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Novel electrodes for supercapacitor: Conducting polymers, metal oxides, chalcogenides, carbides, nitrides, MXenes, and their composites with graphene

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Abstract

The recent electronic appliances and hybrid vehicles need a high energy density supercapacitor that can deliver a burst and a quick power supply. The high energy density supercapacitor can be obtained by designing proper electrode materials along with appropriate electrolytes. This review begins with different mechanisms of energy storage, giving a brief idea regarding how to design and develop different materials to achieve proper electrodes in the pursuit of high-energy density supercapacitor without compromising its stability. This review later focuses on the engineering of different electrode materials like conducting polymer, metal oxides, chalcogenides, carbides, nitrides, and MXenes. Lastly, the hybrid electrodes made up from composites between graphene and other novel materials were investigated. The hybrid electrodes have high chemical stability, long cycle life, good electronic properties, and efficient ionic transportation at the electrode-electrolyte interface, showing great potential for commercial usage.

Introduction

Researchers across the globe look for green energy technology to decrease the dependence on fossil fuel to mitigate pollutants and their adverse effects. [1], [2] The development and implementation of renewable energy sources in the modern society are an urgent need. [3], [4] Renewable energy sources have adherent problems such as they depend upon the time of day and weather conditions. It is necessary to advance energy storage technology so energy will be available irrespective of time and energy source readiness. [5], [6] To address this concern, batteries and supercapacitors are considered as two types of most significant electrochemical energy storage devices. [7], [8], [9], [10], [11], [12] Batteries have features of high energy density, steady linear discharge at a high specific voltage which is implemented as energy back up for commercial applications. [6], [13] However, they have limitations like low power density, low cycle life, and explosive in nature. [14] Supercapacitors are ultimate candidates due to high power density, long cycle life (>100,000 cycles), quick charge and discharge, and quick burst power supply which is essential in electronic and electrical appliances. [4], [13], [15] The power output of supercapacitor is higher than that of the battery ($0.5–10 KW kg^{-1}$) but lower than that of a capacitor. Nevertheless, specific energy is the highest for supercapacitor. Supercapacitors have the advantage of high power performance down to 40 °C, which is difficult for batteries. [16] Another advantage of supercapacitors is safe nature for high power delivery (during the charging-discharging process).