

Highly nanoporous carbon derived from potassium biphthalate by a template carbonization method



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ABSTRACT

A simple but efficient template carbonization method has been implemented for the production of highly nanoporous carbon by the reaction of potassium biphthalate with zinc, magnesium, or aluminum metal. The mass ratio and carbonization temperature are pivotal factors influencing the structures of the carbons. It explicitly reveals that the carbons produced in the potassium biphthalate-zinc metal system exhibit superior porosities and better electrochemical performances. Taking the **Zn-3:1-900** sample as an example, it has a large BET surface area of 1605.1 m² g⁻¹ and a high total pore volume of 1.18 cm³ g⁻¹. A large specific capacitance of 338.2 F g⁻¹ is achieved at a current density of 1 A g⁻¹ and it can retain a 100.5 F g⁻¹ even at a high current density up to 100 A g⁻¹ when measured in a three-electrode system. It also exhibits a high energy density of 76.7 Wh kg⁻¹ obtained in a two-electrode system. Furthermore, in the two kinds of electrode systems, all of the carbons display excellent cycling stabilities.

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1. Introduction

Supercapacitors comprise a family of electrochemical capacitors commonly determined by the storage principles of double-layer capacitance and *pseudo*-capacitance [1]. Supercapacitors are not limited by the electrochemical charge transfer kinetics of batteries, thus exhibiting high charge and discharge rates as well as lifetimes of over a million cycles [2]. This makes it bridge the gap between conventional capacitors and rechargeable batteries. From a practical viewpoint, capacitor materials are expected to have high surface area and/or pseudo-active species for high charge storage, proper pore size and pore structure for electrolyte diffusion, and high electrical conductivity for fast charge transportation [3]. Up to now, carbon-based materials that can well settle for the above requirements have proved to be elusive candidate for superior supercapacitors [4,5].

Since Knox and co-workers pioneered the template synthesis of porous carbons, the template carbonization method has become a powerful tool for producing carbon materials with precisely controlled structures at the nanometer level [6]. Unlike

the conventional activation carbon production by a carbonization process followed by activation treatment, the nanoporous carbon derived from template carbonization method can inherit the shape and/or size of the scaffold used and, in particular, no further activation process is required [7]. Therefore, it is more environmentally friendly and thus holds a great promise for carbon synthesis. At present, template has several modes, primarily including individual hard or soft template [8] as well as their combination one (so-called dual template) [9], for the formation of porous structures. With respect to hard template matrix, zeolite [10] and silica [11] are mostly employed for ordered porous carbon synthesis. However, it should be pointed out that this kind of template has to be dissolved out by corrosive acids, such as HF, after carbonization. Alternatively, other kinds of hard templates such as MgO and ZnO that can be readily removed by milder/greener acid (HCl or H₂SO₄) have been consequently proposed. These magnesium oxides or zinc oxides usually stems from the thermal decomposition of metals of acetate, citrate, nitrate or carbonate [12,13].

Herein, we have developed a simple but efficient template carbonization method to produce nanoporous carbon, using potassium biphthalate as carbon source and zinc, magnesium, or aluminum metal as template. The effects of mass ratio and carbonization temperature upon intrinsic structures were investigated in details. In addition, three-electrode system and two-electrode system with different electrolytes

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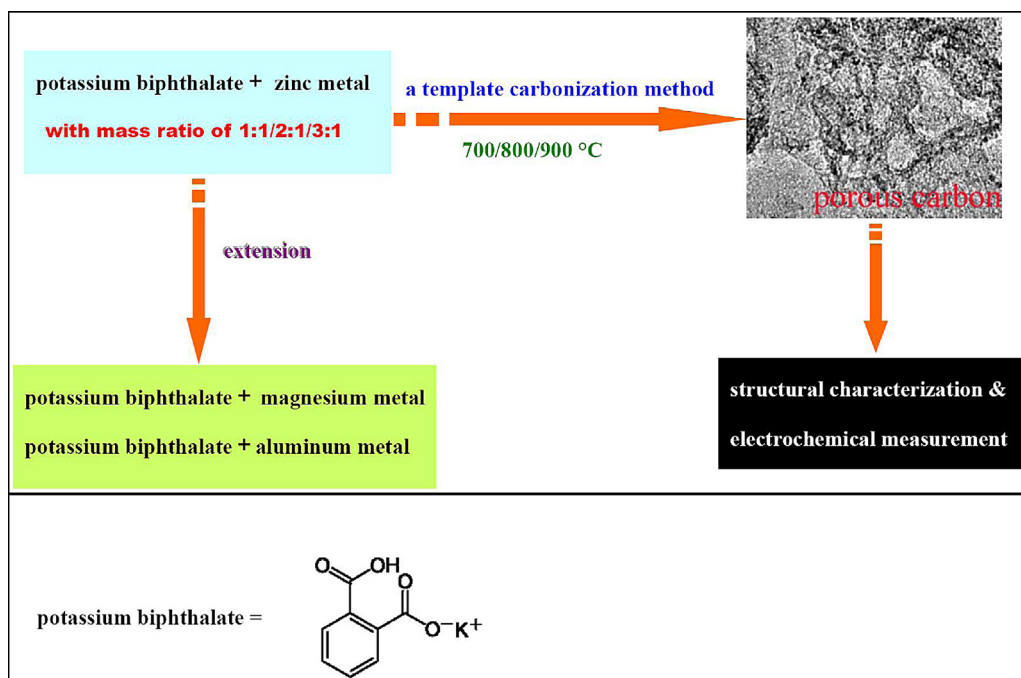


Fig. 1. Schematic illustration for the production of nanoporous carbon.

were applied to measure the corresponding electrochemical performances.

2. Experimental

In this work, potassium biphthalate and zinc metal with different mass ratios (1:1, 2:1, 3:1), for the first time, were reported to react each other for highly nanoporous carbon synthesis at different carbonization temperatures (700, 800, 900 °C) by a template carbonization method. The as-obtained carbon samples were named as **Zn-3:1-700/800/900** as well as **Zn-1:1/2:1-900**. Among them, the **Zn-3:1-900** has exhibited the highest electrochemical performance and thus it was deeply studied. Furthermore, as the extension of the present synthesis method, magnesium or aluminum metal was also used to produce nanoporous carbon, named as **Mg-3:1-900**, **Al-3:1-900**, by a template carbonization method. The schematic illustration for the production of nanoporous carbons can be depicted in Fig. 1.

2.1. Typical synthesis procedure for Zn-3:1-900 sample.

Potassium biphthalate and zinc metal with the mass ratio of 3:1 were ground, and then transferred to a porcelain boat, flushed with Ar flow for 30 min, and further heated in a horizontal tube furnace up to 900 °C at a rate of 5 °C min⁻¹ and maintained at this temperature for 2 h under Ar flow. The resultant product was immersed/sonicated with dilute HCl solution to remove soluble/insoluble substances, subsequently washed with adequate deionized water. Finally, the sample was dried under vacuum at 120 °C for 12 h to obtain the **Zn-3:1-900** sample.

2.2. Characterization

X-ray diffraction (XRD) patterns were obtained on a Rigaku D/MAX2500 V with Cu K α radiation. Raman spectra were recorded at ambient temperature on a Spex 1403 Raman spectrometer with an argon-ion laser at an excitation wavelength of 514.5 nm.

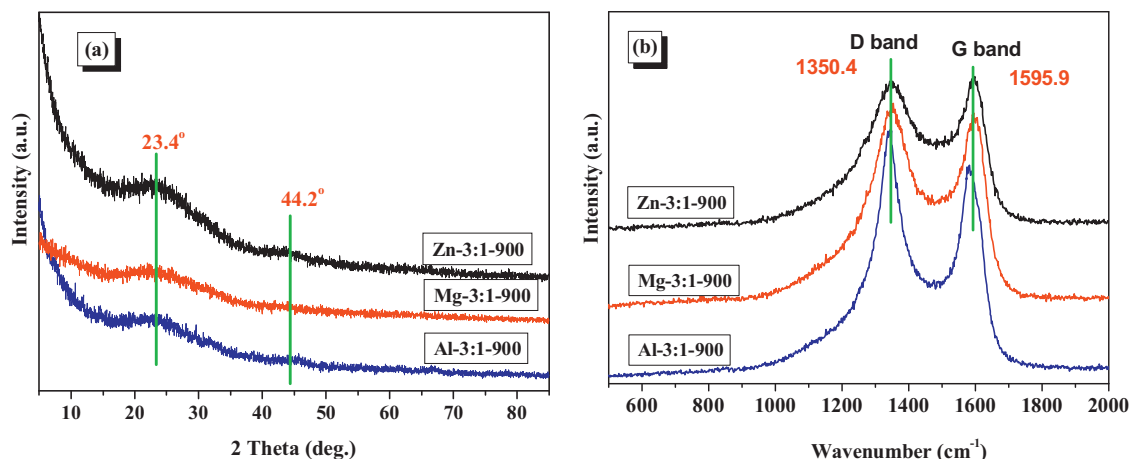


Fig. 2. Zn-3:1-900/Mg-3:1-900/Al-3:1-900 samples: (a) XRD patterns (the inset is the unit structure of potassium biphthalate); (b) Raman spectra.

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