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Hydrogen storage characteristics of carbon fibers derived from rice straw and paper mulberry

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ABSTRACT

Highly porous carbon fibers based on rice straw and paper mulberry have been successfully prepared via wet spinning and carbonization process. From the comparison of the morphological structure and specific surface area, the porous carbon fibers derived from rice straw shows a high specific surface area of 2260 m^2/g. This material exhibits excellent hydrogen storage properties with a gravimetric hydrogen uptakes of 4.35 wt% at 77 K and 10 bar.

1. Introduction

Hydrogen is an advantageous energy source because it is renewable and its use would reduce the emission of pollution. It has been considered as an ideal energy medium for replacing fossil fuels such as oil and coal [1,2]. The high efficiency of hydrogen as a fuel is due to the fact that it is very light which, on the other hand, is the major obstacle for its efficient storage. The success of hydrogen economy in the future depends on our ability to discover efficient and cost-effective hydrogen storage materials. Considerable scientific efforts have been made to study carbon materials, metal-organic frameworks (MOF), metal hydrides [3–7], and so on. Among the above promising materials, carbon-based materials have received continuous interest as potential hydrogen storage media due to their high surface areas, tunable texture structures and low gas-solid interactions, which provide high hydrogen uptake capacity. Porous activated carbons can be manufactured from various biomass raw materials such as wood, straw wastes and coconut shell in order to obtain a cheaper and more cost effective product [8–10]. In these regards, we focused on controlling the morphology of activated carbon fibers derived from rice straw and paper mulberry in order to obtain the high capacity of hydrogen storage. The morphology and hydrogen storage capacity of porous carbon fibers would be influenced by properties of starting materials such as molecular weight or its distribution. The hydrogen storage properties of porous carbon fibers derived from rice straw and paper mulberry would be compared.

2. Experimental

The rice straw and paper mulberry, chopped to about 10 cm, were used as raw materials. They were treated for 24 h at room temperature under alkali conditions (20% NaOH) in order to break down lignin in the biomass and then obtain pure cellulose. The alkali treated rice straw and paper mulberry (12 g) were dissolved in 87% N-methylmorpholine-N-oxide (MMNO) (87 g) with propyl gallate (1 g) at 100 °C, where N-methylmorpholine-N-Oxide (MMNO) was chosen as the most appropriate solvents system for cellulose due to its ecological safety and high activity of interaction with cellulose [11]. The obtained dark honey colored solution was poured into a spinning vessel. A nitrogen gas supply was then used to force the solution through a single 0.1 mm spinneret orifice. Spinning dope was extruded at 100 °C from the spinning nozzle into the air. After running for 50 min in the air, it entered into the coagulant bath (water). The fiber was elongated in the coagulant bath by the tension applied by a take-up roller, then removed from the coagulation bath at a velocity of 10 m/min. After winding, the filaments on the bobbins were immersed in the distilled water for 24 h to extract remaining solvent. Finally, the fibers were dried at 50 °C in the oven for 6 h. The formed fibers were activated with various concentrations of KOH solutions (2 M, 4 M, and 8 M). The KOH treated rice straw and paper mulberry regenerated fibers were stabilized in air at 300 °C for 2 h

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with heating rate of 1 °C /min. The stabilized fiber was then carbonized in N_2 atmosphere at 800 °C for 2 h with heating rate of 5 °C /min. The activated carbon fibers from rice straw and paper mulberry are denoted as AC-RSF(activated carbon fibers from rice straw) RSF-KOH-2M, RSF-KOH-4M, RSF-KOH-8M, AC-PMF(activated carbon fibers from paper mulberry), PMF-KOH-2M, PMF-KOH-4M and PMF-KOH-8 M, respectively. The weight-average (Mw) and number-average (Mn) molecular weight of the cellulosic materials were determined by gel permeation chromatography (GPC) (YL9100, Youngin Instrument Co., Korea). Field-emission scanning electron microscopy (FE-SEM) images were taken on a HITACHI (S-4800) microscope. The BET surface areas of the prepared samples were measured from nitrogen adsorption-desorption isotherms at 77 K (ASAP 2020 Micromeritics). Hydrogen adsorption at 77 K was measured with hundreds of miligram of each samples by using a magnetic suspension microbalance system (ISOSORP HyGrA, Rubotherm).

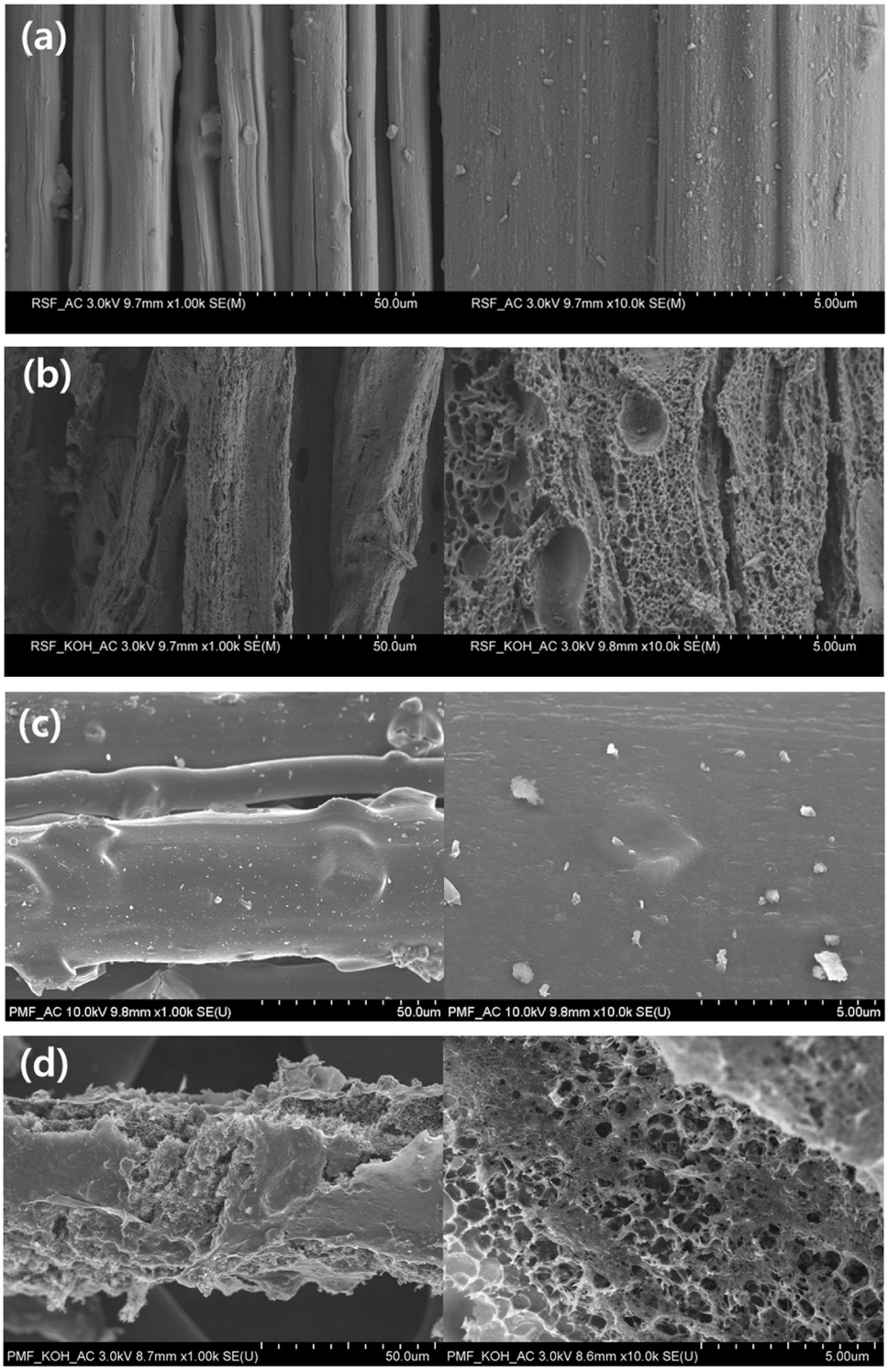

Fig. 1. FE-SEM images of the as-prepared products:(a) AC-RSF, (b) RSF-KOH-8M, (c) AC-PMF and(d) PMF-KOH-8M.