ABSTRACT

Two-dimensional (2D) materials, including hBN and graphene, possess exceptional electronic, thermal, and barrier properties, making them promising candidates for development of functional composites. This study explores their integration into polymer matrices to develop functional, sustainable composites. 2D hBN was used to reinforce carboxymethyl cellulose (CMC): a cellulose-derivative, enhancing its rheology and enabling precise 3D printing of high-quality composites with controlled geometry and porosity. Increasing hBN content improved dielectric properties and energy harvesting performance, although higher loadings led to brittleness and reduced mechanical strength. To address this fragility, layered PVA-hBN/CMC composites were developed, however interface failures were observed at larger hBN/CMC layer thicknesses. These layered constructs, capable of generating voltage in response to mechanical stimuli, show potential for wearable wound healing/sensing applications. A fully green method for composite development was also employed, where graphene was exfoliated from graphite using a yeast-mediated process, combined with CMC, and deposited onto a PVA substrate to form PVA-graphene/yeast/CMC biocomposites. Their interfacial properties and energy harvesting performance were evaluated. Additionally, graphene oxide membranes fabricated on polyimide demonstrated efficient small-volume biomolecule filtration when integrated into centrifugal membrane filtration devices. This underexplored approach provides a practical solution for many challenging molecular separations in standard biological laboratory settings. Overall, the work highlights sustainable strategies for incorporating 2D materials in composites and integrating it with various technology, extending their applications into novel areas.