Advanced and Smart Fibrous Materials: AI-Assisted Sol-Gel Functionalization of MOFs and Bio-Nanoparticles for Sustainable Nano-Nonwovens

Project Objective

The primary objective of this project is to develop a new generation of multifunctional fibrous materials based on biopolymers that combine sustainability with advanced functional properties. The project focuses on creating nano-nonwovens from polylactide (PLA), polyhydroxyalkanoates (PHA), and poly(ethylene furanoate) (PEF), which will be enhanced with metal-organic frameworks (MOFs), cellulose nanocrystals, and nano-lignin using an innovative sol-gel method .

Research Description and Methodology

The research encompasses a systematic approach to nano-nonwoven functionalization through the application of electrospinning combined with advanced computational modeling. The project's novelty lies in utilizing the sol-gel method for surface coating deposition instead of conventional bulk incorporation of additives, which preserves the beneficial properties of the fibrous matrix while imparting new functionalities . The project integrates artificial intelligence and machine learning algorithms to predict material properties and optimize process parameters with accuracy exceeding 85% .

Rationale for Research Topic

The growing demand for sustainable functional materials stems from global environmental challenges and the need to reduce fossil resource exploitation . The MOF market demonstrates dynamic growth with a projected value of $555 million by 2025, yet commercialization remains limited due to processing difficulties . The project addresses the critical gap between academic innovations and industrial scalability by developing processing methods compatible with large-scale production .

Most Important Expected Results

The anticipated outcomes include achieving three key functionalities: gas adsorption enhancement of at least 300% compared to baseline materials, antibacterial efficacy exceeding 90% against E. coli and S. aureus bacteria, and superhydrophobicity with water contact angles above 150°. The materials will simultaneously retain their fundamental textile properties such as lightness, softness, and porosity . The project will contribute to developing a new class of smart textiles with applications in gas filtration, selective sensors, antibacterial materials, and environmental applications . High-impact journal publications and potential patent applications are expected, creating foundations for industrial production of next-generation multifunctional fibrous materials .