Direct growth of MoS₂ nanostructures on carbon fiber yarns for supercapacitors

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Abstract

Wearable electronics is nowadays a reality in enabling monitoring, sensing and storing/harvesting energy systems. Fiber-based structures owing to the high specific surface area combined with suitable inorganic nanostructures, organic or polymeric materials have unique potentialities to respond to whether mechanical, thermal, chemical, electrical, or even optical stimulus. [1] When integrating functionality and wearability, these devices can reach high capacity and enable unique characteristics in electrochemical devices such as electrochromic, flexible lithium-ion batteries and supercapacitors. [2]

In this work, we investigate the possibility to use carbon fiber yarns (CFYs) as electrodes for fiber-shaped supercapacitors. Pristine CFYs present a capacitive behavior that gradually changes to pseudo-capacitive with their functionalization with inorganic nanostructures such as molybdenum disulfide (MoS₂).

MoS₂ is a Transition metal dichalcogenide (TMD) and can be found in 3 phases: 3R and 2H semiconducting phases and 1T metallic phase. 1T-MoS₂ is much more conductive than the other phases due to an octahedral shape with many electrochemically active sites on its edges [3], a layered structure like graphite with a two-dimensional morphology like graphene which make it a promising candidate for an active material for supercapacitor electrodes while also being abundant and environmentally friendly [4][5]

The functionalized CFYs with MoS₂ displayed a specific capacitance of 116 Fg⁻¹ at 5 mVs⁻¹, and 150 Fg⁻¹ at 1 Ag⁻¹, respectively.

Methods and Techniques

MoS₂ was grown directly, on the carbon fibers yarns, via oven assisted hydrothermal method. The morphology of the grown MoS₂ nanostructures, on the CFYs, was observed with SEM-FIB and electrochemically tested and characterized, in a three-electrode configuration. Cyclic voltammetry (CV), Galvanostatic Charge Discharge (GCD) and Electrochemical Impedance Spectroscopy (EIS) using a Gamry Potentiostat Reference 600.

Results and Discussion

Morphological and structural characterization

- Hydrothermal growth of a uniform layer of MoS₂ on the carbon fiber yarns, was successfully achieved at 180 °C for 12 h, as depicted in SEM images.

- In the XRD pattern, of the synthesized MoS₂ nanostructures, the identified diffraction peaks can be indexed to the hexagonal MoS₂ phase (JCPDS 37-1492);

- Regarding the electrochemical characterization, the MoS₂ nanostructures displayed also a capacitive behavior but a low impedance, at low frequencies, when compared with the pristine CFYs.

- In a three-electrode configuration, the synthesized nanostructures displayed a voltage window of 1 V, and a specific capacitance of 116 Fg⁻¹ at 5 mVs⁻¹ and 150 Fg⁻¹ at 1 Ag⁻¹, respectively. In addition, the specific capacitance decreases exponentially while increasing the scan rate and the current density.

- A retention of 80 % of the original capacitance was observed after 2000 cycles, at 100 mVs⁻¹.

References

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