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Synthesis and characterization of novel nitrogen doped biocarbons from distillers dried grains with solubles (DDGS) for supercapacitor applications

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ABSTRACT

Nitrogen doped biocarbon materials were effectively synthesised from distiller's dried grains with solubles (DDGS) using urea as the nitrogen source. The use of urea in the pre-treatment of DDGS on the fixation of elemental nitrogen in the biocarbon materials was investigated. Urea addition increases the nitrogen content in the obtained biocarbon, which is found to have 9.28 ± 0.67% for the DDGS:Urea weight ratio of 1:3. Physicochemical properties of the intrinsic and nitrogen doped biocarbon material were investigated by employing Raman and BET surface area analysis. Nitrogen rich biocarbon obtained using the DDGS:Urea weight ratio of 1:3 was taken for the fabrication of an electrochemical double layer capacitor. The fabricated symmetric supercapacitor with 2-electrode configuration showed the specific capacitance of 49.7 $F{\cdot}g^{-1}$ and 100.7 $F{\cdot}g^{-1}$ respectively for the intrinsic and nitrogen doped carbon materials at a current density of 0.5 $A{\cdot}g^{-1}$.

1. Introduction

Supercapacitors receive progressively more attention due to their large energy-storage densities, rapid charge/discharge rates and long cyclability (Li et al., 2015). Hence, they have been widely used for many applications, which include flexible and wearable electronics (Dubal et al., 2018), automotive (Kouchachvili et al., 2018), and electrical grid systems (Argyrou et al., 2018). A niche in which supercapacitors show promise is in the automotive sector, where supercapacitors display properties necessary for regenerative braking systems such as quick charge-discharge and good energy capacities (Frenzel et al., 2011). The electrochemical performances of the supercapacitors are mainly dependent on the physicochemical and morphological features of the electrode materials, which can be classified into three major categories such as carbon-based materials, transition metal compounds and conducting polymers (Deng et al., 2018). In particular carbonaceous materials that include activated carbons, carbon aerogels/xerogels, carbon nanofibers, carbon nanotubes and graphene have been extensively explored for the fabrication of supercapacitor electrodes (Q. Wang et al., 2016). Carbon materials exhibit many advantages for energy storage applications including, their eco friendliness, structural/morphological diversity, chemical stability against strong acids and bases, and relatively low cost (Frackowiak and Béguin, 2001). In addition to that, the amphoteric feature of the carbon materials leads to having inherent rich electrochemical properties at donor and acceptor levels (Frackowiak and Béguin, 2001). An effective capacitive and cycling performance of the supercapacitor can be attained through the high surface area and pores of the carbon materials and hence activated carbons are found to be the most promising (Frackowiak, 2007). Conventionally, the activated carbons are prepared from fossil resources. With the increasing concern over unsustainable production methods for high demand materials such as activated carbon, the production of environmentally-friendly alternatives to existing carbon-based technologies is a modern imperative (Snowdon et al., 2014).

As a result, the biocarbons (BioCs), which are the solid carbon

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