and unspinnable lignin solution to one that could be easily spun into smooth fibers. Carbon nanofibers produced from Bio-KLB possessed fiber diameter of 279 nm, tensile strength of 16.7 MPa, and elastic modulus of 1.5 GPa. Ultrafine Bio-KLB-based carbon nanofibers were tested for their potential to adsorb methylene blue in water treatment. Substantially high adsorption capacity of 548.65 mg/g was obtained from the Langmuir model. The great mechanical performance and the potential application in dye treatment demonstrate the feasibility of adopting lignin as a cost-effective, high-quality, and green precursor for carbon nanofibers.

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