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Sustainable synthesis of cobalt nanoparticles for supercapacitors application

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1. Introduction

Supercapacitors belong to a category of electrochemical energy storage systems distinguished by their impressive power density and specific capacitance. These systems have the capability to efficiently release energy with high density within a relatively brief time period. Supercapacitors have garnered significant attention due to their benefits, including extended cycle life, high power density, rapid charge-discharge rates, and safe operation.

Many techniques to produce nanoparticles use toxic chemical reductants, require long reaction times, and involve high-temperature treatments, which impede scalability. In contrast, gamma radiation synthesis offers an appealing alternative for nanoparticle fabrication due to its environmentally friendly characteristics. This method operates at room temperature in an aqueous solution, eliminating the need for toxic reagents or the production of unwanted by-products. As a result, no additional purification is necessary.

This study focuses on developing electrodes based on cobalt oxide nanoparticles produced using gamma radiation for supercapacitors application.

2. Methodology

A 15 mL solution of cobalt oxide nanoparticles was prepared by mixing cobalt acetate tetrahydrate (0.1 M, >98%, Sigma-Aldrich) in ultrapure water in glass vials and irradiated with gamma radiation at 50 kGy. After irradiation, the dispersions were vacuum filtered using polytetrafluoroethylene filter paper (0.2 µm, Sartorius Stedim Biotech GmbH) and air-dried, following the procedure described by N.U. Saidin et al. (2023).

X-ray diffraction (XRD) measurements were performed on a X-ray diffraction from Rigaku, model SmartLab SE available at the Nuclear Reactor Center (CERPq-IPEN/CNEN-SP), equipped with copper tube and scintillation detector, with counting times of 6 seconds per step size of 0.1º.

Cyclic voltammetry (CV) experiments were carried out in a 0,1M KOH media to evaluate the electrochemical characteristics and performance. The working electrode was made of cobalt oxide, the counter electrode of carbon and silver served as the reference electrode.

3. Results and Discussion

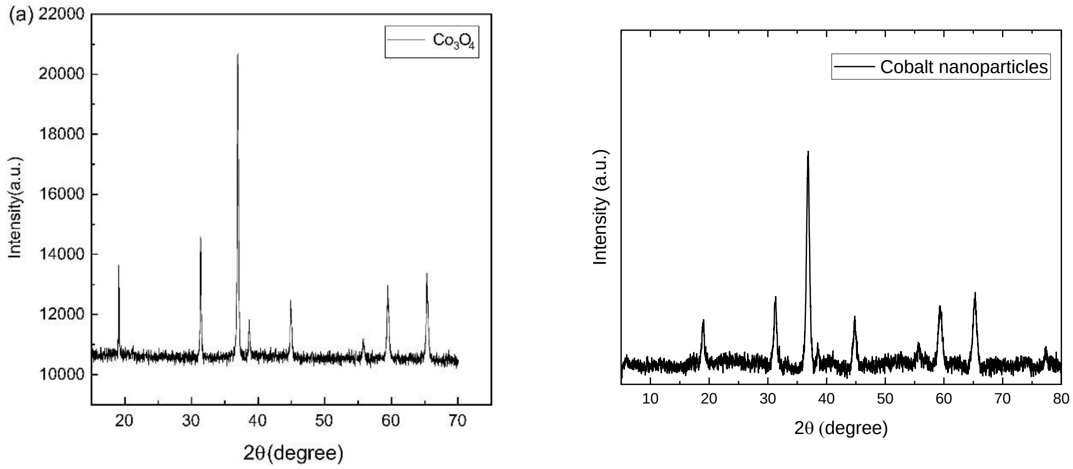

Figure 1: On the left, Reference diffractogram of cobalt oxide (Co_3O_4) [4]. On the right: diffractogram obtained from the nanoparticles synthesized.

From the diffractogram obtained for the nanomaterial, it was possible to detect peaks corresponding to Co3O4, which were compared with reference data from the literature. This enabled us to confirm the attainment of the expected material from the synthesis.

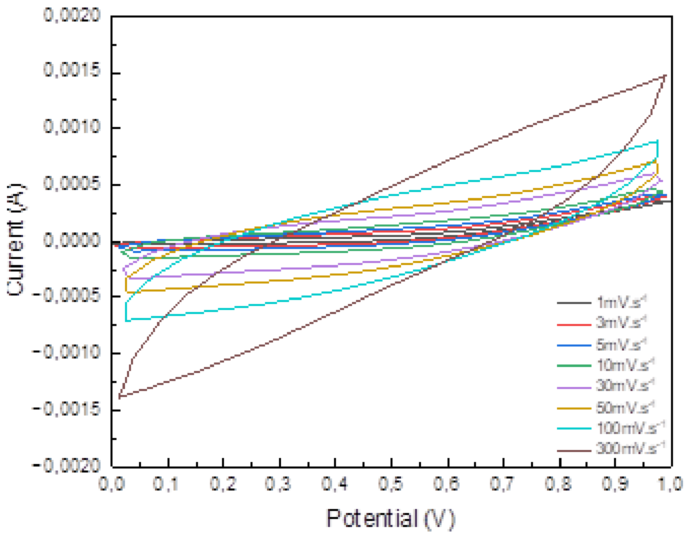

Figure 2: Cyclic voltammograms obtained for 0,1M KOH in different scan rates.

The cyclic voltammetry tests were conducted over a potential range from 0.0 V to 1.0 V, using scan rates of 1, 3, 5, 10, 30, 50, 100, and 300 mV/s. The patterns of the voltammograms obtained were consistent with those expected for supercapacitor materials, the current increasing with the rate of the VC. The curve shape, however, showed the typical pseudo capacitor behavior.

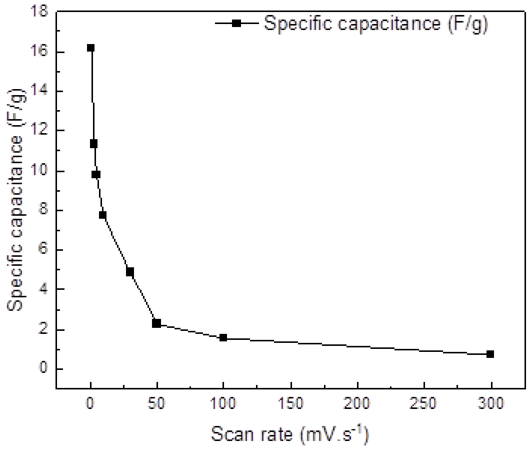

Figure 3: Specific capacitance curves calculated for various scan rates.

The specific capacitance of these electrodes was calculated from the CV curves according to the general equation (Eq. 1) [23]. In this equation, *C* represents the specific capacitance, *m* indicates the mass of the active material (g), V_f - V_i denotes the potential window (V), (v) represents the scan rate (V.s^{-1}), and *I(V)* refers to the current response at a given potential.

$$C = \frac{1}{mv(Vf-Vi)} \int_{Vi}^{Vf} I\,(V)dV \qquad (1)$$

From the specifically calculated capacitances obtained, it was possible to confirm the material's capacity to store energy and its potential for applications as supercapacitors.

4. Conclusions

Based on the results, the XRD analysis confirm the success in the synthesized of Co irradiated material, as well as to assess the potential of the obtained material for storage capacity. The VC curve showed the shape of pseudo capacitor behavior. However, it is necessary to emphasize the need for further electrochemical measurements, such as galvanostatic charge-discharge measurements and electrochemical impedance spectroscopy, to obtain information on the electrochemical stability of the obtained material and the energy storage mechanisms of the material.

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