2D Materials Coated Cotton Yarns for Sustainable and Flexible Supercapacitors

Dr Neeraj Kumar,
Dr Shayan Seyedin
School of Engineering, Newcastle university, Newcastle upon Tyne, United Kingdom.
Contact@ neeraj.kumar2@newcastle.ac.uk; shayan.seyedin@newcastle.ac.uk

Abstract

The future of wearable technology and the Internet of Things hinges on the development of robust, safe, and portable electronic textiles that can interface with the human body and survive extreme mechanical deformations while maintaining their performance [1]. Textile energy storage devices (e.g., supercapacitors) are required to power these wearable electronics and seamlessly integrate into existing fabrics through traditional textile technologies such as weaving and knitting. Various attempts have been made to develop wearable supercapacitors using flexible electrodes based on metal wires (Cu, Ni, and Au), pristine or composite fibers/yarns, and conductive films. However, they are not satisfactory in terms of capacitance, energy density, flexibility, and mechanical robustness [2]. This work presents a novel approach for fabricating high-performance, flexible supercapacitors by coating 2D materials on sustainable substrate. Cotton yarn, a natural and biodegradable fiber, serves as the substrate for electrodes. MXene, a two-dimensional (2D) transition metal carbide ($Ti_2C_3T_x$), is coated onto the cotton yarn to create a high-surface-area negative electrode, showing excellent gravimetric capacitance of ≈272 F g^{-1} (at 2 mV s^{-1}) in 1 M H_2SO_4 electrolyte due to excellent conductivity and pseudocapacitive behaviour. The positive electrode is constructed using the hydrothermally grown molybdenum disulfide (MoS_2) onto reduced graphene oxide (rGO) deposited on a cotton yarn, demonstrating gravimetric capacitance of ≈125 F g^{-1} (at 2 mV s^{-1}). This composite structure offers a synergistic charge transfer effect whereby MoS_2 provides excellent pseudocapacitive behaviour, while rGO enhances conductivity, double layer capacitance, stability, and mechanical flexibility. Moreover, the asymmetric supercapacitor device is assembled using a gel electrolyte. The yarn-based supercapacitor devices developed in this work exhibit excellent electrochemical performance, high capacitance, and excellent cycling stability, enabling easy fabrication of wearable supercapacitors. This work contributes to the advancement of flexible electronics and encourages environmentally conscious design suitable for fibre-based energy storage systems.

References

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