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Highly stable fish-scale derived lamellar carbon for high performance supercapacitor application

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Highlights

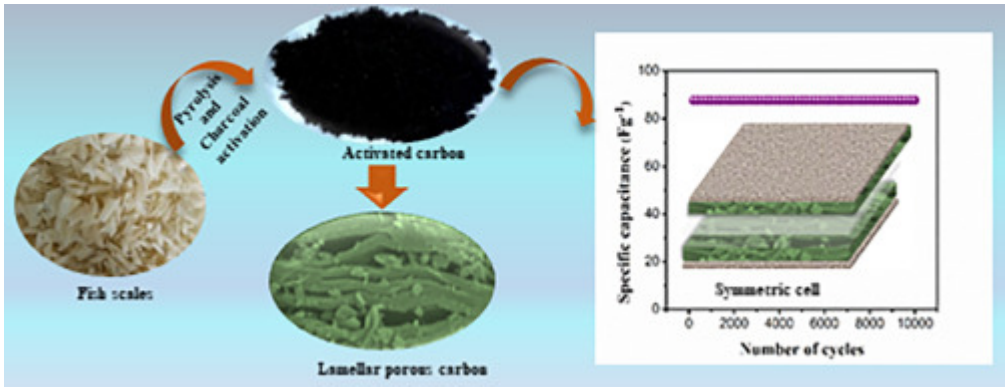
- Lamellar porous carbon was synthesised via facile one step chemical free approach.
- FSC exhibits superior electrochemical capacitance with an excellent cyclic stability.
- Symmetric cell achieves high volumetric capacitance of 259 Fcm^{-3} with 100% retention over 1000 cycles.

Abstract

Implementation of bio-waste as activated carbon precursor is the best strategy for preparation of low cost, ecofriendly and high performance supercapacitor electrode. Foregoing research work introduces simple physical activation for preparation of hierarchically porous activated carbon. The fish scale carbon shows enhanced specific

capacitance of 195 Fg^{-1} at 0.25 Ag^{-1} with high cyclic stability of 25,000 cycles at 4 Ag^{1} followed by great capacitance retention. Additionally, two electrode pouch cell delivers maximum volumetric capacitance of 259 Fcm^{-3} at specific capacitance of 88 Fg^{-1} and shows excellent 100% capacitance retention over 10,000 cycles. Interestingly fabricated symmetric cell delivers highest energy density and power density of 15 $Whkg^{-1}$ and 2200 Wkg^{-1} respectively. FSC exhibits attractive properties which are combination of plentiful porous structure, heteroatom self-doping and physicochemical stability, also in accordance of electrochemical performance fish scales are promising precursor for high performance carbon electrode material.

Graphical abstract



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Introduction

Exploring sustainable energy storage devices is an intense quest. Existing energy resources are meagre to effectuate the energy demand of the rapidly growing world's population. With increases in consumption of conventional fossil fuels and their limited stocks causes whooping prices of energy resources [1]. In the perspective of high energy density, available energy storage devices like batteries are very effective. However, the chemically energy storing phenomenon of batteries affects cyclic stability and ultimately decline its performance. Thus, more reliable supercapacitive devices with high energy density and power density, fast charging/discharging rates, and prolonged cycling stability have come into focus in recent years. But, relatively lower energy density than commercial batteries hinders their application [2]. In general, materials possessing large surface area, high electrical conductivity, hierarchically distributed porous structure and good chemical stability are favourable for supercapacitor application providing higher specific capacitance and excellent rate capability [3]. Nanostructured carbon materials possess excellent combination of all these properties and can be available in various

forms like activated carbon, carbon dots, graphene sheets, carbon nanofibers, carbon nanotubes, carbon aerogels, etc. make them most suitable electrode material for supercapacitor [4]. Owing to high surface area, good electrical conductivity, tailorable porous structure and chemical inertness activated carbon is widely used as electrode material amongst various forms of carbon nanomaterials [5]. Traditional sources of activated carbon include fossil fuels, coal, petroleum coke are scanty and expensive. Also, the process involved in preparation of activated carbon from these sources causes emission of harmful gases which are environmental pollutants. Hence, abundantly available, low cost, environment friendly and renewable "biomass" is highly desired as a source of activated carbons [6], [7].

Biomass is an organic waste and can be derived from plant waste, animal waste or marine waste [8]. Utilizing biomass for energy storage application is a green chemistry aspect and exceptionally attractive. Biomass based carbon exhibits interconnected hierarchical porous structure which provides excellent mass transport and charge transfer kinetics and naturally rich heteroatom content enhances electroactive sites and wettability of electrode [9]. In recent years various biomass derived carbon materials have been studied for supercapacitor application such as coffee endocarp [10], oil palm [11], paper flower [12], water hyacinth [13], pig bone [14], cow dung [15], tobacco stem [16], cotton stalk [17], bovine bone [18], sunflower seed shell [19], feather finger grass flower [20] and many more. Synthesis of biomass carbon is a two-step process that includes carbonisation using pyrolysis or hydrothermal treatment followed by activation (physical or chemical activation). Physical activation is simple, feasible, more eco-friendly as compared to chemical activation providing a relatively higher degree of graphitization and avoids maintenance of an inert atmosphere [21].

Recently, fish scale based activated carbon was pronounced for many applications like methylene blue adsorption [22], dye adsorption [23], and also in energy storage devices because of its extraordinary structure [24], [25]. Fish scale is basically composed of organic collagen fibres and inorganic hydroxyapatite. In carbonisation process organic collagen converts into carbon while formation of lamellar porous structure was devoted to presence of hydroxyapatite phase which serve as natural template. [26]. Here, in this work we use fish scales as activated carbon precursors for the preparation of supercapacitor electrodes. Rather than using a more complicated method we choose simple pyrolysis followed by physical activation to obtain naturally heteroatom doped carbon. The electrochemical characterization of as prepared carbon was carried out using CV and GCD in both three and two electrode systems with aqueous 1 M H_2SO_4 electrolyte. The highest specific capacitance in three electrode system was found to be 195 Fg^{-1} at 0.25 Ag^{-1} with 100% retention upto 25,000 cycles at 4 Ag^{-1}. While two electrode pouch cell assembly shows highest energy density and power density of 15 $Whkg^{-1}$ and 2200 Wkg^{-1} respectively with no loss in specific capacitance upto 10,000 cycles showing

excellent rate capability. This pioneering research provides not only excellent electrode material for supercapacitor application but also provides a low cost and eco-friendly strategy of bio-waste management.

Section snippets

Synthesis of electrode material

Fish scales of Rohu fish (*Labeo Rohita*) were collected from Khajari lake, Dist. Gondia, India. At the outset fish scales were washed several times with double distilled water and dried overnight in an air oven at 80°C. Dried fish scales were pyrolysed for 3 h at 300°C. After this, the sample was crushed to obtain fine pre-carbonised powder. A pre-carbonised carbon sample was then activated using physical activation in the charcoal atmosphere at 800°C in a muffle furnace for 1 h. Finally,…

Structural and morphological analysis

The novel fish scale carbon was prepared by facile physical activation method. Fig. 1a illustrate the experimental approach for preparation of fish scale carbon. In brief, synthesis of FSC includes initial pyrolysis at 300°C for 2 h. followed by physical activation at 800°C. The structural parameters of FSC sample was analysed using X-ray diffraction pattern. Fig. 1b shows XRD pattern of FSC which consists of two broad peaks which reveals the amorphous nature of as prepared FSC. The more…

Conclusion

In conclusion, a facile strategy of supercapacitor electrode material was employed with FSC. The as-synthesised FSC exhibits uniformly distributed porous morphology and have naturally doped heteroatom content. Interestingly, fish scales based carbon delivers high specific capacitance of 195 Fg^{-1} at 0.25 Ag^{-1} current density along with extraordinary capacitance retention of 100% at 25000 continuous charge discharge cycles. Such enhancement in the cyclic stability of carbon material makes it as a …

Credit authorship contribution statement

Pooja A. Zingare: Data Curation, Investigation and writing original draft.

Sanjay J. Dhoble: Writing- Reviewing and Editing.

Abhay D. Deshmukh: Conceptualization, resources and supervision.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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