

# The Modification of Acidic Surface Functionality of Wood-Based Activated Carbon

Yuvarat Ngernyen<sup>1</sup>, Chaiyot Tangsathitkulchai<sup>\*1</sup>, Malee Tangsathitkulchai<sup>2</sup>

<sup>1</sup> School of Chemical Engineering, Institute of Engineering

<sup>2</sup> School of Chemistry, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima 30000, Thailand

## Abstract

The purpose of this work is to introduce and characterize the surface oxygen functional groups on the wood-based activated carbon. The activated carbons prepared from eucalyptus wood sawdust were oxidized with hydrogen peroxide [H<sub>2</sub>O<sub>2</sub>], ammonium persulfate [(NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>], nitric acid [HNO<sub>3</sub>] and air in order to introduce and modify the surface oxygen functional groups. The existence of the oxygen functional groups was ascertained by several techniques including elemental analysis, determination of the point of zero charge (pH<sub>pzc</sub>), Boehm titration and Fourier Transform Infrared Spectroscopy (FTIR). The porous structure of the original and oxidized activated carbons were also characterized by nitrogen adsorption isotherm data at -196°C. The total amounts of oxygen functional groups reported as meq/g of combined carboxylic, lactonic and phenolic groups obtained by Boehm titration technique were in the following order: HNO<sub>3</sub> > air > H<sub>2</sub>O<sub>2</sub> > (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>. The results from FTIR showed that the activated carbon oxidized with air gave the highest concentration of carboxylic acid and lactonic groups, which was in agreement with Boehm titration's results. The results of elemental analyses also showed an increase in the oxygen contents of all oxidized activated carbons, with HNO<sub>3</sub> > air > H<sub>2</sub>O<sub>2</sub> > (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>. Fixation of the oxygen functional groups on the surface of the activated carbons decreased the pH<sub>pzc</sub>, surface area and porosity. The results indicated that oxidation with HNO<sub>3</sub> caused the drop in surface area and porosity of the activated carbons to a greater extent than with the other oxidizing agents.

**Keywords:** Activated carbon; Surface functional groups; Surface oxidation; Boehm titration; Adsorption isotherms

## 1. Introduction

Activated carbon has been widely used in adsorption processes because of its large surface area, high adsorption capacity and high degree of surface reactivity. The capacity of adsorption of activated carbon depends largely on its porous properties and to a lesser extent on the surface functionality. The contributing role of surface functional groups in adsorption is to interact with specific or polar adsorbates. The surface chemistry of activated carbon is determined by the acidic and basic character of the surface. The acidic behavior is associated with oxygen functional groups such as carboxyl, lactone and phenol. The purpose of this work is to modify the acid surface functional groups of wood-based activated carbon using different types of oxidizing agents both in liquid and gas phases.

## 2. Experimental

### 2.1. Materials

The eucalyptus wood was obtained from a furniture plant in a form of shredded wood chip and was milled and sieved to the size fraction of 20×30 mesh. The sieved wood sawdust was impregnated with 50 wt% H<sub>3</sub>PO<sub>4</sub> solution for 1 h with the chemical weight ratio of H<sub>3</sub>PO<sub>4</sub> and wood sawdust being 0.5. The impregnated wood sawdust was

carbonized at 400°C for 1 h. For liquid phase oxidation, the original activated carbon (AC) was oxidized with 40% m/v H<sub>2</sub>O<sub>2</sub> (AC-HO), saturated solution of (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub> in 2 N H<sub>2</sub>SO<sub>4</sub> (AC-NH) and 1 N HNO<sub>3</sub> (AC-HNO). For treatment with H<sub>2</sub>O<sub>2</sub> and (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, the experiments were performed at room temperature for 24 h while for treatment with HNO<sub>3</sub>, the experiment was performed by boiling with a reflux condenser for 24 h. For gas phase oxidation, the test activated carbon was oxidized with air (AC-air) in a tube furnace at 250°C for 24 h.

### 2.2. Characterization techniques

Different analytical techniques and instruments are used to detect and verify the existence of surface functional groups of the original and oxidized activated carbon. These include the Boehm titration method [1], Fourier Transform Infrared Spectrophotometer (FTS 175C, BIO-RAD), determination of point of zero charge (pH<sub>pzc</sub>) by the pH drift method [2], C, H, O, N analyzer (LECO) and surface area and pore volume analyzer (ASAP 2010, Micromeritics).

## 3. Results and discussion

The values of the acidity, basicity and the amounts of surface oxygen functional groups determined from Boehm titration are shown in Table I. The amounts of each acidic groups (carboxylic, lactonic and phenolic) increases with

\* Corresponding author

E-mail address: chaiyot@ccs.sut.ac.th