NANOENGINEERED BIOPOLYMER-FULLERENE C_{60} COMPOSITE FILMS FOR BIOFOULING RESISTANCE

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Biofilm formation on medical devices and clinical surfaces remains a major contributor to persistent infections, as mature biofilms are highly tolerant to conventional antibiotics and disinfectants. Once established, these biofilms are difficult to eradicate, underscoring the need for antimicrobial surface strategies that do not rely on drug release or promote resistance. Antimicrobial photodynamic therapy offers such an approach by generating reactive oxygen species upon light activation, provided the photosensitizer can be stably immobilized within a solid material.

In this study, biopolymer–fullerene composite films were fabricated and structurally characterized as a materials platform for photodynamically active antimicrobial surfaces. Fullerene C_{60} nanoparticles were physically incorporated at 0.5 wt% into polylactic acid (PLA), poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), and chitosan matrices using a thermophysical melt-processing route. PLA and PHBV composites were obtained through extrusion followed by hot pressing, while chitosan films were prepared by hot pressing due to limited extrusion compatibility. This solvent-free approach enables stable photosensitizer immobilization without chemical modification.

Raman spectroscopy and hyperspectral Raman mapping confirmed successful incorporation of C_{60} across all matrices. Characteristic fullerene modes were clearly detected, with the intense Ag(2) band at 1467 cm^{-1} serving as a reliable spectral marker. Raman mapping further revealed localized fullerene-rich domains formed during melt processing.

X-ray diffraction and differential scanning calorimetry revealed matrix-dependent structural responses. PLA composites showed reduced crystallinity and pronounced cold crystallization, consistent with a largely amorphous structure. PHBV retained semicrystalline order with increased melting transitions and crystallite size, indicating a nucleating effect of C_{60}. Chitosan films displayed reduced structural order and modified dehydration-related transitions, suggesting partial disruption of the hydrogen-bonded network.

Overall, thermophysical processing provides a scalable route for producing biopolymer–fullerene composite films while preserving polymer integrity. The confirmed incorporation and matrix-dependent structural effects of fullerene establish a basis for further investigation of photodynamic activity and antimicrobial performance.

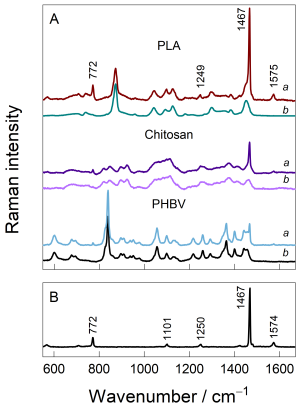

Fig. 1. (A) Raman spectra of PLA, chitosan, and PHVB samples with (a) and without fullerene (b). Spectra were collected by averaging the Raman mapping data of 500 individual spectra. (B) Raman spectrum of fullerene.

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