Journal of Energy Storage xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

Processing of α-Fe_2O_3 Nanoparticles on Activated Carbon Cloth as Binder-Free Electrode Material for Supercapacitor Energy Storage

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ARTICLE INFO

Keywords:
α-Fe_2O_3 Nanoparticles
Activated Carbon Cloth
Binder Free Processing
Supercapacitors
Energy Storage devices

ABSTRACT

The need for flexible energy storage devices has stimulated the interest in the development of nanostructures in supercapacitors for energy storage. In this work, a hydrothermal method is used to optimize the growth of α-Fe_2O_3 nanoparticles on carbon cloth (CC) and activated carbon cloth (ACC). The resulting composition, morphologies and microstructures displayed interesting features that are suitable as electrodes material for electrochemical capacitors. These are integrated as binder-free, symmetric device, which were then assembled and tested. The device assembled with the activated carbon cloth exhibited higher electrochemical performance (specific capacity of 295.56 mAhg^{-1}, specific energy of 37 WhKg^{-1} and specific power of 0.5 kWKg^{-1} in a 3 M KOH electrolyte at 1 A g^{-1}. The device also had good capacitance retention of 96.6 % after 10000 charge-discharge cycles. The implications of the results are discussed for potential applications of the α-Fe_2O_3-ACC in supercapacitors for energy storage systems that address global energy needs.

1. Introduction

New research directions towards flexible electronics have greatly inspired the development of thin film energy storage devices, [1,2] as well as thin-film batteries [3] and micro-supercapacitors (MSCs) [4]. Supercapacitors (SCs) have exceptional properties such as high power density, long lifetimes, facile fabrication, low cost, and little or no maintenance requirements [5] They are used in hybrid electric vehicles (HEVs) to increase efficiency. They can also complement or replace batteries in electrical energy storage applications [6]. Since hybrid vehicles turn off the engine completely when the car comes to a stop, supercapacitors can offer efficient power for rapid restarts. There is, therefore, an interest in the development of high performance energy storage devices. Furthermore, with the opportunities for further integration into electric or hybrid electric vehicles, it is increasingly important for supercapacitors to be small, lightweight, stretchable and flexible. However, currently available supercapacitors with liquid electrolytes are limited by the leakage of electrolyte, low energy densities (both in weight and volume), and the low yield of the electrode materials.

In the case of organic electrolytes and ionic liquids, they are associated with challenges of low ionic conductivity (high internal resistance), highly flammable, high electrolyte leakage and are quite expensive [7], but they are capable of withstanding very high potential which stands as a merit to these electrolytes. Apart from these electrolytes, redox active electrolytes are also being investigated, for example, Le-Qing Fan et. al. [8] reported a redox-active ionic liquid-based ionogel electrolyte (IGE) consisting of 1-butyl-3-methylimidazolium iodide (BMIMI) IL, poly (vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) and carbon nanotubes (CNTs) prepared using a solution casting method. The devices fabricated using this electrolyte displayed a high specific energy of 50.1 Wh kg^{-1} as a result of pseudocapacitance contribution from the redox-reactions and the increased ionic conductivity of CNTs network that provided fast ion transfer channel. A redox-active poly(vinyl alcohol) (PVA)-based gel polymer electrolyte (GPE) [9] with a maximum ionic conductivity of 61.1 mS cm^{-1} also achieved a high energy density of 43.1 Wh kg^{-1}. Research report on carbon hydrangeas with typical ionic liquid matched pores was also

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https://doi.org/10.1016/j.est.2020.102042
Received 25 July 2020; Received in revised form 26 October 2020; Accepted 29 October 2020