ABSTRACT

Enhancing the functional performance of synthetic textiles, especially polyethylene terephthalate (PET), is a key focus in material science and textile engineering. While PET is popular in active wear due to its durability and light weight, its hydrophobicity and flammability pose challenges for moisture management and safety. To overcome these issues, the aim of this study is to investigate surface modification of PET with advanced nanomaterials like nanodiamonds (NDs) and hydroxyapatite (HAp), aiming for multifunctional and sustainable high-performance textiles.

Nanodiamonds (NDs) have emerged as a promising class of carbon nanomaterials, used for their unique properties including low toxicity, ease of surface functionalization, and excellent biocompatibility. Traditionally, NDs are synthesized through methods, which are energy-intensive, require hazardous chemicals, and involve lengthy reaction times. Recognizing the need for more sustainable alternatives, this study investigates the synthesis of NDs via probe ultrasonication at ambient temperature and pressure, using organic salts as precursors in an aqueous medium. This method significantly reduces environmental impact and operational complexity. Characterization techniques such as FESEM, HRTEM, FTIR, Raman, and XRD revealed that ultrasonication time is a critical factor: shorter durations (30 min) yield metastable morphologies, while longer ultrasonication (1 hour) produces high-quality cubic nanodiamonds. Acid purification further sharpens the diamond Raman peak at 1332 cm^{-1} and confirms the cubic crystal structure, demonstrating that this green approach can reliably produce well-defined NDs and its *in-situ* and *ex-situ* application of PET surface to achieve

multifunctionalities such as water absorbency and fire retardancy. The development enables the scalable production of nanodiamonds for advanced textile applications without compromising environmental safety.

Building upon the green synthesis of NDs, the next part of the study discusses their direct application onto PET fabrics to address the flammability and hydrophobicity of PET fabric. In this study, a novel *in-situ* approach is employed, wherein carbon nanostructures are synthesized directly on the PET surface using atmospheric pressure dielectric plasma. This approach eliminates the requirement for independent nanoparticle synthesis and later deposition, resulting in a more consistent and firmly attached nanodiamond coating on the textile fibres. FESEM and HRTEM analyses confirm the presence and morphology of the carbon nanostructures, while Raman and FTIR spectroscopy validate the formation of NDs and their chemical integration with the fabric. The functionalized PET fabrics exhibit marked improvements in flame retardancy, with LOI values up to 26-28, as well as enhanced hydrophilicity, which is crucial for comfort and moisture management in active wear. *In-situ* functionalization not only simplifies the process but also produces textiles with durable, multi-functional properties.

While treatment with NDs significantly improve flame resistance and surface hydrophilicity, further enhancements in moisture management and UV protection are desirable for high-performance active wear. To this end, hydroxyapatite (HAp), a biocompatible ceramic commonly found in bone and teeth, was explored as a surface coating for PET fabrics. In this study, HAp was synthesized via two distinct chemical precipitation methods (coded as HAp1 and HAp2) and applied *ex-situ* to PET using a

dip-pad-cure process. Both HAp coatings resulted in notable improvements in water absorbency, wicking ability, quick-drying behavior, and ultraviolet protection factor (UPF). However, fabrics treated with HAp1 demonstrate superior performance and durability, even after multiple washing cycles. Detailed characterization using FESEM, FTIR, Raman, and XPS reveals that the HAp1 process yields finer particles that interact more intimately with the PET fiber surface, leading to stronger adhesion and more robust functional properties. The successful application of HAp coatings not only addresses the hydrophobicity of PET but also introduces multifunctionality.

Recognizing the promising results of HAp coatings, the further studies were directed towards the *in-situ* synthesis of hydroxyapatite (In-HAp1 and In-HAp2) directly on PET fabrics. This approach aimed to maximize the functional benefits of HAp while ensuring long-term durability under real-world conditions. The *in-situ* dip-pad-cure method produces a uniform and continuous HAp layer, with In-HAp1 in particular yielding a nanoscale coating that adheres tightly to the fiber surface. Comprehensive evaluations using FESEM, FTIR, Raman, and XPS demonstrate that In-HAp1-treated fabrics maintain their enhanced UPF and moisture management properties even after repeated washing, outperforming In-HAp2. The improved performance is attributed to the controlled growth and finer particle size achieved in the In-HAp1 process, which facilitate stronger interactions with the PET substrate, which were higher then the previous *ex-situ* HAp coating. By leveraging the hydrophilic and UV-blocking properties of HAp, this optimized surface modification transforms PET into a truly multifunctional textile, ideally suited for sustainable, high-performance active wear. Each section of this research builds upon the previous one, starting with the development of a sustainable method for nanodiamond synthesis, moving to their direct

application for flame retardancy and hydrophilicity in PET, and then addressing further enhancements in moisture management and UV protection through bio-ceramic such as hydroxyapatite coatings. By integrating these advanced surface modifications, the research sets a foundation for the next generation of smart, multifunctional, and sustainable textiles.