MoS_2-Based 2D Nanocomposites for Energy Storage Applications

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In the pursuit of high-performance energy storage technologies, this work examines the structural, electrochemical, and magnetic properties of hybrid nanocomposites comprising ferrites and transition metal dichalcogenides (TMDs) [1]. Its primary objective is to explore and optimize MoS_2-$ZnFe_2O_4$ nanocomposites (NCs) as multifunctional electrode materials for supercapacitors by elucidating the structure–property correlations. Addressing the limitations of individual materials—MoS_2's tendency to restack and $ZnFe_2O_4$'s low conductivity—the study leverages their synergistic integration to achieve enhanced energy storage performance. The synthesis of MoS_2-$ZnFe_2O_4$ nanocomposites was carried out using the molar ratios of 1:2, 1:1, and 2:1 for respective MoS_2 and $ZnFe_2O_4$ materials via a hydrothermal route. The 1:1 ratio sample delivered the highest specific capacitance of 2076.9 F/g at 25 A/g and showed 94.3% capacitance retention after 2500 cycles. Structural characterizations confirmed a uniform distribution of NPs on MoS_2 sheets, which mitigated the restacking of MoS_2 and the agglomeration of $ZnFe_2O_4$. For instance, the transmission electron microscopy (TEM) results on the 1:2 ratio nanocomposite, shown in Figure 1, reveal that the $ZnFe_2O_4$ material uniformly coats the MoS_2 sheets. This was further confirmed by carrying out an elemental mapping analysis of the same samples using scanning transmission electron microscopy (STEM) in conjunction with X-ray energy-dispersive spectroscopy (EDS) techniques (Figure 2). Overall, the study elucidates the intricate relationships between nanoscale structure, electronic configuration, and electrochemical performance in ferrite-TMD systems. It demonstrates that combining MoS_2 and $ZnFe_2O_4$ into a single hybrid nanostructure enables mutual property enhancement, resulting in performance that far exceeds that of either component alone. This work is believed to help advance the rational design of next-generation hybrid electrode materials for energy storage and sensing, integrating green synthesis, experimental characterization, and computational modeling. The presented result will demonstrate that energy-storage mechanisms of TMD-ferrite systems can be investigated effectively using in-situ electrochemical transmission electron microscopy (TEM) methods.

References

[1] Rasamani, et al., Interlayer-expanded MoS_2, Materials Today, **20** (2), 83-91, (**2017**)

Figures

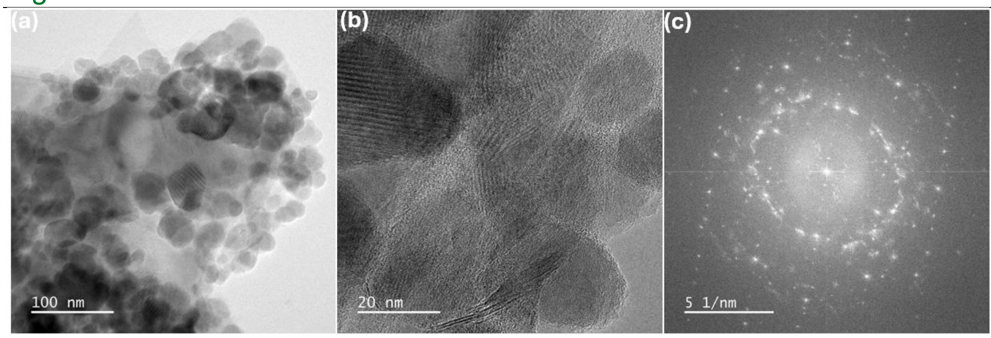

Figure 1: Morphological and Structural Analysis of 1:2 MoS_2-$ZnFe_2O_4$ nanocomposites using TEM.

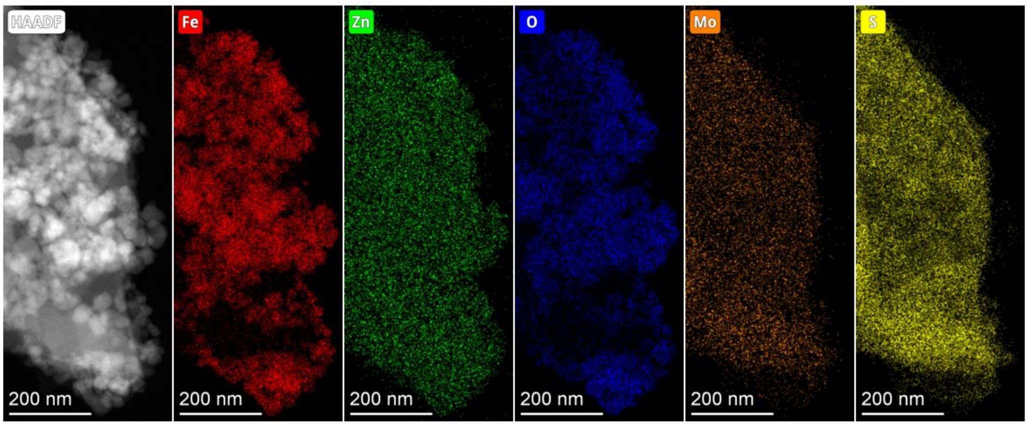

Figure 2: Elemental Mapping Analysis of 1:2 MoS_2-$ZnFe_2O_4$ nanocomposites using STEM-EDS technique.