High-performance conductive nanocomposites based on CNF/PLA reinforced by functionalized graphene derivative

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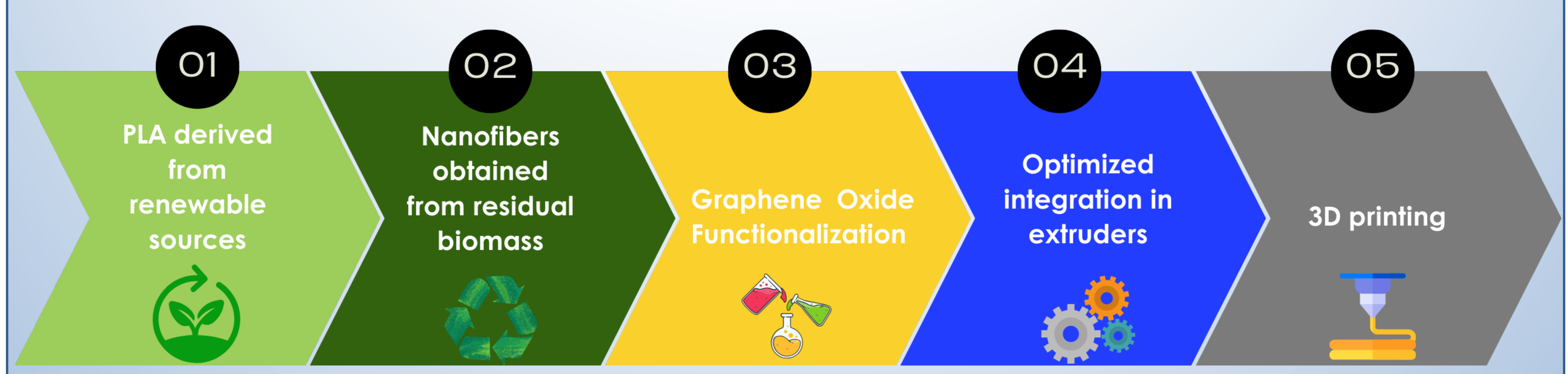
INTRODUCTION

The growing demand for sustainable materials is driven by global challenges such as environmental degradation and resource scarcity. Polylactic acid (PLA), a biodegradable polymer derived from renewable resources, offers an eco-friendly alternative to petroleum-based plastics. However, its limitations in thermal and mechanical properties require reinforcement to meet the needs of advanced applications. Cellulose nanofibers (CNF) enhance PLA's performance through their strength and renewability, while graphene derivatives contribute conductivity and thermal stability. The functionalization of graphene with ionic liquids further improves compatibility within the polymer matrix, enabling uniform dispersion and enhanced material properties. Together, these components create nanocomposites that combine sustainability with superior performance, particularly for demanding sectors like aerospace and electronics.

Development of Conductive Nanocomposites for Sustainable Applications

The development of renewable polymer composites that meet the demanding requirements of mechanical performance and advanced technological applications poses significant challenges. Balancing sustainability with functionality requires addressing intrinsic limitations of biodegradable polymers, such as low thermal stability and limited mechanical strength. Additionally, achieving multifunctional properties, such as electrical conductivity and flame retardancy, further complicates material design. These challenges are amplified by the need for uniform dispersion of reinforcing agents, efficient interfacial bonding, and compatibility with industrial processing techniques. Overcoming these hurdles is essential for creating high-performance composites capable of addressing critical applications in sectors like aerospace, electronics, and energy, while adhering to green chemistry principles. The composite integrates PLA, CNF, and functionalized graphene derivatives to overcome challenges in thermal stability, flame retardancy, and sustainable prototyping. CNF reinforces mechanical strength and thermal resistance, while graphene functionalized with ionic liquids enhances dispersion, conductivity, and flame-retardant properties by forming a protective char layer. This synergistic combination delivers a lightweight, high-performing material that meets stringent industrial demands and aligns with sustainable prototyping practices for aerospace and electronics.

Sustainable Pathway for Nanocomposite Development



01 PLA derived from renewable resources to ensure proper processing and maintain its eco-friendly characteristics.

02 Extract nanofibers from biomass residues using mechanical or chemical methods.

03 Functionalize graphene oxide using ionic liquids as green alternatives to conventional solvents.

04 Ensure uniform mixing to maintain the structural and conductive properties of the composite.

05 Utilize sustainable manufacturing methods like 3D printing to fabricate final products tailored for specific applications.

Characterization of functionalized nanoparticles

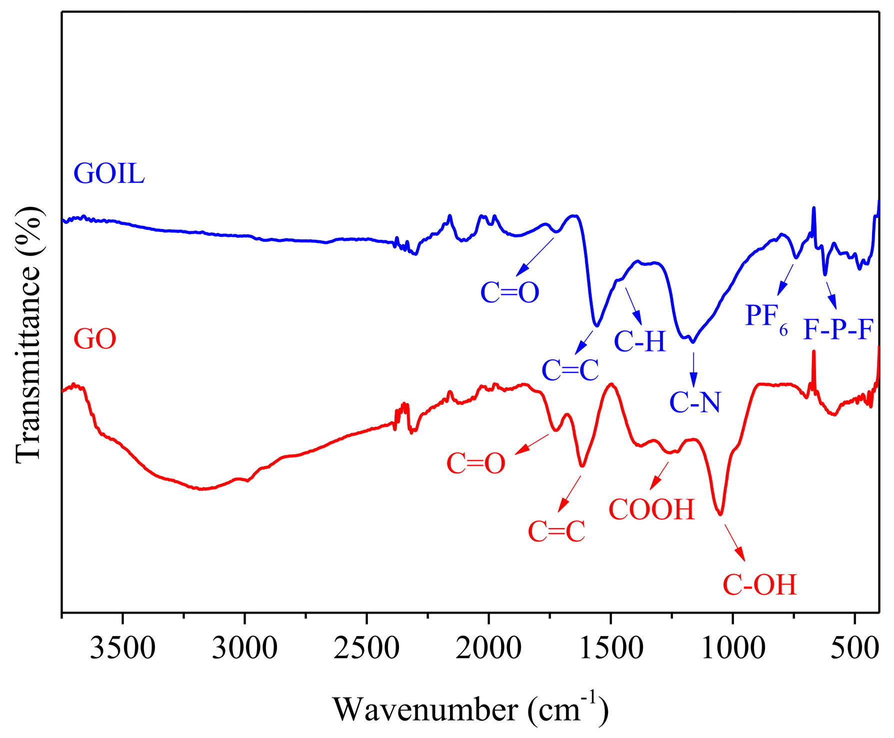


Figure 1 – FT-IR spectra of samples: GO and GOIL.

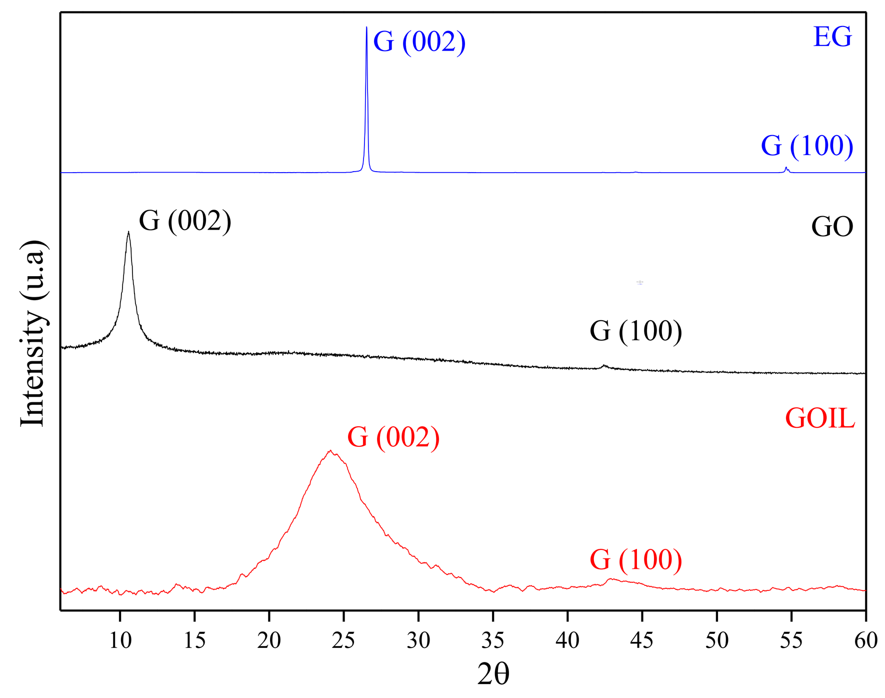


Figure 2 – XRD diffractogram of samples: EG, GO and GOIL.

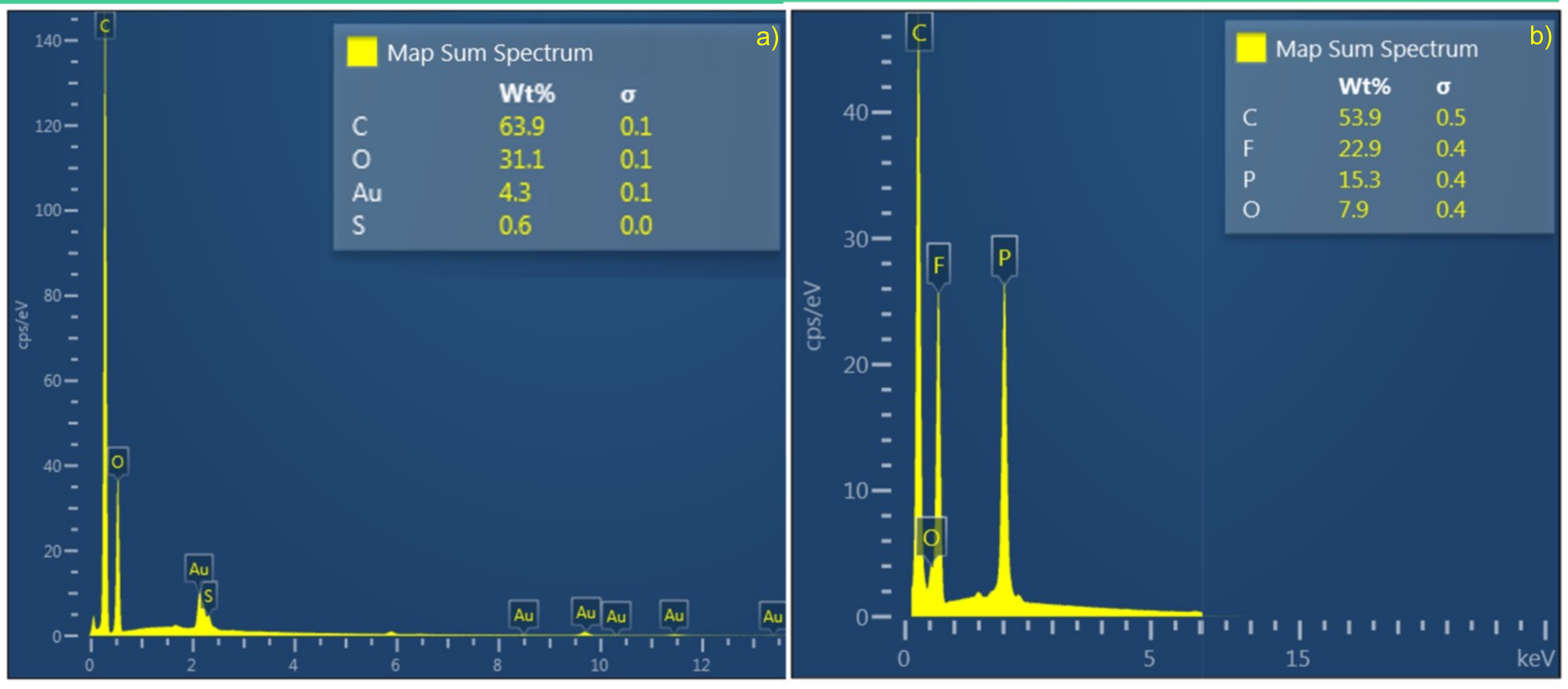


Figure 3 – Elemental composition analysis (EDS) of the samples a) GO and b) GOIL.

CONCLUSION

The successful functionalization of graphene oxide with ionic liquids was confirmed through FTIR spectra, X-ray diffraction patterns, and EDS elemental analysis, all of which revealed the presence of the desired functional groups on the nanoparticles. These results validate the effectiveness of the functionalization process, paving the way for the next stage of the project. The forthcoming phase will focus on developing the ternary nanocomposite by integrating PLA, CNF, and functionalized graphene oxide. This material will then be used to fabricate test specimens via additive manufacturing (FDM), enabling precise evaluation of its mechanical, thermal, and flame-retardant properties. These analyses will ensure the composite meets the sustainability and performance requirements outlined in the project objectives.