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Fabrication and Experimental Testing of a Symmetric Supercapacitor Using Copper Foil Electrodes

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Abstract- ***Supercapacitors are electrochemical energy storage devices characterized by high power density, rapid charge–discharge capability, and long cycle life. This paper reports the fabrication and experimental testing of a symmetric supercapacitor using copper foil as the current collector and a carbon-based composite as the active electrode material. The device was fabricated using locally sourced materials, including activated charcoal, graphite powder, sodium silicate binder, and a sodium hydroxide aqueous electrolyte. Detailed quantitative procedures are presented: 56.84 g sodium silicate was dissolved in 100 ml de-ionized water to form a 2 M binder solution; 20 g activated charcoal and 4 g graphite were mixed with 8 ml binder in 55 ml water to form the conductive slurry; copper sheets of 18 cm × 4 cm were etched and coated using the doctor blade method. The device was charged for 250 s to 1.55 V and delivered a discharge current of 0.41 mA with a total discharge time of 641 s. From these measurements, the capacitance was calculated as 170 mF, the energy as 407.4 J, and the power as 0.64 W. The results confirm typical supercapacitor behavior and demonstrate the feasibility of low-cost copper foil-based devices for educational and low-power energy storage applications.***

Index Terms- ***Activated carbon, Capacitance, Copper foil, Electrolyte, Energy storage, Graphite, Supercapacitor***

I. INTRODUCTION

The increasing demand for efficient and sustainable energy storage systems has intensified research into alternatives to conventional batteries. Supercapacitors, also referred to as ultracapacitors or electrochemical capacitors, bridge the gap between traditional capacitors and batteries by offering high power density, fast charge–discharge rates, and long cycle life [1], [2]. Unlike batteries, which store energy through chemical reactions, supercapacitors store energy primarily through electrostatic charge separation at the electrode–electrolyte interface, enabling rapid energy transfer and excellent cycling stability.

Despite these advantages, the relatively low energy density of supercapacitors compared to batteries limits their application in long-duration energy storage. Consequently, considerable effort has been devoted to improving electrode materials, current collectors, and electrolytes [3]. Carbon-based materials such as activated carbon, graphite, graphene, and carbon nanotubes are widely used because of their high surface area and good electrical conductivity [4]. In practical devices, metal foils such as aluminum or copper serve as current collectors due to their low resistivity and mechanical robustness.

Copper foil is particularly attractive because of its high electrical conductivity, good mechanical strength, and low cost. This work focuses on the fabrication and experimental testing of a symmetric supercapacitor using copper foil as the current collector and a carbon-based composite as the active material. Emphasis is placed on a low-cost fabrication route using locally available materials and on reporting detailed quantitative procedures and measurements.

II. RELATED WORK

Extensive research has been conducted on supercapacitors employing various electrode materials and electrolytes. Activated carbon remains one of the most widely used materials due to its high surface area and affordability [1]. Advanced carbon nanostructures such as graphene and carbon nanotubes have been reported to enhance power and capacitance because of their superior electrical and structural properties [4].

In addition to electric double-layer capacitors, pseudocapacitive materials such as transition metal oxides and conducting polymers have been investigated to increase energy density through fast and reversible redox reactions [2]. Copper foil has been widely adopted as a current collector in electrochemical energy storage devices, including lithium-ion batteries and supercapacitors. Prior studies indicate that surface treatment and uniform coating of copper substrates with carbon-based materials can improve electrode performance and reduce internal resistance [3]. These findings motivate the use of copper foil in the present low-cost symmetric supercapacitor design.

III. MATERIALS AND METHODS

A. Materials

The materials used and their sources are summarized in Table I. De-ionized water was used in all solution preparations.

TABLE I
MATERIALS USED AND SOURCES

Material	Source
Copper sheet (scrap)	Local supply

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Material	Source
Activated charcoal	Qualitex Enterprise, Lagos
Graphite powder	Qualitex Enterprise, Lagos
Sodium silicate	Qualitex Enterprise, Lagos
Sodium hydroxide pellets	Joechem Chemicals, Port Harcourt
Ethanol, HCl, H_2O_2	Joechem Chemicals
De-ionized water	ACE-CEEFOR, UNIPORT
Casing, POS paper (separator)	Local stores, Choba

B. Synthesis of 2 M Sodium Silicate Binder

A 2 M sodium silicate solution was prepared by measuring 56.84 g of sodium silicate and dissolving it in 100 ml of de-ionized water. The solution was placed on a magnetic stirrer and mixed uniformly for 30 minutes to obtain a homogeneous binder solution. This sodium silicate solution was used as the binder for the conductive electrode material.

C. Preparation of Conductive Materials

The conductive slurry was prepared by measuring 20 g of activated charcoal and 4 g of graphite powder. To this mixture, 8 ml of the sodium silicate binder was added and dissolved in 55 ml of de-ionized water. The mixture was stirred on a magnetic stirrer with light heating until a uniform slurry was obtained.

D. Preparation of Electrodes

Copper sheets were cut from scrap copper material to dimensions of 18 cm × 4 cm. The copper sheets were first cleaned thoroughly with ethanol and further etched using a mixture of hydrochloric acid and hydrogen peroxide. The copper sheets served as the current collectors. After etching, the electrodes were allowed to dry. The prepared conductive slurry was then deposited on the copper plates using the doctor blade method. The coated electrodes were dried at room temperature and prepared for device assembly.

E. Synthesis of Electrolyte

Sodium hydroxide pellets were dissolved in de-ionized water and stirred until a uniform solution was obtained. This aqueous sodium hydroxide solution was used as the electrolyte. A suitable electrolyte should offer a wide voltage window, high electrochemical stability, high ionic concentration and conductivity, low viscosity, and low toxicity.

F. Device Assembly

A waste drug case was utilized as the device casing, while POS paper was used as the separator. Using a syringe, the electrolyte was added to the device, and the electrodes were positioned facing each other with the separator in between. The device was covered while exposing the terminals.

IV. EXPERIMENTAL SETUP AND MEASUREMENT PROCEDURE

The device was first charged using a DC power supply for 4 minutes 10 seconds (250 s). The maximum motor spin time was 260 s, and the total discharge time was 641 s. Using a digital multimeter, the electrical parameters were measured as:

- Voltage, $V = 1.55$ V,
- Current, $I = 0.41$ mA.

The capacitance was calculated using

$$C = \frac{Q}{V} = \frac{It}{V}, \tag{1}$$

the energy using

$$E = IVt, \tag{2}$$

and the output power using

$$P = VI. \tag{3}$$

The device was also tested using a DC motor. The motor was observed at maximum speed for 260 s and finally came to a halt after 641 s, which corresponds to the complete discharge time.

V. RESULTS AND DISCUSSION

From the measured values ($V = 1.55$ V, $I = 0.41$ mA, $t = 641$ s), the capacitance was calculated as

$$C = \frac{0.41 \times 641}{1.55} \approx 0.17\,\text{F} = 170\,\text{mF}.$$

The energy was calculated as

$$E = 0.41 \times 1.55 \times 641 \approx 407.4\,\text{J},$$

and the power as

$$P = 1.55 \times 0.41 \approx 0.64\,\text{W}.$$

Table II summarizes the measured and calculated parameters.

TABLE II
MEASURED AND CALCULATED PERFORMANCE PARAMETERS

Parameter	Value
Charge time	250 s
Maximum motor spin time	260 s
Discharge time	641 s
Voltage, V	1.55 V
Current, I	0.41 mA
Capacitance, C	170 mF
Energy, E	407.4 J
Power, P	0.64 W

The results confirm that the fabricated device exhibits typical supercapacitor behavior. Although the performance is modest compared to commercial devices, the use of simple materials and fabrication steps demonstrates the feasibility of low-cost energy storage devices for educational and prototyping purposes.

VI. CONCLUSION

A symmetric supercapacitor was successfully fabricated using copper foil electrodes and a carbon-based composite active material. Detailed quantitative fabrication steps and measurements were presented. The device achieved a capacitance of 170 mF, an energy of 407.4 J, and a power of 0.64 W. These results demonstrate the practicality of copper foil-based supercapacitors fabricated from locally available materials. Future work will focus on improving electrode microstructure, optimizing electrolyte composition, and enhancing device packaging to improve performance.

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