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Carbon dots as a sustainable electrolyte enhancer in aqueous alkaline electrochemical capacitors

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ABSTRACT

In the endeavour to increase the energy density and to widen the potential window of aqueous alkaline electrochemical capacitors (EC), this study explores the role of carbon dots (CDs) as an additive in potassium hydroxide electrolyte. The CDs with an average size of ~2.2 nm and negative surface potential are synthesized from a dispersion of palm kernel shell powder in water using a low-temperature hydrothermal process. Electrochemical measurements show that the CD–electrolyte ion (K^+) interaction has improved counter ion adsorption in porous carbon electrodes via lowering the characteristic resistances and time constants, which significantly improved the fraction of adsorbed charges than diffusively stored. The improved ionic conductivity is attributed to the improved wettability introduced by the hydrophilic functional groups in the CDs. These parametric changes widened the potential window and marked an 80 % increase in the specific energy and over a 10 % increase in specific power in a practical EC with similar mass-loading as commercial devices. The device with CDs demonstrated superior cycling stability and Coulombic efficiency than the control device without them. These findings underscore the potential of CDs as a promising avenue for advancing the performance parameters of aqueous electrolyte EC, aligning with the overarching goal of realising economical, environmentally friendly, and sustainable energy storage solutions.

1. Introduction

The quest for electrical energy storage devices with better charge storability and deliverability from materials of sustainable resources has gained significant attention recently as an effort to confront climate change. Traditional battery technologies that dominate the market face challenges in meeting the requirements of high-power applications, long cycle life, and rapid charge-discharge capabilities. Furthermore, conventional electrode and electrolyte materials in present-day batteries lack sustainability and create several socioeconomic problems [1–4]. In this context, electrochemical capacitors, synonymously, supercapacitors (SCs), have emerged as a promising solution due to their capability of delivering high power density and long life spans using sustainable materials such as carbon. However, their relatively lower energy density than conventional batteries has been a crucial factor limiting their widespread adoption in numerous applications requiring both high power and energy densities [5,6].

The choice of a suitable electrolyte plays a pivotal role in determining the operational potential window, which directly affects the achievable energy density. Among the wide variety of electrolytes, aqueous electrolytes hold the upper hand by their lower toxicity, non-flammability, lower viscosity, higher ionic conductivity, lower internal resistance in comparison to organic electrolytes, and lack of current collector corrosion [7,8]. However, the potential window of aqueous electrolytes is limited by the water electrolysis occurring at 1.23 V, which prevents these electrolytes from achieving higher voltages and

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