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Charge–discharge performance of carbon fiber-based electrodes in single cell and short stack for vanadium redox flow battery

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HIGHLIGHTS

- Carbon-fiber based electrodes are investigated in a zero-gap flow field cell configuration.
- Charge–discharge curves are carried out in single cell and short stack for VRB application.
- Three electrode half-cell data are corroborated both in single cell and short stack for VRB.

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ABSTRACT

Electrode materials, having a different graphitic character, are investigated by using a zero-gap flow field cell configuration for vanadium redox flow battery applications (VRFBs). Carbon felt (CF) and carbon paper (CP) are used as electrodes for the membrane–electrode assemblies (MEAs) realization. The samples are electrochemically characterized both as-received and after chemical treatment by using a 5 cm^2 single cell. A Nafion 117 membrane is used as polymer electrolyte separators. A MEAs scale-up from 5 to 25 cm^2 is carried out in order to assembly a 3-cells short stack in series connected. Charge–discharge cycles are carried out both in a small area single cell and in a 3-cells short stack for all samples. CF treated and untreated samples show SOC values of 45% vs. 22% at 60 mA cm^{-2}, respectively. After the chemical treatment, the worst performance of the CF sample is attributed to the mass transport issues due to the beginning of corrosion phenomena. On the contrary, CP treated electrode shows a better energy efficiency values than raw sample (72% vs. 67% at 60 mA cm^{-2}) without any morphology change on the electrode surface. A proper stack assembly and flow field scale-up record similar performance to the small single cell configuration.

1. Introduction

The redox flow batteries (RFBs) represent a promising large-scale storage technology [1–7]. Deep discharge capacity, long cycle life, high efficiency and flexible design are some of the main characteristics of this storage technology [3,8–10]. In particular, vanadium redox flow batteries have the advantage to exist in solution in four different oxidation states, minimizing the cross-contamination of the half-cell electrolytes that means to increase the lifetime of the device [9,11,12]. The configuration of VRFB mainly consists of two external electrolyte tanks, containing the electrolyte solutions, VO_2^+/VO^{2+} and V^{3+}/V^{2+}, into the cathode and anode compartment respectively, two pumps for the flow rate management and the battery, consisting in a stack in which each single cell is connected in series. Materials and components selection is fundamental in order to improve the battery electrochemical performance [11–26]; membrane-electrode assemblies (MEAs) constitute the active part of each single cell; on the electrode surface the charge transfer at the electrode/electrolyte interface occurs [5,14–23]. Recently, the strong affinity with the fuel cell technology has allowed to better understand the significant role that the flow field design can play in this specific technology application [27–29], minimizing overpotential phenomena [30]. Commonly, VRFB flow field cell architecture is constituted by flow-through, this means with no flow field [22,31–33]. Even though this aspect allows an entirely electrode active area utilization, mass transport constraints as well as ohmic resistance phenomena are more evident. A zero-gap flow field design allows both an homogeneous distribution of the reactants on the electrode surface and a better electrode–electrolyte interface able to reduce internal resistances

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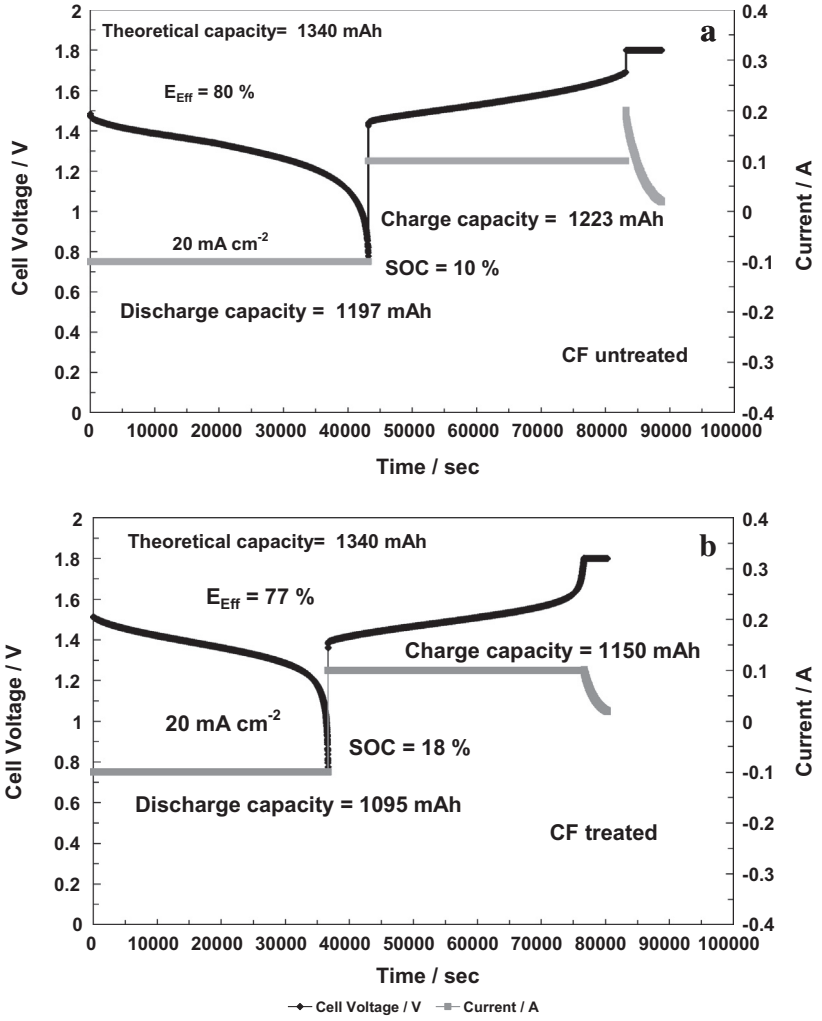

Fig. 1. Charge–discharge curves for CF untreated (a) and treated (b) at 20 mA cm^{-2} in 5 cm^2 single cell.

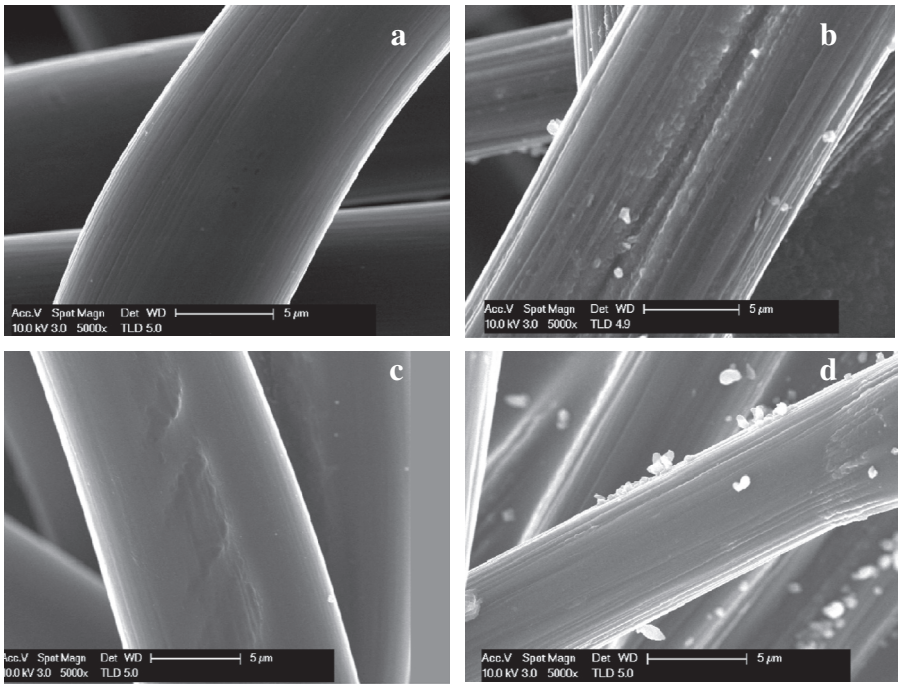

Fig. 2. SEM images of CF untreated and treated (a–c) and CP untreated and treated (b–d).