PEDOT:PSS-Enhanced Hollow-Core Regenerated Cellulose Hydrogel Fibres for Leak-Proof Phase Change Thermal Energy Storage in Smart Building Envelopes

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Abstract:

The development of high-performance thermal energy storage (TES) materials is essential for reducing the energy footprint of modern buildings. However, the integration of phase change materials (PCMs) into architectural components is often limited by poor thermal conductivity and the risk of leakage during phase transitions. In this work, we demonstrate a multifunctional 3mm hollow-core hydrogel fibre fabricated from regenerated cellulose crosslinked with 7.5 wt% epichlorohydrin (ECH), to create a robust, leak proof fibre for polyethylene glycol (PEG 1000) encapsulation. This optimized matrix achieved a peak reswelling capacity of 1744.44%. The incorporation of poly(3,4-ethylenedioxythiophene): poly (styrene sulfonate) (PEDOT: PSS) established a percolating network within the cellulose matrix, which resulted in a significant enhancement in thermal conductivity, reaching 1.87 W m^{-1} K^{-1}. Infrared thermography under simulated environmental conditions confirmed that these composite fibres provide superior thermal buffering, effectively regulating indoor temperature fluctuations through latent heat storage. Furthermore, the fibres exhibited a unique acoustic transition, shifting sound transmission loss peaks toward higher frequencies (up to 6625 Hz), offering a dual-functional solution for noise mitigation. This innovative fibre-based strategy demonstrates significant potential for the next generation of smart building envelopes, combining efficient energy management with enhanced structural and acoustic performance.