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HEMP-derived activated carbon fibers by chemical activation with phosphoric acid

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ABSTRACT

Activated carbon fibers were prepared by chemical activation of hemp fibers with phosphoric acid at different carbonization temperatures and impregnation ratios. Surface properties of the activated carbons fibers were significantly influenced by the activation temperature and the impregnation ratio. An increase of either of these parameters produced a high development of the porous structure of the fibers. Activated carbon fibers with apparent surface area of 1350 m^2/g and mesopore volume of 1.25 cm^3/g were obtained at 550 °C with an impregnation ratio of 3. The activated carbon fibers presented a high oxidation resistance, due to the presence of phosphorus compounds on the carbon surface. The oxidation resistance results suggest that C–O–PO_3 and mainly C–PO_3 and C–P groups act as a physical barrier, blocking the active carbon sites for the oxidation reaction.

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1. Introduction

Hemp is one of the most productive and useful plants known. It grows quickly without any great need of pesticides in most locations and climates with only moderate water and fertilizer requirements, becoming a valuable and environmentally friendly crop.

Hemp has many industrial applications such as the production of paper, textiles, building materials, food, medicine, paint, detergent, varnish, oil, ink, and fuel [1]. However, hemp transformation generates a high proportion of waste. Specifically, the textile industry employs less than 50%$_w$ of the hemp, producing significant amounts of waste [2,3]. Spain produced about 40,000 ton of hemp residue only from the textile industry (2004). Development of recycling processes of such biomass waste is generating great interest, and the production of activated carbons could be an appropriate solution.

The world demand of activated carbon is steadily increasing due to its well-known extensive use as adsorbent for purification and separation in many processes. Activated carbons can be manufactured from many carbonaceous precursors, but the most commonly used raw materials are wood, coal, coconut shells and some polymers [4–8]. The use of several lignocellulosic by-products, such as nutshells, fruit stones, lignin, sugarcane and sawdust from a few rapid growing wood species, as renewable precursors for low cost activated carbon production, is being widely studied [9–23]. The use of hemp residues to produce activated carbon is very feasible and presents the advantage of the potential revalorization of a residual material. In this respect, preparation of activated carbon fibers by physical activation with steam and chemical activation with $ZnCl_2$ of hemp fibers have already been reported in the literature [2,3].

The aim of this work is the preparation of activated carbon fibers by chemical activation of hemp fibers with phosphoric acid, analyzing the influence of the activation temperature and the impregnation ratio on the activated carbon porous structure and surface chemistry. The oxidation resistance of the activated carbon fibers was also studied, analyzing the effect of surface phosphorus compounds, retained in the matrix structure upon activation, on the oxidation reaction.

2. Experimental

2.1. Preparation of carbon and activated carbon fibers

The starting materials were hemp fibers supplied by Alsativa (Sociedad Cooperativa Agraria Andaluza del Cáñamo, Pórtugos, Granada). Hemp was previously cleaned from leaves and tops and kept at room temperature. The fibers were cut in fractions of around 3 cm long.

The precursor was impregnated by incipient wetness with 85% (w/w) H_3PO_4 aqueous solution at room temperature and dried for 24 h at 60 °C in a vacuum dryer. The impregnation ratio, *R*, (H_3PO_4/precursor mass ratio) varied from 1 to 3.

The impregnated hemp fibers were activated under continuous N_2 flow (150 cm^3 STP/min), in a conventional tubular furnace. The activation temperature was reached at a heating rate of 10 °C/min and maintained for 2 h. Different activation temperatures within

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