Development of a Microbial Electrolytic Capacitor for Energy Storage

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Abstract

This experimental study investigated electrocatalytic properties of a novel device consisting of a graphite/Tuff composite electrode combined with an aqueous bioelectrolyte (0.1 M NaCl) enriched with electroactive bacteria (EcB). Systematic electrochemical analyses using cyclic voltammetry (CV) and chronoamperometry revealed that this hybrid system has promising energy storage capacities under the applied potential. The involved mechanisms combined electrochemical double-layer phenomena at the porous surface of the carbonaceous material with redox processes catalyzed by the microbial biofilm. The results demonstrate significant catalytic efficiency, resulting in high charge densities and good system stability, opening up interesting prospects for the development of energy storage solutions incorporating biological components. This original approach combines advantages of nanostructured carbon materials with catalytic properties of electroactive microorganisms.

Keywords: chronoamperometry; CV; EcB.

Introduction•

The advancement of green energy technologies including wind and solar power [1] along with their applications, such as in electric vehicles [2], has driven the development of innovative energy conversion systems and electronic components to enhance efficiency and optimize energy consumption [3] The electrical energy system is made up of three main parts: generation, transmission and distribution systems. The last one is closest to the consumer and the most important one, as it is linked to the distribution of electrical energy from the source to the client [4]. To improve power factor, reactive power at the distribution channel must be reduced, which will automatically decrease total reactive current. The electrolytic capacitor (EC) installed in distribution circuit will contribute to reactive power reduction, as it provides reactive power required

•The abbreviations list is in page 242.

for the load [5, 6]. EC due to deburring process is not sufficient, and its degree of impregnation is insufficient due to non-uniform and insulating materials. Inadequate technology and other manufacturing problems caused by insulation defects can shorten the life of a EC [7]. A new method controlling multi-objective optimization has been developed [8]. Multi-objective energy management increases energy conversion efficiency, prevents battery degradation and optimizes energy consumption in real time [8, 9]. It can be performed using adaptive weighting based on fuzzy logic and multi-objective evolutionary algorithms [10, 11].

Experiment

The work was carried out at Molecular Electrochemistry and Inorganic Materials laboratory at Beni Mellal Faculty of Science and Technology, using three electrodes connected to the EC: reference electrode, connected to the EC with a rod; working electrode, connected to the relevant EC by a wire; and counter-electrode, i.e. auxiliary electrode, connected to part of the EC. These electrochemical measurements were carried out using a potentiostat (model PGSTAT 100, Ecochemie BV, Utrecht, Netherlands) equipped with VoltaMaster 4 software. The electrolyte used in this work consisted of EcB (Gram-negative) and 0.3 g NaCl.

Results and discussion

Fig. 1 shows two CV recorded at CPE and Tuff-modified CPE surfaces, in a 0.1 M NaCl solution, at 100 mV/s.

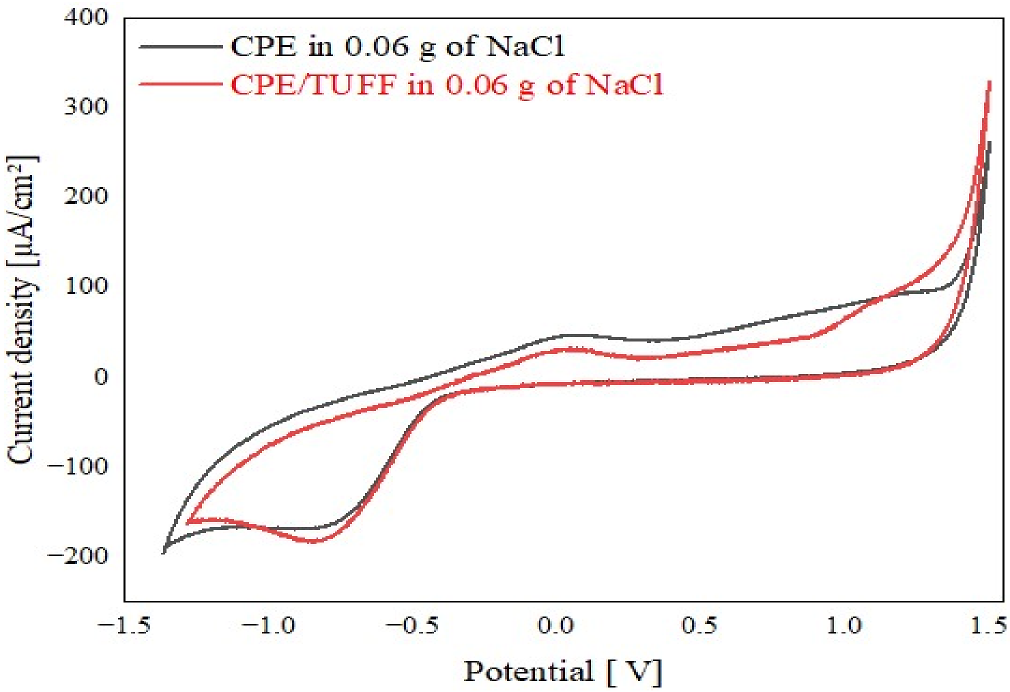

Figure 1: CV recorded at surface electrodes of CPE and Tuff-modified CPE in NaCl.

Obtained CV results show well-defined and different allures, which indicates that electrode modification was successful.
Fig. 2 shows two CV recorded on the CPE surface in a solution containing mutated EcB and on the surface of Tuff-modified CPE in an electrolytic medium containing NaCl (0.1 M) and mutated EcB, at a velocity of 100 mV/s. Specific capacitance (Cp = 9.65 F/g) of EcB was determined from these CV.

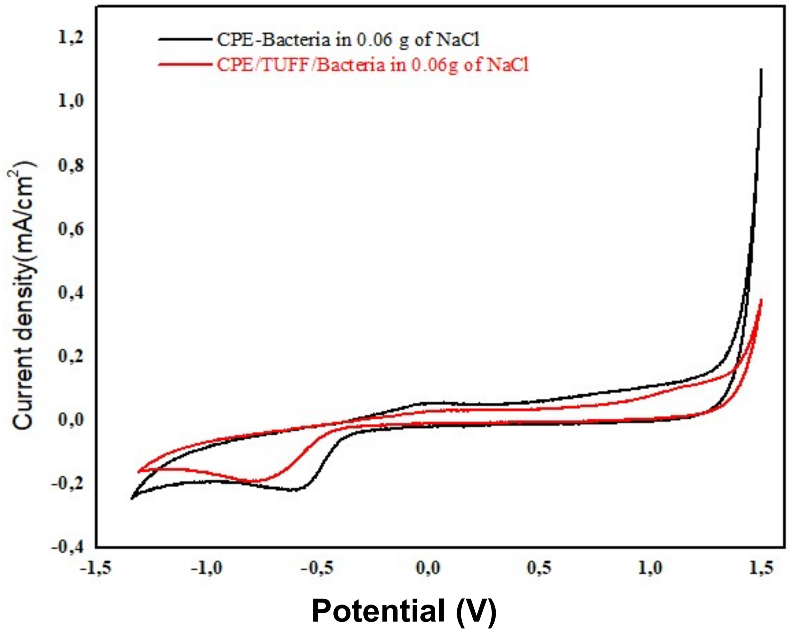

Figure 2: CV recorded on the surface of CPE/EcB and TUFF-modified CPE/EcB electrodes.

Fig. 3 shows charge/discharge at 10 mA/cm^2 of Tuff-modified CPE electrode in an electrolyte medium consisting mainly of NaCl (0.1 M) containing EcB.

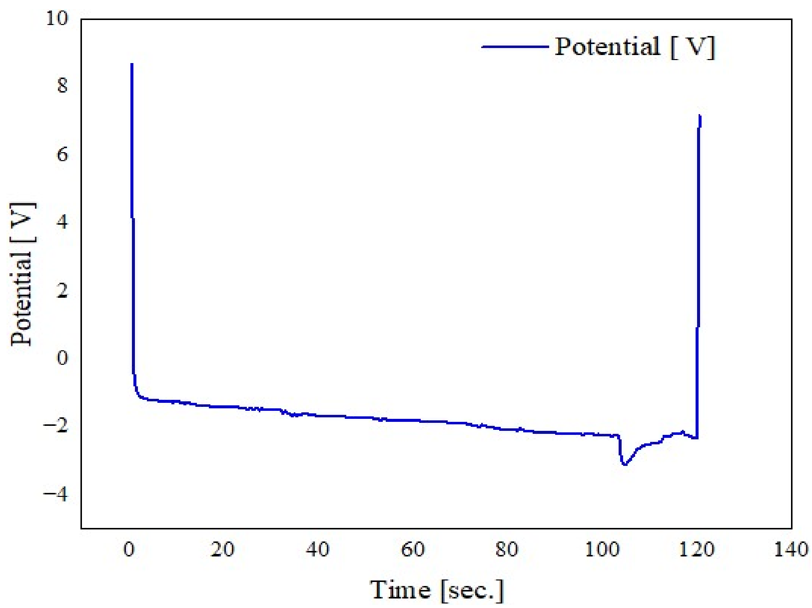

Figure 3: EC charge/discharge curve at 10 mA/cm^2.

Fig. 4 shows charge/discharge at 50 mA/cm^2 of Tuff-modified CPE electrode in an electrolyte medium of 0.1 M NaCl containing EcB.

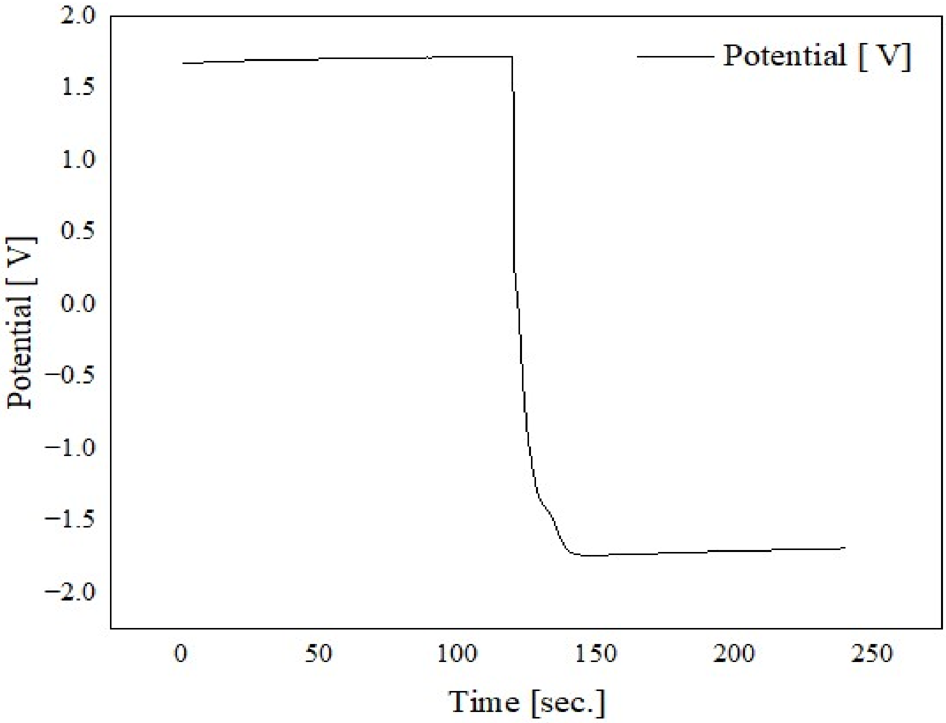

Figure 4: Charge/discharge curve at 50 mA/cm^2.

Fig. 5 shows CV recorded at the surface of Tuff-modified CPE electrode. The shape of this CV is almost rectangular, within a range of more than 1200 mV.

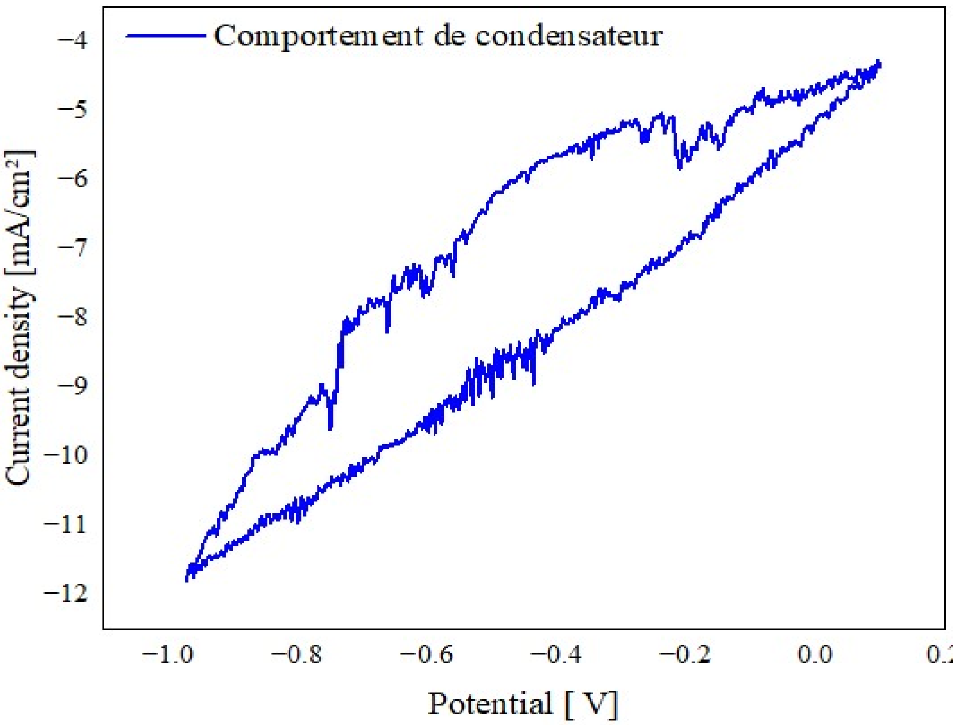

Figure 5: CV recorded on the surface of the Tuff powder-modified CPE electrode.

Fig. 6 shows charge/discharge at 10 mA/cm^2 for Tuff-modified CPE in an electrolytic medium consisting essentially of NaCl (0.1 M) and EcB. This image was obtained after several voltammetric cycles, and from these results one concludes that EC maintained its performance after several charge/discharge cycles.

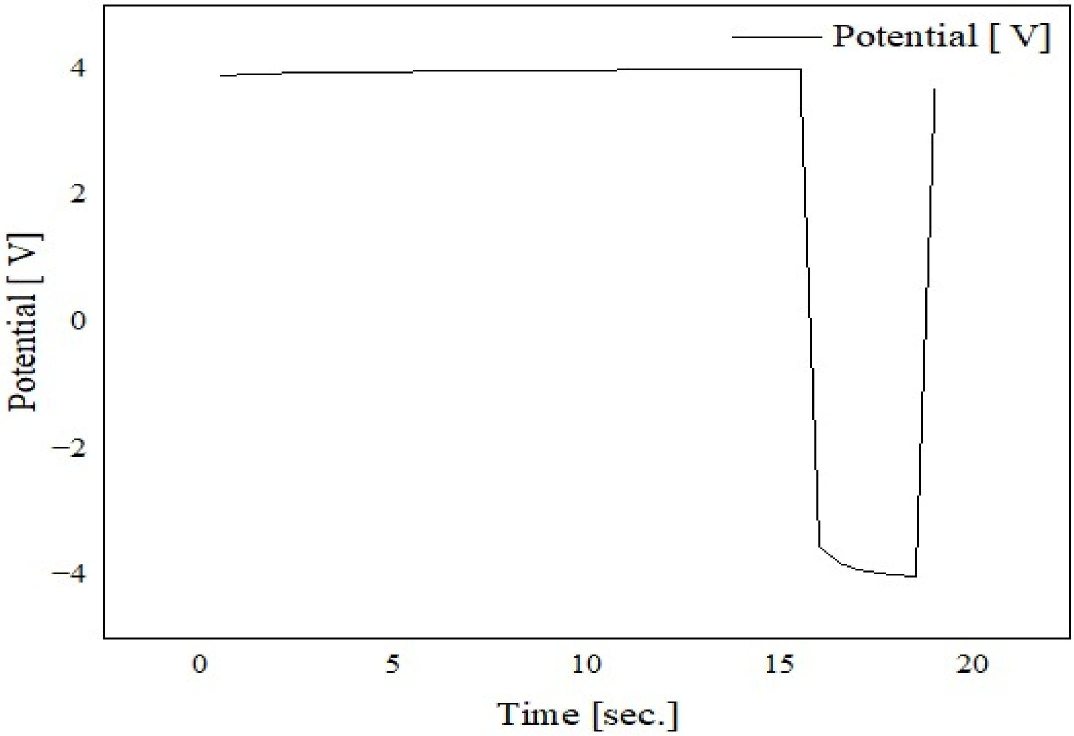

Figure 6: Charge/discharge curves at 10 mA/cm^2 for Tuff-modified CPE electrode in 0.1 M NaCl with EcB.

Conclusion

This work presented an electrochemical EC, primarily intended for environmental and health fields, made up of two electrodes consisting essentially of carbon graphite and TUFF, and a dielectric based on insulating paper, impregnated in an electrolyte composed of NaCl (0.1 M) and mutated EcB. The electrode material was prepared to well-studied standards, in order to improve energy storage time (charge) and enhance specific capacity of CPE, so as to release it on demand (charge). The two methods used in this work were CV and chronoamperometry.

Authors' contributions

M. Oukbab: corresponding author; did experimental protocol; reviewed and edited original draft of the manuscript. **M. Enasraouy**: investigation; data analysis. **R. Najih**: acted as supervising professor. **A. Chtaini**: acted as supervising professor; designed experimental protocol; wrote initial draft of the manuscript.

Abbreviations

CPE: carbon paste electrode
CV: cyclic voltammetry
EC: electrical capacitor
EcB: *E.coli* bacteria
NaCl: sodium chloride

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