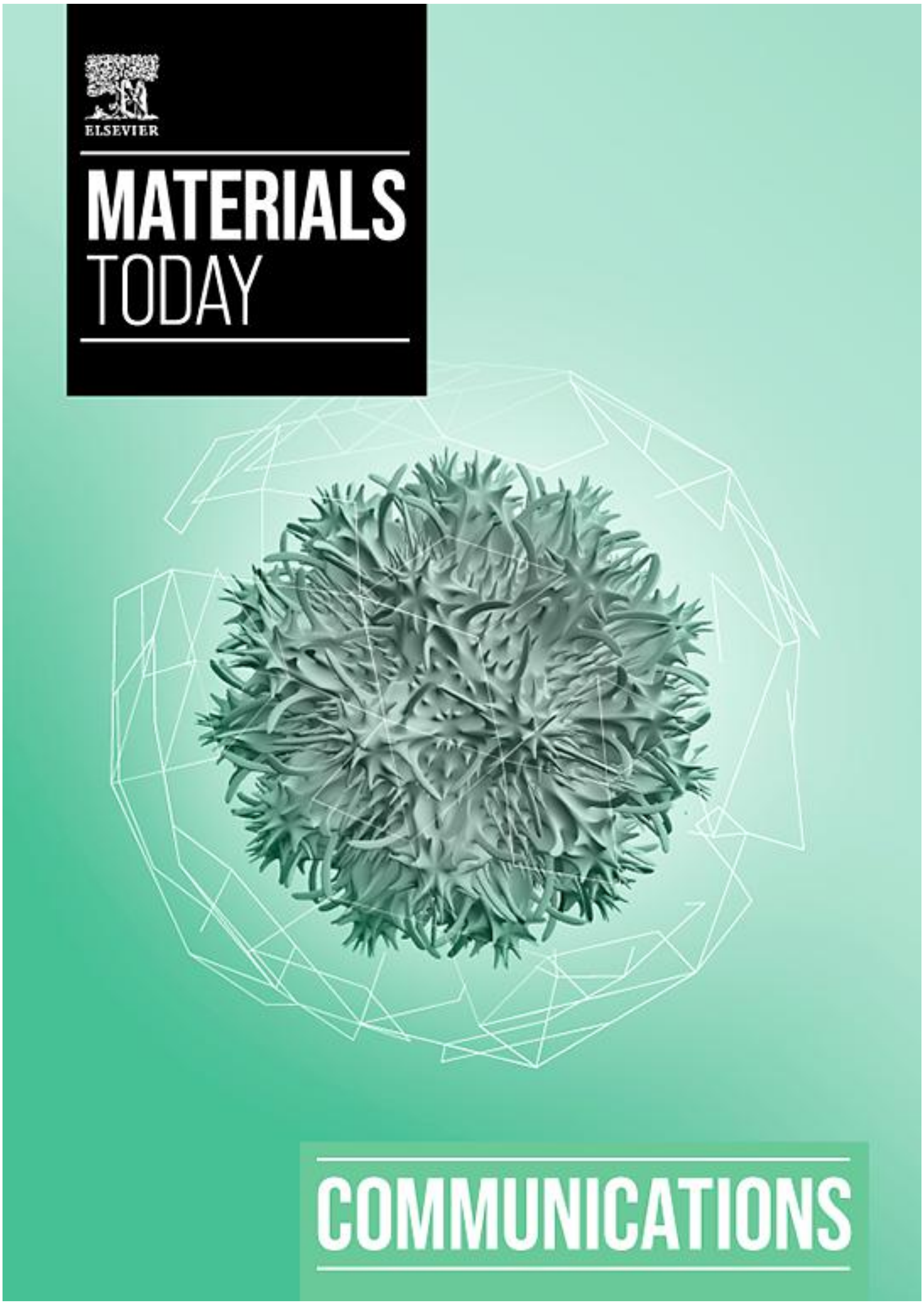
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Hydroxylated boron nitride nanosheets modified phase change hydrogels for enhanced thermal conductivity and electronic device thermal management

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ABSTRACT

Thermal energy storage technology using phase change materials is a viable solution for effectively addressing heat dissipation issues in electronic devices. However, current phase change materials have some disadvantages such as meltdown leaks, rigidity, and low thermal conductivity which affect their further application in thermal management. In this study, composite phase change hydrogels were synthesized via in situ polymerization using sodium acetate trihydrate as the phase change material, acrylamide as the support matrix, and hydroxylated boron nitride nanosheets obtained by urea-assisted ball milling modification as the modified filler. The three-dimensional network structure of this hydrogel effectively prevents leakage while maintaining a high energy density of 174.5 J/g, and the composite phase change hydrogel is also endowed with thermal flexibility and moderate adhesion strength. The introduction of hydroxylated boron nitride nanosheets enhances the thermal conductivity of phase change hydrogel to 2.24 $W\,m^{-1}\,K^{-1}$. After thermal management tests, compared to the electronic chip without composite phase change hydrogel the critical time of the electronic chip was extended by 2780 s, and the thermal equilibrium temperature was reduced by 12.3 ℃, demonstrating excellent thermal management performance. Therefore, the developed composite hydrogel demonstrates strong potential for thermal management in electronic devices.

1. Introduction

With the rapid advancements in internet technology and artificial intelligence, electronic devices are becoming increasingly integrated and miniaturized to satisfy growing performance demands [1]. However, this trend presents significant heat dissipation challenges due to substantially increased internal heat flux, potentially shortening device lifespan or causing thermal runaway [2,3]. Consequently, effective thermal management strategies are essential for maintaining the stability and reliability of electronic devices. Phase change materials (PCMs) have emerged as promising candidates for passive thermal management solutions. By absorbing or releasing latent heat at nearly constant temperatures, PCMs effectively alleviate overheating issues [4–6]. Compared to traditional active cooling methods, phase change energy storage exhibits several advantages, including compactness, lightweight design, rapid response, silent operation, and low energy consumption [7–10]. Numerous PCM-based composites have been developed for thermal management applications. However, current PCMs still suffer from problems such as easy leakage [11,12], high rigidity [13], and low thermal conductivity [14], which greatly limit the further application of PCMs.

Compared to vacuum impregnation and other encapsulation methods, hydrogels effectively encapsulate. Sodium acetate trihydrate (SAT) due to their robust three-dimensional network structure and excellent hydrophilicity, introducing hydrated salts into the gel network as water at high temperatures, softening the gel, and transforming them into crystalline salts at low temperatures, thus hardening the gel. This unique soft-hard conversion mechanism imparts phase change hydrogels (PCH) thermal flexibility and moderate adhesion strength. Three-dimensional network networks provide continuous heat-conduction pathways that lower interfacial resistance and enable rapid, uniform heat spreading at low filler fractions, thereby mitigating hot spots while preserving latent heat; they also improve shape stability/leakage resistance and can integrate multifunctional responses when the network is

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