Preparation of Nano-Cu Composite Silicon-Based Coating with Low Surface Energy and Study of Antifouling Mechanism

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Abstract Marine biofouling has always posed a significant challenge for the marine industry. Fouling-release coatings (FRCs) are commonly used in marine anti-fouling due to their low cost and environmentally friendly properties, among which silicone-based coatings with low surface energy are most widely used. In this study, we successfully prepared a novel nano-enzymatic composite low-surface-energy coating by modifying silicone with polyurethane and incorporating nano-Cu which exhibits peroxidase-mimicking activity. Firstly, we modified the nano-Cu using isophorone diisocyanate (IPDI) and polyethylene glycol (PEG). Characterization via x-ray diffraction(XRD), Fourier transform infrared spectroscopy(FTIR), x-ray photoelectron spectroscopy(XPS), and scanning electron microscopy(SEM) confirmed the successful modification. Then we synthesized the silicone-based polyurethane coating through a two-step process, utilizing IPDI, bis-hydroxy-capped polydimethylsiloxane (HO-PDMS-OH), and 4,4'-methylenebis(3-chloro-2,6-diethylaniline) as raw materials. Ultimately, we obtained the nanocomposite low-surface-energy coatings by adding 0.1 wt% of nano-Cu to the aforementioned coatings. We tested the water contact angle (WCA) of the coating surface and performed surface free energy (SFE) calculations. The results indicated that the contact angle shifted from 103.8° to 97.6° after adding modified nano-Cu, while the surface energy changed from 22.3 mJ/m^2 to 21.6 mJ/m^2, demonstrating that the coating retains its hydrophobicity and low surface energy properties. Furthermore, we evaluated the antifouling performance of the coatings through antibacterial and anti-diatom experiments. The bactericidal rate of the composite coatings containing nano-Cu reached 97%. In the presence of trace amounts of H_2O_2, the bactericidal rate approached nearly 100% due to the mimetic peroxidase activity of the nano-Cu. In conclusion, this study presents a promising pathway for developing high-performance silicon-based antifouling coatings, which hold great potential for real-world marine antifouling applications.

Keywords antifouling, silicone, polyurethane, model enzyme, nanocomposite

Reference

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