Green Synthesis of Cobalt Sulphide as an Electrode Material for Supercapacitor Application

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Abstract

The growing global demand for efficient, sustainable, and high-performance energy-storage systems has intensified research into supercapacitor materials. Supercapacitors, known for their high power density, long cycle life, and rapid charge–discharge capabilities, occupy an important technological niche between traditional capacitors and batteries. Their performance, however, depends largely on the properties of the electrode materials used. Among several transition-metal compounds, cobalt sulphide (CoS, Co_9S_8, Co_3S_4, etc.) has emerged as a promising electrode material due to its rich redox activity, high electrical conductivity, and favorable pseudocapacitive behavior. In recent years, the green synthesis of cobalt sulphide has gained significant attention as it offers an environmentally benign, low-energy, and sustainable alternative to conventional chemical methods. Green synthesis utilizes plant extracts, microorganisms, and eco-friendly reaction conditions to produce nanostructured cobalt sulphide with desirable properties. This article explores the principles, methods, advantages, and supercapacitor performance of green-synthesized cobalt sulphide, highlighting its potential for next-generation energy-storage devices. Traditionally, cobalt sulphide nanostructures are synthesized by hydrothermal reactions, solvothermal processes, chemical precipitation, or thermal decomposition, techniques that typically require harsh reducing agents, toxic solvents, and high temperatures. Such methods, though effective, impose environmental and economic burdens. In contrast, green synthesis adopts sustainable practices by employing naturally derived reducing and stabilizing agents from plant extracts (such as aloe vera, neem, ginger, green tea, or fruit peels), bacteria, fungi, or algae. These biological systems contain phytochemicals—polyphenols, flavonoids, alkaloids, tannins, and proteins—that act as reducing agents to transform cobalt and sulphur precursors into cobalt sulphide nanoparticles. Beyond reducing the use of hazardous chemicals, these phytochemicals also serve as capping agents, preventing agglomeration and enabling the formation of controlled nanostructures. A typical plant-mediated green synthesis of cobalt sulphide involves extracting bio-active compounds from plant parts through simple aqueous extraction. The resulting extract is mixed with cobalt salts such as cobalt nitrate or cobalt chloride. A sulphur source—commonly thiourea, sodium sulphide, or even sulphur-containing bio-molecules—is then added. The phytochemicals initiate and regulate nucleation and growth of cobalt sulphide particles at relatively low temperatures. This mild reaction environment reduces energy consumption, making the method suitable for large-scale and cost-effective production. The synthesized cobalt sulphide is further washed, dried, and sometimes annealed at low temperature to improve crystallinity. The resulting material often exhibits unique morphologies such as nanoflakes, nanospheres, nanorods, or porous structures, all of which contribute to enhanced electrochemical performance. The green synthesis of cobalt sulphide offers an eco-friendly, scalable, and efficient approach to producing high-performance electrode materials for supercapacitors. By leveraging the natural reducing and stabilizing abilities of plant extracts and biological systems, researchers can create nanostructured cobalt sulphide with superior morphology, conductivity, and pseudocapacitive behavior. These features contribute to high specific capacitance, excellent rate performance, and prolonged cycling stability. As energy-storage technology continues to evolve, green-synthesized cobalt sulphide stands out as a sustainable and technologically promising material capable of supporting next-generation supercapacitors and advancing global clean-energy goals.

Keywords: Green, Synthesis, Cobalt, Sulphide, Electrode, Supercapacitor