Fe_2O_3 based supercapacitors derived from electric arc furnace dust

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The increasing global energy demand—driven by population growth, industrialization, and the shift toward sustainable technologies—has emphasized the need for energy storage systems that are both efficient and reliable [1]. In this regard, supercapacitors have attracted significant interest as next-generation energy storage devices due to their superior cycle life, low weight, high power density, and stable operation over a wide temperature range [2].

Transition metal oxides are among the most promising electrode materials for supercapacitors owing to their high specific capacitance and wide electrochemical windows. Their charge storage is primarily based on pseudocapacitive mechanisms involving fast and reversible redox reactions both on the surface and within the bulk of the material [3]. However, conventional synthesis methods for metal oxides often require high temperatures, controlled environments, or complex procedures, increasing energy use and production costs.

To address these challenges, the use of recycled waste-derived materials as electrodes has gained attention, offering both cost reduction and environmental benefits [4,5]. Electric arc furnace dust (EAFD), a byproduct of steelmaking, is rich in metal oxides formed by the condensation of volatilized metals in exhaust filters [6]. Its composition makes it a promising low-cost and energy-efficient raw material for the fabrication of metal oxide-based supercapacitor electrodes.

In the current study, EAFD was subjected to an acid leaching process using H_2SO_4 solutions to extract iron and other metal ions into solution. The resulting leach liquor was subsequently treated through a jarosite precipitation process to selectively remove iron in the form of jarosite. The obtained jarosite phase was then thermally decomposed via calcination to produce Fe_2O_3 particles. The structural and morphological properties of the synthesized Fe_2O_3 were thoroughly characterized by X-ray diffraction (XRD) to identify its crystalline phases, and by scanning electron microscopy (SEM) to examine its surface morphology and particle size distribution. The synthesized Fe_2O_3 was further utilized as an electrode material for the fabrication of asymmetric coin-cell supercapacitors. The electrochemical performance of the assembled devices was systematically evaluated using a combination of cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and galvanostatic charge-discharge (GCD) techniques. These electrochemical analyses provided insights into the specific capacitance, charge–discharge behavior, and cycling stability of the Fe_2O_3-based supercapacitors, highlighting the material's potential for use in energy storage applications.

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