PÔSTER - RESUMO - DISPOSITIVOS ELETRÔNICOS, ELETROQUÍMICOS, SUPERCAPACITORES E BATERIAS

DRYING-DRIVEN STRUCTURAL OPTIMIZATION OF BIOPOLYMER–MXENE HYBRID GELS ELECTRODES TOWARD REDUCED ACTIVE MATERIAL LOADING

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MXene has emerged as a leading 2D material for electrochemical energy storage due to its high electrical conductivity and rich surface chemistry[1,2]. However, the self-restacking of nanosheets limits ion accessibility and reduces active material utilization within dense electrodes[1,3]. Recent studies indicate that performance improvements in MXene-based systems require enhanced structural efficiency and interfacial stability within the electrode architecture[2,4,5]. Although MXene–polymer hybrid gels have been widely explored, the influence of drying pathways on structure–property relationships and active material efficiency remains insufficiently clarified[5–8]. We investigate whether a biopolymer–MXene hybrid architecture can retain electrochemical performance while reducing the MXene content to one-quarter of that used in

pristine MXene electrodes, and how solvent removal governs the resulting microstructure and charge-storage behavior. Specifically, hybrid gels were prepared by incorporating Ti3C2T? MXene into a cellulose-based biopolymeric matrix and processed via ambient drying (xerogels), freeze-drying (cryogels), and supercritical drying (aerogels). The effect of drying route on shrinkage, density, and structural connectivity was systematically examined. X-ray diffraction and Raman spectroscopy confirmed the structural integration of MXene lamellae within the polymer network, with drying-dependent organization. XPS and FT-IR analyses indicated interfacial interactions between MXene surface terminations and biopolymer functional groups, suggesting stabilization of the hybrid framework [8,9]. Electron microscopy and micro-computed tomography revealed that ambient drying induces controlled densification, leading to a compact yet interconnected architecture.

Despite exhibiting a lower nitrogen-accessible surface area than the aerogel, the xerogel displayed enhanced structural utilization efficiency. Gravimetric capacitance measured in 3 M H_2SO_4 at 2 $mV \cdot s^{-1}$ yielded comparable values of 95 $F \cdot g^{-1}$, 91 $F \cdot g^{-1}$, and 100 $F \cdot g^{-1}$ for aerogel, cryogel, and xerogel electrodes, respectively, normalized to the total electrode mass. Notably, the xerogel approaches the 120 $F \cdot g^{-1}$ obtained for pristine MXene electrodes prepared and evaluated under identical conditions, despite containing fourfold less MXene. Electrochemical impedance spectroscopy indicated preserved ionic accessibility and stable charge-transfer characteristics, with drying-dependent variations in low-frequency response, which reflects distinct ion transport regimes across xerogel, cryogel, and aerogel architectures [10]. These findings demonstrate that controlled densification and interfacial stabilization can partially compensate for reduced active material content by improving structural efficiency. Furthermore, ambient drying eliminates solvent exchange and high-pressure processing steps, providing a simplified, more affordable, and potentially scalable fabrication pathway to decrease MXene consumption while maintaining competitive supercapacitor performance.

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