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Effect of phosphorous groups on the stabilization and activation of low-cost lignin fibers prepared by electrospinning

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Introduction

The feasible wider use of carbon fibers in many of their current and potential applications demands a reduction of their manufacturing costs. In this sense, the use of lignin as an abundant, renewable and low-cost carbonaceous precursor and a simple and versatile production technique, such as the electrospinning, represents an advantageous and promising approach [1-3]. Particularly, the devIlopment of high-value co-products from lignocellulosic biomass-derived industries, such as biorefineries and pulp and paper mills, could suppose a significant opportunity to reduce their associated costs and environmental impacts. However, the use of lignin itself in the production of carbon fibers requires of successive stabilization and carbonization steps that currently slow down, raises the price and, therefore, limits their commercialization and industrial application [1]. In this work, a new method to produce novel sub-micrometer carbon fibers by electrospinning of phosphorous-containing lignin solutions is proposed.

Experimental

Lignin fibers were prepared by electrospinning of Alcell® lignin solutions. A coaxial configuration was used (Fig. 1a) and the influence of different experimental parameters such as solution viscosity and concentration, flow rates and applied voltage was studied. The fibers were subsequently thermostabilized and carbonized under oxidizing and inert (N_2) atmospheres, respectively, up to different temperatures. After washing and drying, the carbon fibers were characterized by optical and electronic (SEM, TEM) microscopies, gas adsorption (N_2 (-196 ºC); CO_2 (0 ºC)), thermogravimetry, elemental analysis, TPD and XPS.

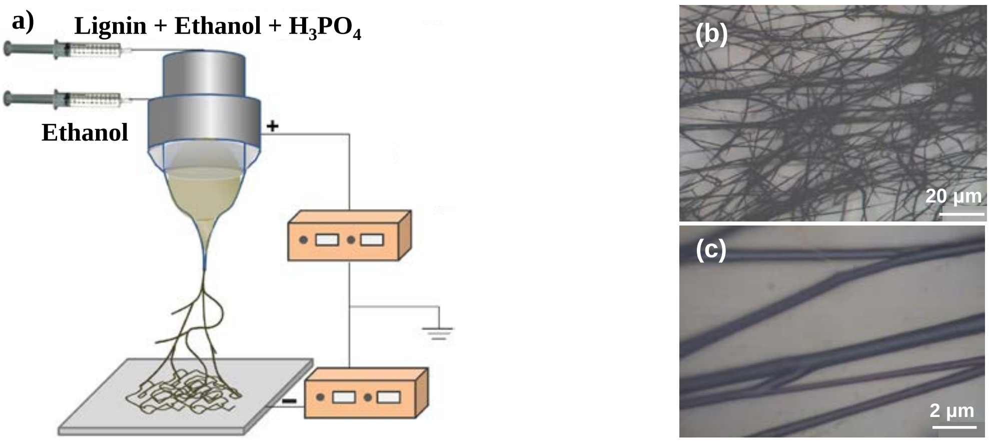

Figure 1. a) Experimental set-up for a coaxial electrospinning; b-c) Optical microscope images of different carbon fibers.

Results and Discussion

The presence of H_3PO_4 in the lignin precursor solution (i) increases its electrical conductivity, giving rise to branched fibrous materials with diameters ranging between 500 and 700 nm (average) (Fig. 1b-c); (ii) it remarkably accelerates their thermostabilization up to 50-60 times, avoiding fusion; as well as (iii) it allows their chemical activation directly during the carbonization step, leading to carbon materials with high surface areas, above 2000 m^2/g, a rich surface chemistry with different phosphorous and oxygen groups, with concentrations above 15 wt.% and a high oxidation resistance. Such properties make these materials very attractive in diverse applications like catalysts, catalyst supports or electrodes for energy storage.

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