ELECTROLYTE MATTERS: UNDERSTANDING ITS IMPACT ON SUPERCAPACITOR PERFORMANCE

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Abstract. *The article examines how sodium and lithium ions can be inserted into thin films of MoS_2 synthesized by DC magnetron sputtering, with the aim of using these films for energy storage. These films possess unique properties and structures that make them promising candidates for energy storage. The insertion of sodium and lithium ions has substantially boosted their energy storage capacity and electrical conductivity. The research also demonstrated that the insertion process is reversible, suggesting that the thin films could potentially be employed in rechargeable batteries. However, additional research is necessary to refine the insertion procedure, enhance the stability and performance of the films, and investigate other possible uses. Overall, this study provides valuable insights into the potential use of sputtered MoS_2 thin films for energy storage applications.*

Keywords: *capacitance, carbon cloth (CC), intercalation, lithium, molybdenum disulfide.*

Introduction

The need for energy in daily life, both at industrial and household levels, has existed for ages. Fossil fuels have traditionally supplied this energy [1], but they are harmful to society and nearly depleted. Thus, there is an increasing demand for non-conventional or renewable energy sources such as wind, hydro, thermal, tidal, and solar [2]. However, the irregular availability of these sources highlights the importance of energy storage devices such as fuel cells, batteries, and supercapacitors [3].

Supercapacitors can be categorized into three main types: electrochemical double layer capacitors (EDLCs), pseudocapacitors, and hybrid capacitors. EDLCs are based on the principle of charge separation at the electrode-electrolyte interface, while pseudocapacitors involve surface redox reactions at the electrode-electrolyte interface. Hybrid capacitors combine the characteristics of both EDLCs and pseudocapacitors, offering high energy and power densities [4].

Generally, a supercapacitor comprises various parts, including the electrode, current collectors, electrolyte, and separators, that work together to store and release electrical energy efficiently. We would dig out our focus on electrolyte and their affection towards super capacitive performance. The electrolyte ions diffuse into the layers of electrodes, especially a 2D working electrode to cause intercalation. Intercalation of ions into the electrode material can improve the supercapacitive performance by modifying charge storage and diffusion of ions [5].

Experimental Section

Materials and chemicals. The molybdenum disulfide sputtering target with 99.999% purity was acquired from Testbourne Ltd in the UK. Flexible carbon cloth was purchased from Nanoshel India Pvt. Ltd. The chemicals used in this study, including sodium sulfate (Na_2SO_4) and lithium perchlorate ($LiClO_4$), were obtained from Merck Sigma-Aldrich and used without additional purification.

Synthesis Method. To create a flexible supercapacitor electrode, a low-cost carbon cloth mesh was first cut into 2 cm × 1 cm slices and cleaned with a solution of acetone and isopropyl alcohol. The substrate was then mounted on a resistive heating stage within the sputtering chamber, and a commercially available MoS_2 sputtering target was utilized to deposit thin films. The deposition process was carried out using 4N purity Argon gas at room temperature for 15 minutes under a constant DC power of 45 W, substrate-target distance of 60 mm, and working pressure of 10 mTorr, while the temperature was increased to promote thin film growth [6]. Prior to the deposition, a base vacuum of 1×10^{-6} was maintained in the sputtering chamber.

Results and Discussion

Structural and Morphological Characterization

Fig. 1 (A, B, C) shows the FE-SEM of MoS_2 thin films at different magnifications. At higher magnification it has been found that the MoS2 exhibits a sheet like structure on carbon cloth. Additionally, the porous nature of carbon cloth and deposited MoS_2 on top of it (Figure 1 A & B) can prove to be significant for the diffusion and absorption of electrolytes.

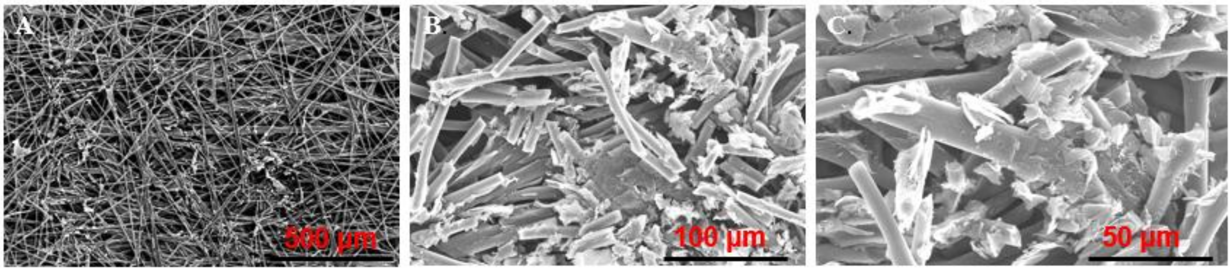

Figure 1. (A, B, C) FESEM image of MoS_2 thin film sputtered on CC

Raman spectra (Fig 2) show the characteristics signal of MoS_2 with the peaks from carbon cloth (1318 cm^{-1}). The peaks at positions 294 cm^{-1}, 226 cm^{-1}, 411 cm^{-1} corresponds to the E^1_{2g} and A^1_g peaks of the MoS_2 films. These E^1_{2g} and A^1_g peaks are related to in plane and out-of-plane vibrational modes of MoS_2, respectively.

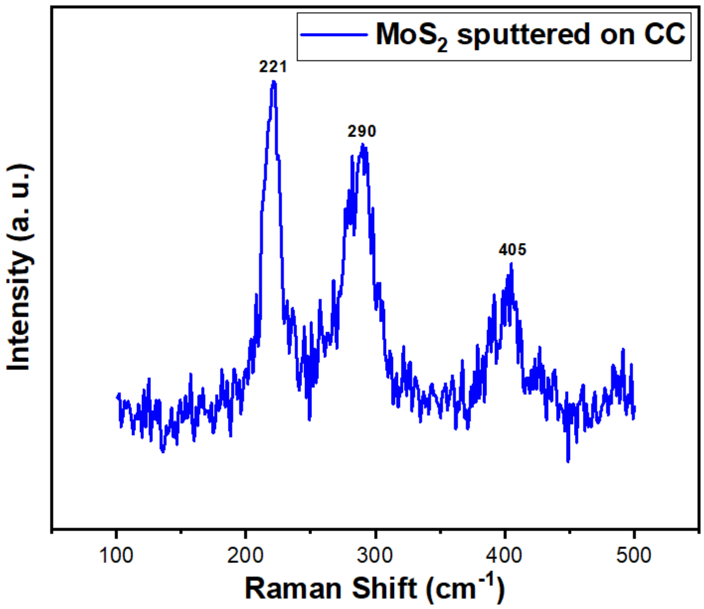

Figure 2. Raman Spectra of MoS_2 thin film sputtered on CC

Electrochemical Characterization

Figure 3 demonstrates cyclic voltammetry (CV) studies of MoS_2 thin films in sodium sulphate, Na_2SO_4 and lithium perchlorate, $LiClO_4$ electrolytes. In both the electrolytes, the area under curve was found to be increased with an increasing number of potential scans due to intercalation of the alkali ion like Na or Li. The process of intercalation is possible since MoS_2 is layered material. The MoS_2 electrode provides electrochemical active sites and/or voids, facilitating the charge storage mechanism via intercalation and EDLC. With increase in the scan rate the specific capacitance values were decreased because electrolyte ions do not get enough time to interact with MoS_2 electrode. The electrode provided edge-active sites and high effective surface area, facilitating the charge storage mechanism. The Sp. capacitance values for Na_2SO_4 was 9.5238 F/g, 3.8095 F/g, 1.9047 F/g at 20 mV/s. 50 mV/s, 100 mV/s scan rates respectively. The Sp. capacitance values for $LiClO_4$ was 13.4249 F/g, 8.6727 F/g, 5.9060 F/g at 20 mV/s. 50 mV/s, 100 mV/s scan rate respectively. The values stood higher for $LiClO_4$ than Na_2SO_4.

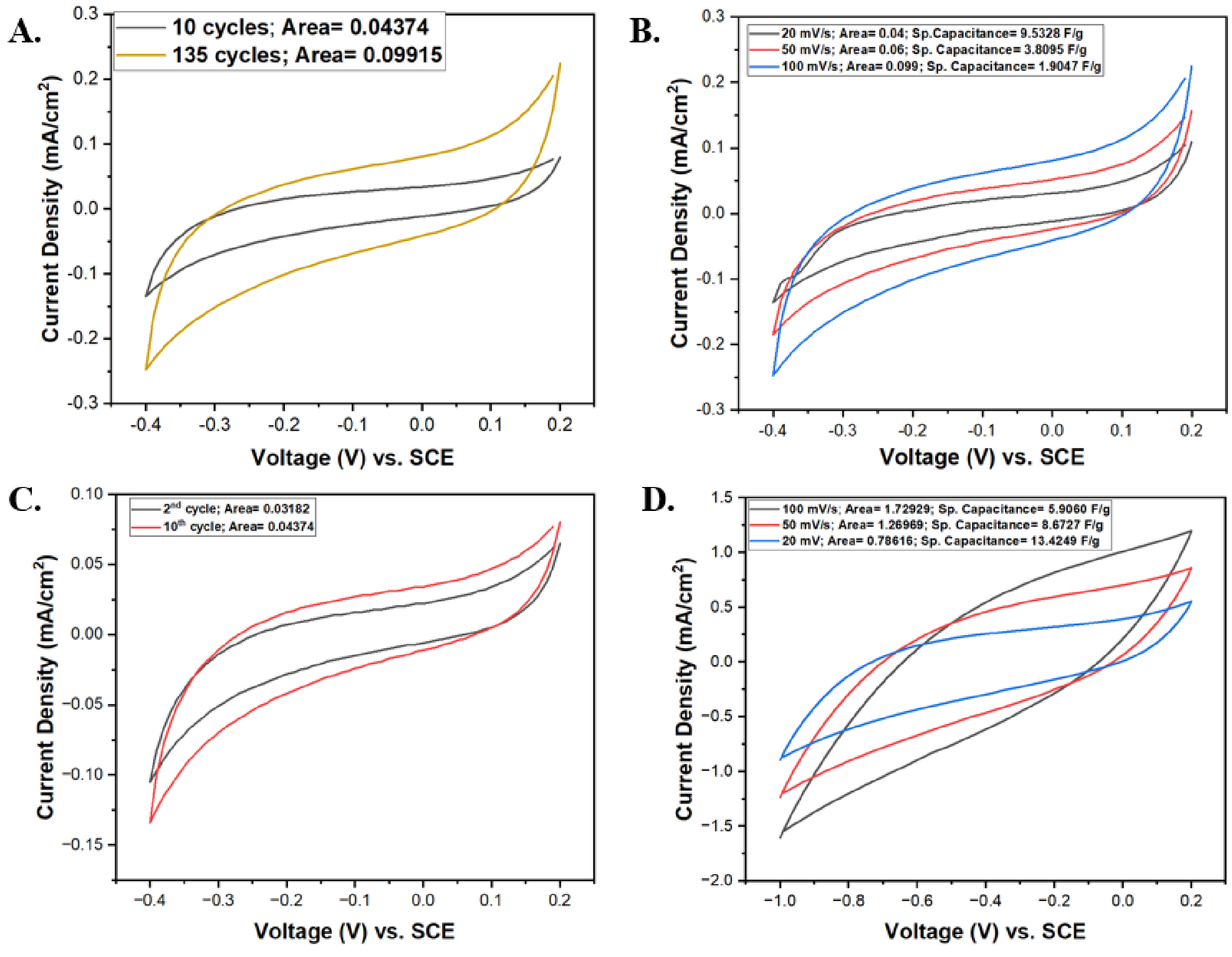

Figure 3. CV curves for (A, B) with Na_2SO_4 as the electrolyte as a comparison of different cycles and different scan rates. CV curves for (C, D) with $LiClO_4$ as the electrolyte as a comparison of different cycles and different scan rates.

Conclusion

In conclusion, sputtered MoS_2 thin films have shown promising results for sodium and lithium ion intercalation. The thin films' unique structure and properties have made them suitable candidates for energy storage applications. The intercalation of sodium and lithium ions has been found to significantly enhance the thin film's electrical conductivity and energy storage capacity. Moreover, the intercalation process has been found to be reversible, indicating the potential for these thin films to be used in rechargeable batteries.

Further research is required to optimize the intercalation process, improve the performance and stability of the thin films, and explore other potential applications. Overall, the results obtained from this study provide valuable insights into the use of sputtered MoS_2 thin films for energy storage applications [7].

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