DURABILITY AND SUSTAINED ANTIMICROBIAL ACTIVITY OF NANOCOMPOSITE COATINGS

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Durable antimicrobial coatings are critical for preventing pathogen transmission on frequently touched surfaces in healthcare and industrial environments. With antimicrobial resistance (AMR) posing a growing global threat – projected to cause up to ten million deaths and US$1 trillion in additional healthcare costs by 2050 [1] – developing long-lasting antimicrobial materials is urgent. Polyvinyl butyral (PVB)-based nanocomposites incorporating active agents such as silver nanoparticles (AgNPs), zinc oxide tetrapods (ZnO-Ts), and biocides (ampicillin, benzalkonium chloride, sodium pyrithione, triclosan) are promising candidates. This work reviews the durability and sustained antimicrobial performance of these coatings during aging.

AgNP-PVB coatings, produced via UV-mediated photochemical synthesis [2], generated AgNPs with average sizes of 15-118 nm depending on irradiation time. UV-Vis-NIR measurements after two years showed no significant shift in absorption bands, and water contact angles (WCAs) remained within ±5° of initial values. Antiviral assays against SARS-CoV-2 RNA confirmed sustained viral inactivation.

PVB-sodium pyrithione (NaPT) coatings demonstrated a unique “self-renewing” property: mechanical abrasion removed superficial polymer layers, exposing fresh biocide and increasing antibacterial efficacy against *E. coli* three-fold compared to unabraded surfaces. PVB-triclosan and PVB-NaPT coatings retained strong antiviral activity, achieving complete bacteriophage *φ6* inactivation and significant SARS-CoV-2 RNA degradation [3].

Synergistic PVB/ZnO-T/NaPT nanocomposites enhance durability and antimicrobial performance. The 3D tetrapod morphology [4] reinforces the PVB matrix mechanically, while ZnO-T and NaPT provide dual antimicrobial action via reactive oxygen species generation, Zn^{2+} ion release, and membrane depolarization. Smaller ZnO-T dimensions and higher NaPT concentrations lowered WCAs and increased efficacy, achieving $\log_{10}$ reductions up to 5.91 against *S. aureus*, *P. aeruginosa*, and *C. albicans*, and biofilm reductions of 87.7%. Surface free energy increased over four months (38.96 to 52.27 mN/m), reflecting aging-related polarity changes. Optimal tetrapod leg diameters approximately double the Debye length improved coating stability.

Overall, PVB-based nanocomposite coatings maintain structural integrity and high antimicrobial activity over time, offering a promising strategy for long-term protection of frequently touched surfaces.

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