Development of Outdoor Clothing Fiber Material Using Graphene Nanoparticle Dispersion Stabilization Technology

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그래핀 입자의 분산 안정화 기술을 적용한 아웃도어 의류용 Graphene/r-PET 섬유 소재 개발

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Abstract

This study presents a method to enhance the dispersion of graphene nanoparticles within recycled PET (r-PET) to develop high-performance outdoor clothing materials. Graphene fibers, known for their far-infrared emission and antibacterial properties, face challenges in achieving consistent color due to dispersion issues. The dispersion was improved through a micronization process and sequential use of dispersants, resulting in a graphene/r-PET master batch with a uniform distribution of graphene particles, as confirmed by FE-SEM analysis. The produced filaments were spun into 50 denier and 100 denier graphene/r-PET yarns, woven into fabrics with high dyeability. The resulting fabric demonstrated excellent tear strength, dimensional stability after washing, and oil repellency, making it suitable for outdoor use. Additionally, far-infrared emissivity and UV blocking tests confirmed its thermal comfort and UV protection capabilities.

This work effectively incorporates graphene into r-PET fibers, providing a pathway for functional, sustainable outdoor textiles. Future research will focus on further improving durability, comfort, and environmental sustainability.

1. Introduction

Graphene fibers are promising for outdoor clothing applications due to their far-infrared emission and antibacterial properties. However, achieving consistent color has been a challenge, primarily due to poor dispersion of graphene within polymers, which underscores the need for further research into dyeable graphene fiber materials. This study aims to enhance the dispersion of graphene particles within recycled PET (r-PET) via a micronization process, leading to the production of graphene/r-PET yarns. The goal was to develop a high-functional, dyeable fabric suitable for outdoor apparel by optimizing both spinning and weaving processes.

2. Methods

2.1 Preparation of Graphene/r-PET Masterbatch

Recycled PET (r-PET) was heated to 60°C in a high-speed mixer before adding 0.5% of graphene particles (less than 200 nm). High-speed mixing was performed for 20 minutes to ensure uniform dispersion of graphene on the r-PET surface. To further stabilize the dispersion, 1.0% of amine-based Zepamine and 0.5% of zinc stearate were sequentially added, each followed by 10 minutes of high-speed mixing. To minimize scattering, 2% of amino-modified silicone oil was also introduced.

The prepared mixture was then processed through twin extruders (L/D-44:1) with reduced temperature (between 210°C and 250°C) and a 20% lower screw RPM to prevent r-PET degradation. A triple mesh system was installed at the extruder nozzle die to enhance dispersibility and remove impurities, aided by a 10% increase in vacuum pressure compared to virgin resin.

2.2 Fabrication of Graphene/r-PET filaments

The spinning process utilized a graphene/r-PET master

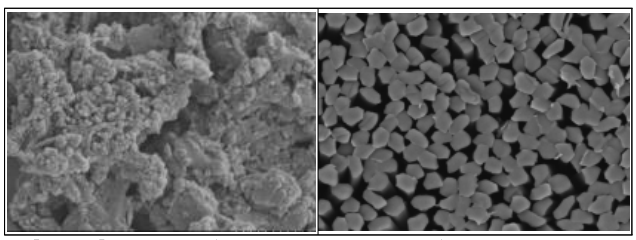
batch, mixed in a 95:5 ratio with r-PET as the primary raw material. Initial spinning trials were conducted at 283°C with a draw ratio of 1:2.9, but adjustments were necessary due to emissive occurrences. The temperature was raised to 286°C, and the draw ratio was reduced to 1:2.8.

The optimization process resulted in successful production of graphene/r-PET filaments, specifically 100 denier (144F) and 50 denier (72F). The 50D/72F filament was combined and twisted to create yarn suitable for weaving with the 100D/144F filament. Texturing was performed using a Murata-33H machine, which involved heating, interlacing, and winding for subsequent processing.

2. Results and Discussion

The optimized graphene dispersion method successfully produced a high-performance graphene/r-PET master batch, with crude ash analysis revealing a graphene concentration of approximately 3,470 ppm for the 0.5% graphene MB. The uniform fiber morphology observed through FE-SEM confirmed effective dispersion of graphene.

Mechanical testing demonstrated the suitability of the developed fabric for outdoor applications. Tear strength tests indicated a high level of durability, while dimensional stability tests showed resilience after multiple wash cycles, affirming its longevity. Oil repellency tests highlighted its ability to resist common outdoor contaminants. Evaluations of far-infrared emissivity and UV blocking capability confirmed the fabric's thermal comfort and effective UV protection, demonstrating its functional benefits for outdoor clothing.



[Fig. 1] Graphene/*r*-PET ash, Graphene/*r*-PET Filament

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