Superomniphobic Organic/Inorganic Nanocomposite Coatings via Hybrid CVD for Next-Generation Electronic Interfaces

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The operational stability of emerging semiconductor devices is often limited by exposure to moisture, organic contaminants, and chemically aggressive environments. Developing multifunctional surface coatings that provide environmental protection while maintaining compatibility with advanced electronic architectures is therefore of significant interest. In this study, a novel hybrid chemical vapor deposition (CVD) approach is proposed for the single-step fabrication of superomniphobic organic/inorganic nanocomposite coatings for next-generation electronic interface applications. The process combines initiated chemical vapor deposition (iCVD) and plasma-enhanced chemical vapor deposition (PECVD) within a single reactor, enabling the simultaneous deposition of a low-surface-energy fluoropolymer layer and nanostructured SiO_2 features. The resulting hierarchical micro/nano architecture promotes the Cassie–Baxter wetting regime, yielding exceptional repellency against both high- and low-surface-tension liquids. Unlike conventional omniphobic surface treatments that require multiple fabrication and surface modification steps, the proposed method provides a solvent-free, scalable, and environmentally benign route for producing multifunctional coatings through a single deposition process.

The PECVD-generated inorganic phase contributes nanoscale roughness, mechanical robustness, and enhanced surface durability, while the iCVD-derived polymer phase enables precise control of surface chemistry and interfacial properties. Through the synergistic integration of these vapor-phase processes, highly durable and chemically resistant coatings can be deposited directly onto technologically relevant substrates. Such coatings are expected to enhance the environmental stability, contamination resistance, and operational lifetime of organic electronic devices, sensors, photovoltaic systems, and flexible semiconductor platforms. The FTIR measurements confirmed the successful incorporation of both the fluoropolymer matrix and silica-based inorganic phase, while SEM analyses revealed a well-defined hierarchical micro/nano surface architecture generated through the simultaneous iCVD/PECVD process. The resulting morphology is expected to facilitate stable Cassie–Baxter wetting conditions and enhanced liquid repellency. The wetting experiments demonstrated water contact angles exceeding 160° with sliding angles below 10°, indicating the successful fabrication of superhydrophobic nanocomposite coatings suitable for advanced electronic interface applications. Besides, the coatings exhibit excellent repellency against low-surface-tension liquids while preserving mechanical robustness and environmental stability. Such multifunctional characteristics highlight the potential of hybrid CVD-derived nanocomposite coatings as protective interfaces for emerging semiconductor and energy devices.