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MoS_2 Confined MXene Heterostructures as Electrode Material for Energy Storage Application

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ABSTRACT

Two-dimensional (2D) titanium carbide Ti_3C_2 (MXene) is exemplified as the promising electrode material for supercapacitors. MXene was derived by etching of Al-layer from MAX phase (Ti_3AlC_2), and MoS_2 was confined on MXenes through incipient wet impregnation of MoS_2 precursor. The prepared MXene and MoS_2/MXene materials were characterized by X-ray diffraction, scanning electron microscope and energy-dispersive X-ray spectroscopy, BET analysis, and X-ray photoelectron spectroscopy. The electrochemical characteristics of MXene and MoS_2/MXene heterostructures were evaluated by different techniques such as cyclic voltammogram, galvanostatic charge-discharge, and electrochemical impedance spectroscopy. The electrochemical measurements revealed that the maximum specific capacitance of the MoS_2/Mxene electrodes reaches up to 342 F g^{-1} at a discharge current density of 0.4 A g^{-1} in an enlarged voltage window of -1.5 V to 1.5 V. Also, Electrochemical impedance studies show that the incorporation of MoS_2 decreases the charge transfer resistance of MoS_2/MXene. Overall, the electrochemical performance of MoS_2/MXene exhibited excellent reversibility, cycle stability, and rate performance. The obtained results uncover MoS_2/MXene as promising electrode materials for supercapacitors.

1. Introduction

The current scenario of deriving energy from clean and renewable energy sources has made energy storage systems as an essential component in the electronic, electrical, defence, and locomotives devices [1, 2]. In this respect, supercapacitors are viewed as the most promising energy storage system, as they perfectly fill the gap between dielectric capacitors and conventional batteries and can be used in high power operators [3, 4]. However, there are challenges related to their lower energy density compared to batteries [5-7]. By concept, the supercapacitors are store and release energy through reversible adsorption of electrolyte ions onto the surface of electrode materials, either electrochemical double-layer capacitors (EDLCs) or pseudocapacitors through reversible faradic redox reactions and sometimes by both mechanism that is mostly controlled by active electrode materials.[8] Even though conventional carbon-based materials like carbon nanotube (CNT), mesoporous carbon (CMK), graphene, which contain high surface area and conductivity, are reported as electrode material for supercapacitors [9]. However, the researchers are still involved in designing electrode materials for improving energy storage capacity with high energy density [10]. The current research expansion in the area of advanced materials invented 2D transition metal carbides, also called MXenes that possess excellent metallic conductivity and highly defined morphologies that makes it as suitable electrode material for supercapacitors [11].

MXenes are 2D transition metal carbides, or nitrides ($M_{n+1}X_n$ T_x) derived from ternary transition metal carbides or nitrides materials so-called MAX phase, ($M_{n+1}AX_n$), where M represents an early transition metal (Sc, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, and so on), A stands for mostly IIIA group elements, n = 1–3, X is carbon and/or nitrogen, and T_x stands for the surface terminations (OH, O or F)[11]. MXenes exhibits superior electrical conductivity due to its metallic nature with transition metal (Ti) atomic layers alternately implanting between carbon atomic layers [12-15]. Also, due to the existence of surface terminations, the delaminated MXene are hydrophilic and electronegative with a high negative zeta potential in the range of -39.5 to -63 mV and can be dispersed in most of the organic solvents [16, 17]. Other important characteristics of MXenes are their open channels that can be spontaneously intercalated by polar organic molecules and metal ions, which makes it as electroactive supercapacitor material [18-20].

Currently, MoS_2 few-layered metal dichalcogenide resembles

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