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Review

Porous silica and carbon derived materials from rice husk pyrolysis char

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ABSTRACT

Biomass pyrolysis is considered one of the most promising technologies for production of sustainable fuels. Rice husk ash (RHA) contains over 60% silica, 10–40% carbon and minor other mineral composition, which is the by-product during the process of rice husk (RH) gasification/pyrolysis. More researchers become interested in how to use this industrial waste, because RHA is available in abundant, sustainable and almost free of cost. In recent years, RHA has been widely used as a construction material to product concrete, or as an adsorbent to adsorb organic dye, inorganic metal ions and waste gases. Due to its high silica content, RHA can be an economically viable raw material for the production of silicates and silica materials. Biochar and biosilica from high silicon-containing biomass, which can be fabricated into the high value-added porous carbon and silicon materials, such as silica/carbon nanoparticles, mesoporous silica/carbon, have lots of chemical and biological characterization for biomedical and electronical applications. Significantly, RH char, a hybrid composite can be converted in to the homogeneous carbon–silica nanocomposite (C/SiO_2) via extraction, which is directly used for synthesis of highly ordered mesoporous carbon and silica materials via a triconstituent co-assembly approach to prepare well-ordered mesoporous polymer–silica and carbon–silica nanocomposites by using resols as a polymer precursor, silicate oligomers as an inorganic precursor, and triblock copolymer F127 as a template. In addition, these materials could be put into extensively use as adsorbents and catalysts for other environmental pollutants treatment. Thus, it has a significant meaning to be engaged in more research works on the physicochemical characteristics of waste biomass to realize the "3R" rules of reducing, reusing and recycling.

Contents

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1. Introduction

Increased volatility in traditional fossil fuel markets has revived interest in the production of alternative fuels from biomass [1,2]. Biomass pyrolysis is considered as one of the most promising technologies to produce sustainable fuels that can be utilized for power generation systems or synthesis gas applications. Pyrolysis is a biomass decomposition process occurred at high temperature in the absence of oxygen. The end products are in the form of gas and liquid as well as carbon-rich solid residue.

Rice husk (RH) char or rice husk ash (RHA) is typical product from RH pyrolysis [3]. The disposal of RHA could be a problem because of its bulky, resulting from its lower density. In some areas, a large amount of RHA is treated as waste and landfilled, leading to air and water pollution. The airborne particles have been linked to respiratory disease in humans [4]. RHA usually contains more than 60% silica (SiO_2), 10–40% carbon and other minor mineral composition. Because RHA is available in abundant, sustainable and almost free of cost, more and more researchers become interested in how to use this industrial waste as resource.

In the past decades, RHA has been widely used as a construction material to product concrete [5–7], or as an adsorbent to adsorb organic dye, such as indigo carmine dye [8], and inorganic metal such as lead, mercury [9], Cd^{2+} and Zn^{2+} metal ions [10]. Due to its high silicon content, RHA can be an economically viable raw material for the production of silicates and silicon materials [11,12]. Some researchers have synthesized ZSM-5 zeolite or MCM-48 from RHA [13,14], but long time (generally about several days) and high temperature (generally at 150 °C) to synthesize these materials have limited this method to utilize RHA. Amorphous silica from RHA is usually extracted with alkali, such as sodium hydroxide [13,15], and sodium carbonate. The residue is obtained with above 50% carbon content after silica leached RHA. However, the disposal of the residue has not been mentioned in these papers. Production of activated carbon (AC) from RH has also attracted many researchers' attention. AC, which is a versatile adsorbent because of its good adsorption property, can be produced from a variety of raw materials, such as packing papers, plastic bottles, by-products of the timber industry (e.g., sawdust), straw, RH, seeds or fruit shell. Recently, there is an increasing interest in the production of AC from agricultural by-products and residual wastes. ACs derived from RH can be achieved through activation with chemical or physical means. Chemical impregnation with KOH or NaOH of RHA followed by activation at 650–850 °C results in ACs with extremely high Brunauer–Emmett–Teller (BET) surface areas (1413–3014 m^2/g) [16]. The aim of using KOH or NaOH is to remove the silica so as to increase the pore in RH. As far as we know, the content of amorphous silica in RH is around 20%, and even more in RHA. The disposal of these silica or silicate is not mentioned when AC is prepared from RH or RHA, either. The RHA is of high silica content and the loose wet structure of RH is destroyed after RH pyrolysis at high temperature. While SiO_2 is extracted from the RHA, the carbon content is increased greatly in the residue, which is more economical for AC preparation in order to realize the highest value of agricultural waste [17].

This review explores and summarizes, in detail, the exciting recent advances on the preparation of silica and carbon derived materials from RHA or RH char as shown in Fig. 1. It is noted that biosilica in RH and RHA can be recycled and reused for preparation

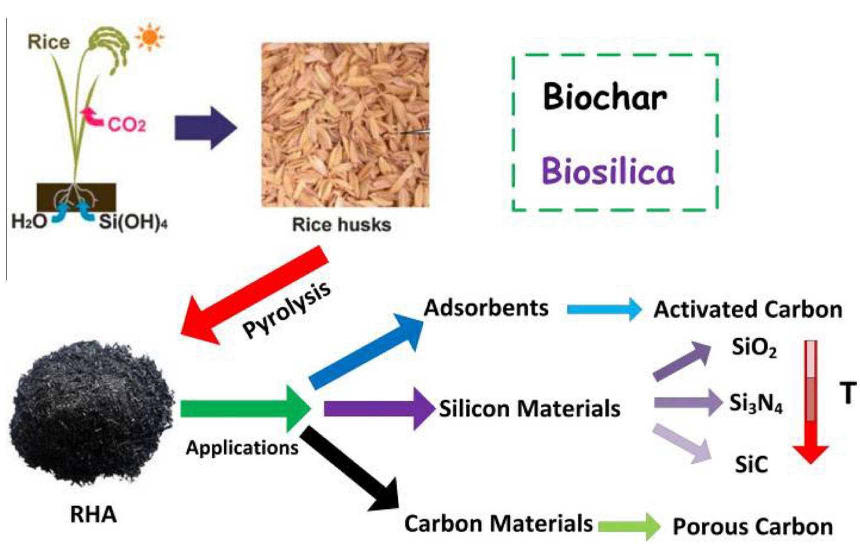

Fig. 1. Overview of the preparation of adsorbents, carbon and silicon derived materials from RHC.