Electrospun Polymeric Nanofibers Incorporating Europium Hydroxide and Reduced Graphene Oxide for Antibacterial Applications

Kun-Yauh Shih*, **Shiou-Ching Yu**

National Pingtung University, Pingtung, Taiwan

E-mail: sky@mail.nptu.edu.tw

Abstract

The electrospinning fabrication of multifunctional nanomaterials has garnered significant attention due to their extensive applications in the biological, medical, and food industries. In this study, nanofibers with superior antibacterial properties were developed by incorporating Europium hydroxide nanorods ($Eu(OH)_3$) and reduced graphene oxide (RGO) into a poly(ethylene oxide) (PEO) polymer matrix via electrospinning. Uniform $Eu(OH)_3$/RGO nanocomposites were synthesized rapidly, one-step microwave-assisted, and dispersed into a PEO solution to fabricate the nanofibers.The prepared $Eu(OH)_3$/RGO/PEO nanofibers were systematically characterized using X-ray diffraction (XRD), Raman spectroscopy, and Fourier-transform infrared spectroscopy (FTIR) to confirm the successful reduction of graphene oxide and the formation of the $Eu(OH)_3$ phase (JCPDS#83-2305). Scanning electron microscopy (SEM) revealed that the optimal morphology of nanofibers was achieved at an electrospinning voltage of 24 kV and a flow rate of 1 mL/h. Antibacterial activity against E. coli was evaluated using minimum inhibitory concentration (MIC), colony counting, inhibition zone diameter, and optical density (OD) measurements. The results demonstrated that $Eu(OH)_3$/RGO/PEO nanofibers exhibited outstanding bactericidal performance, completely reducing viable bacterial counts at 0.1 mg/mL concentration.

This novel $Eu(OH)_3$/RGO/PEO nanocomposite exhibited excellent antibacterial efficacy and holds significant potential for biomedical devices, food packaging, and antimicrobial coatings applications. The study highlights the synergistic effect of $Eu(OH)_3$ and RGO in enhancing antibacterial properties. It paves the way for developing advanced polymer-based materials for biological, medical, and food-related applications.

Introduction

Chitosan (CS), a biocompatible and antibacterial polymer, was blended with polyethylene oxide (PEO) to fabricate nanofibers via electrospinning. By adjusting polymer ratios and voltage, nanofiber morphology and antibacterial properties were optimized. SEM, XRD, and ATR-FTIR were used to analyze structure and composition. Antibacterial tests, including colony counting, MIC, and inhibition zone assays, showed that optimized fibers reduced bacterial viability to 3.69% within 30 minutes. The results demonstrate the strong potential of CS/PEO nanofibers for antimicrobial applications.

Experimental

1. Fabrication of Eu(OH)3/RGO/PEO Fibers

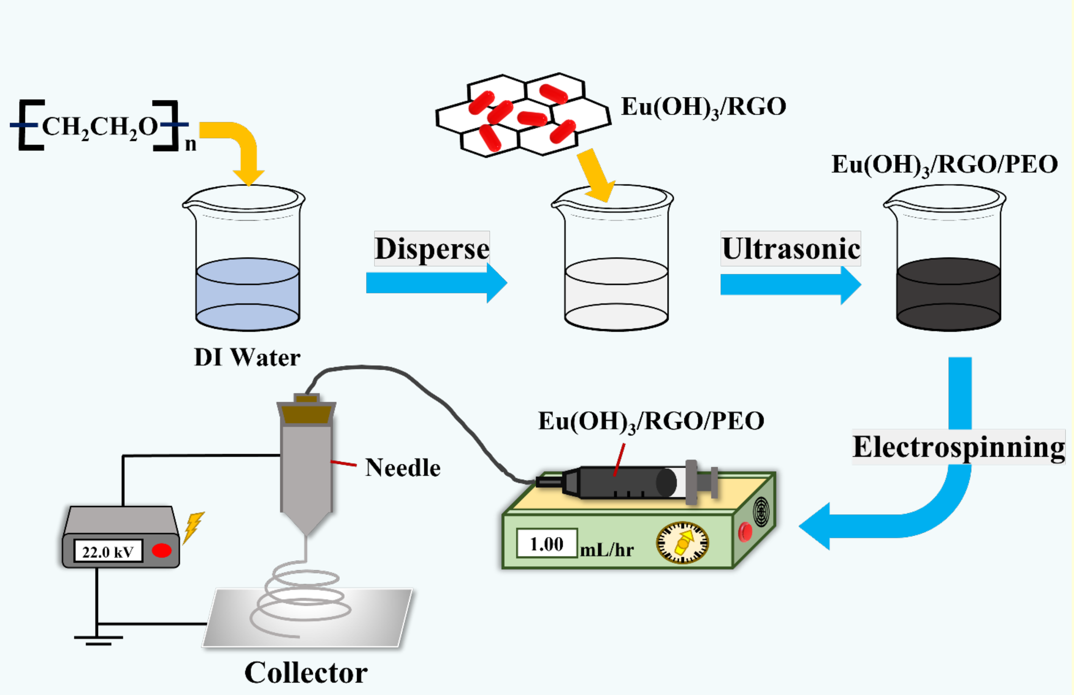

Fig. 1. Schematic diagram of the fabrication of Eu(OH)3/RGO/PEO fibers.

2. Antibacterial Study of Eu(OH)3/RGO/PEO

Chitosan fibers were assessed for antibacterial activity using a colony counting assay. A 1.5 mL suspension of *E. coli* (10^5 CFU/mL) was mixed with the sample, left to react briefly, and 150 μL of the mixture was spread onto agar plates. After incubation at 37 ˚C for 18 hours, colony numbers were recorded.

Results and Discussion

1. XRD Analysis of Crystalline Structure

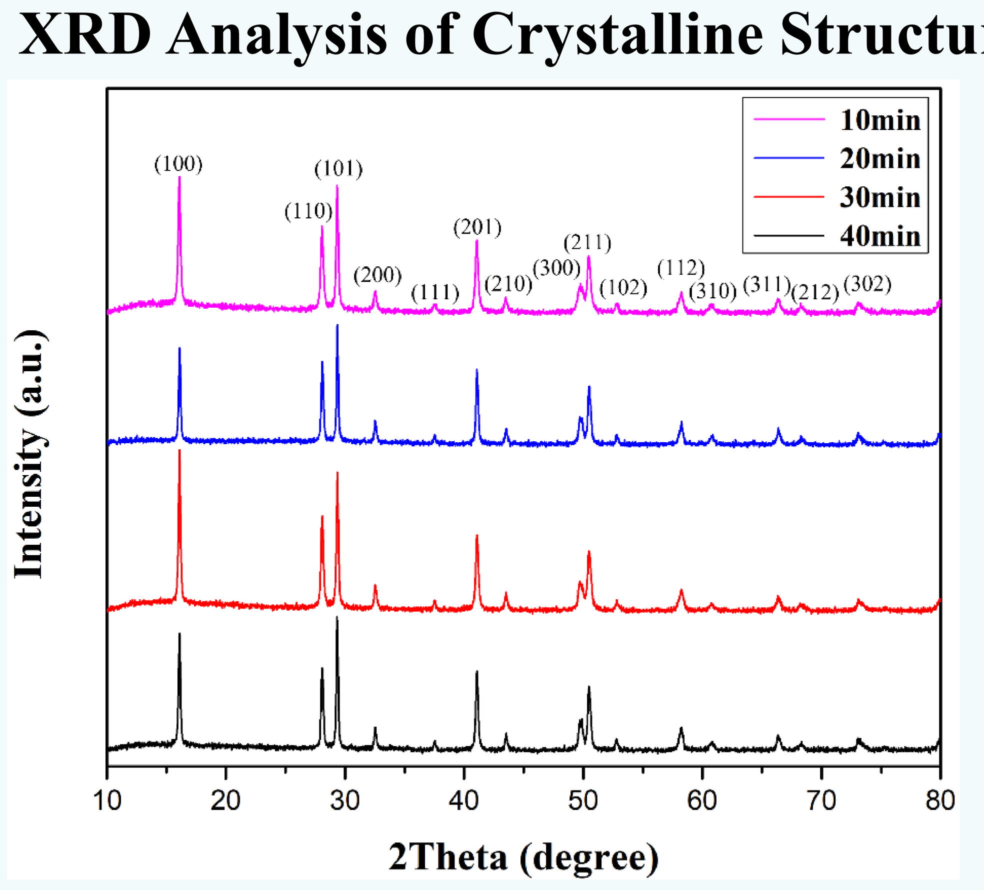

Fig. 2. XRD patterns of $Eu(OH)_3$/RGO composites synthesized at different microwave durations.

2. Morphological Analysis of Electrospun Fibers by SEM

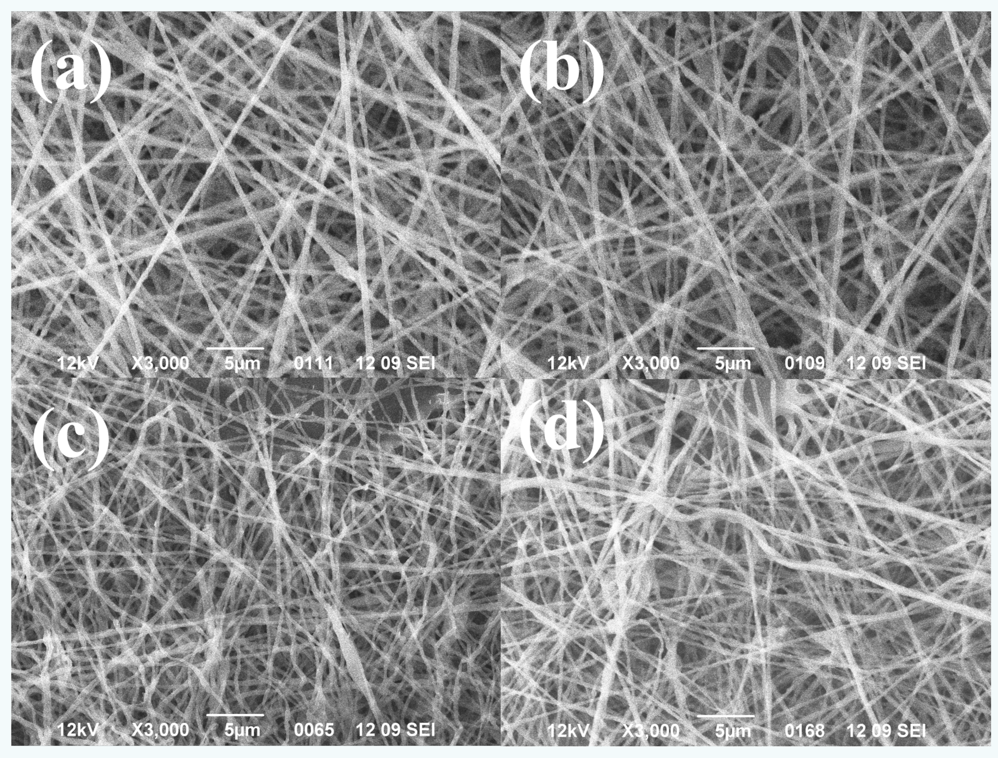

Fig. 3. SEM images of different flow rates on the morphology of $Eu(OH)_3$/RGO/PEO nanofibers :(A) 0.8 mL/hr, (B) 1.0 mL/hr, (C) 1.2 mL/hr, (D) 1.4 mL/hr .

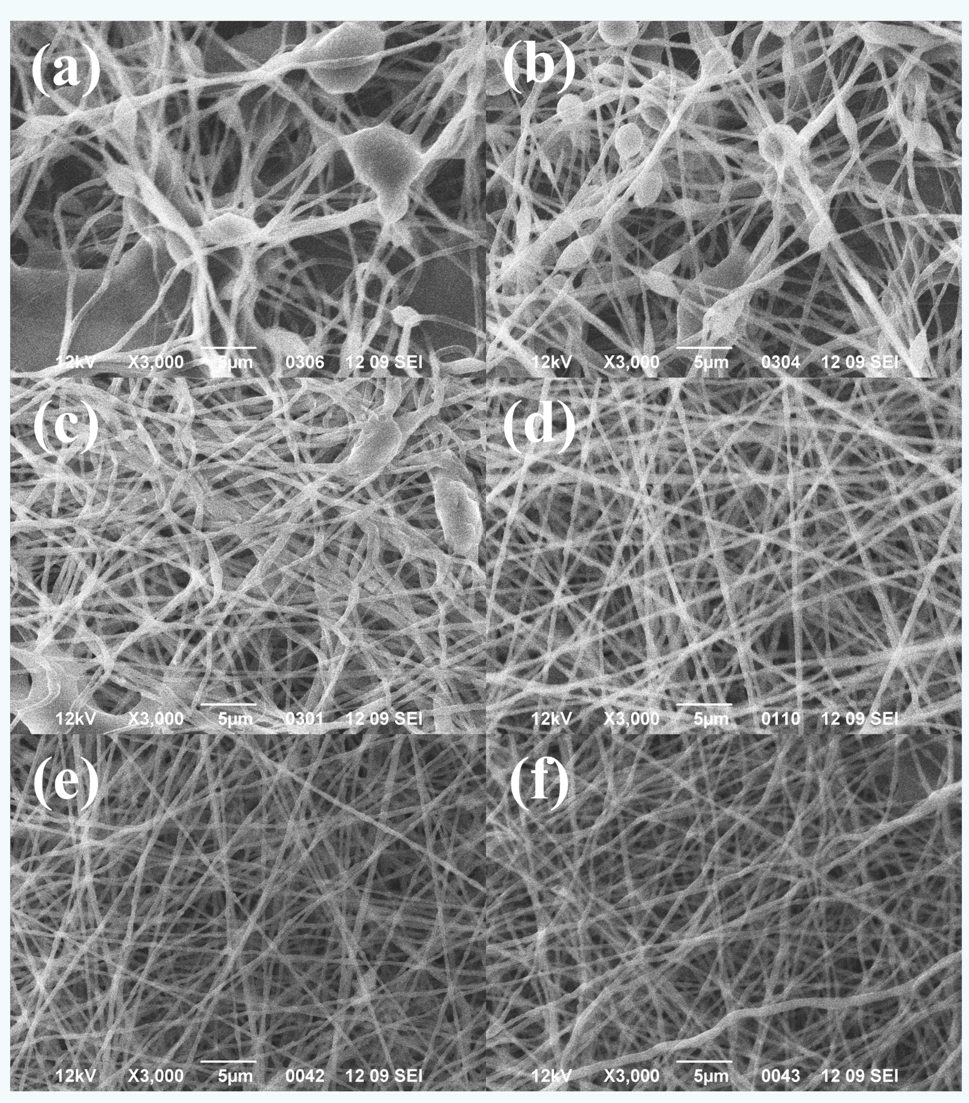

Fig. 4. SEM images of different applied voltages on the morphology of $Eu(OH)_3$/RGO/PEO nanofibers :(A) 8 kV, (B) 8 kV, (C) 12 kV, (D) 16 kV, (E) 20 kV, (F) 24 kV.

3. Functional Group Analysis by FTIR

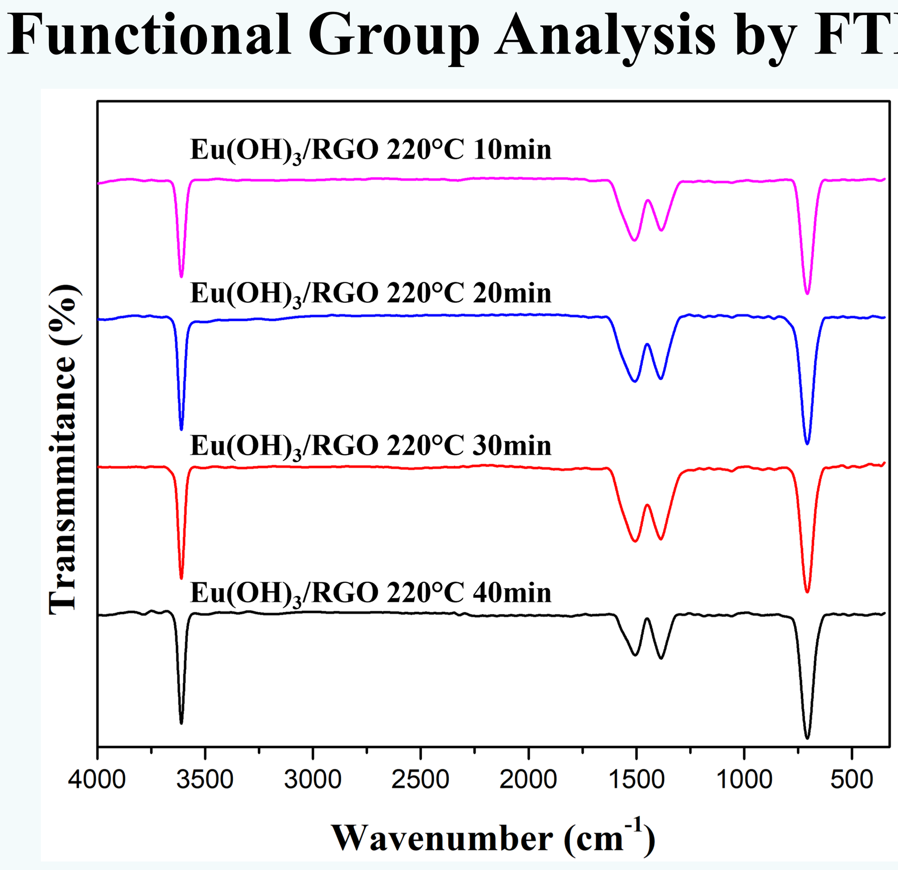

Fig. 5. FT-IR spectra of $Eu(OH)_3$/RGO composites synthesized at different microwave durations.

Results and Discussion

4. Evaluation of Antibacterial Activity

(1). Optical Density (O.D.) Measurement

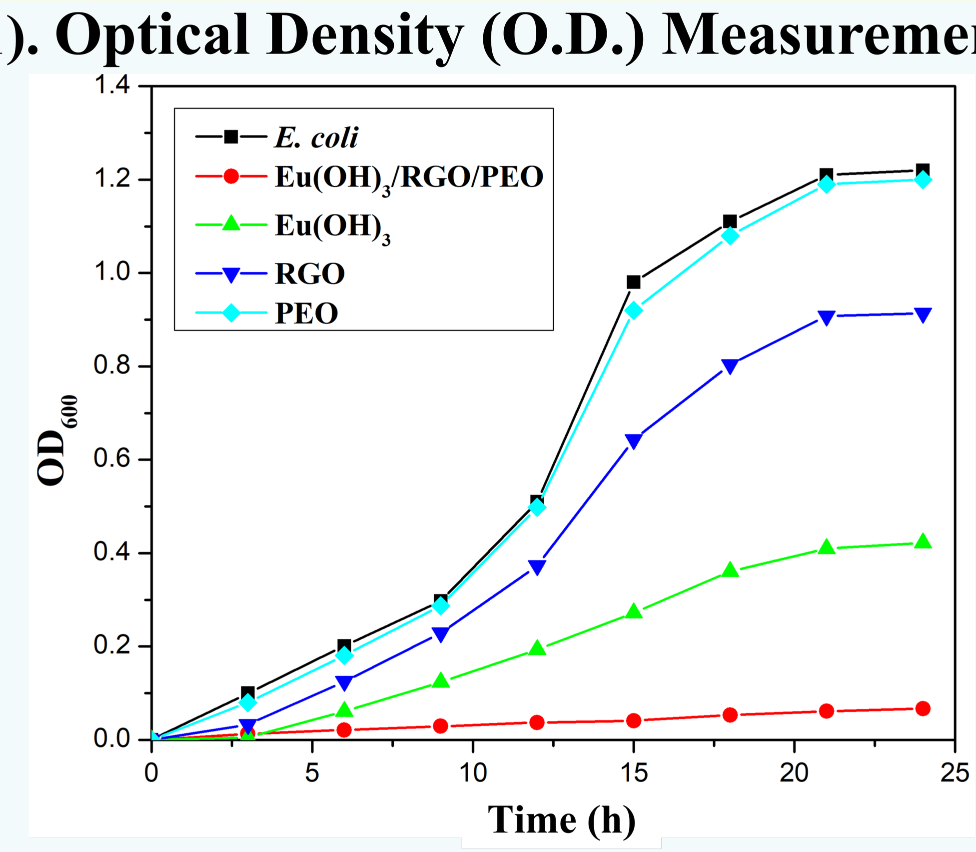

Fig. 6. Antibacterial activity of CS/PEO fibers at different concentrations: (A) Blank, (B) 5 mg/mL, (C) 10 mg/mL, (D) 15 mg/mL, (E) 20 mg/mL, (F) 25 mg/mL.

(2). Minimum Inhibitory Concentration (MIC)

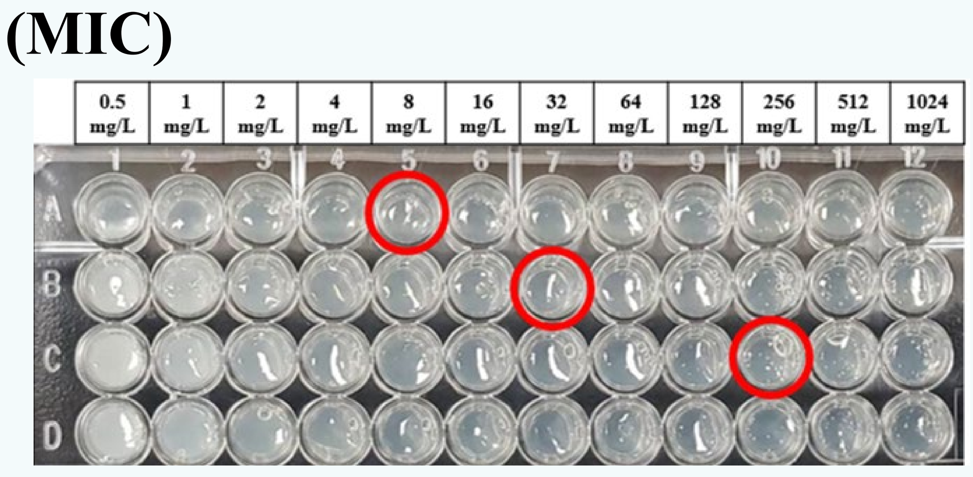

Fig. 7. Minimum inhibitory concentration (MIC) tests of different composite materials: (a) $Eu(OH)_3$/RGO/PEO, (b) $Eu(OH)_3$, (c) RGO, and (d) PEO.

3. Inhibition zone

Table 1. Inhibition zone diameters of various materials against *Escherichia coli*.

	Zone of Inhibition (Diameter ± SD (mm))			
	Ampicillin	RGO	$Eu(OH)_3$	$Eu(OH)_3$/RGO/PEO
E. coli	18.3 ± 1.1	8.1 ± 1.7	15.0 ± 1.1	20.5 ± 0.9

Conclusion

$Eu(OH)_3$/RGO nanocomposites were successfully synthesized via microwave-assisted methods, with optimal conditions at 220 ˚C for 30 minutes. Electrospinning with 9% PEO at 24 kV and 1 mL/h yielded uniform fibers. Antibacterial tests demonstrated complete bacterial inhibition at 0.8 mg/L, with performance comparable to standard antibiotics.

Reference

1. Shih, K.-Y.; Yu, S.-C. Microwave-Assisted Rapid Synthesis of Eu(OH)3/RGO Nanocomposites and Enhancement of Their Antibacterial Activity against *Escherichia coli*. *Mater.* **2022**, *15* (1), 43. DOI: 10.3390/ma15010043.