Self-Standing Superhydrophobic Thin Films Using Soft Lithography and Initiated Chemical Vapor Deposition (iCVD) Techniques

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The growing demand for advanced functional surfaces in flexible electronics, wearable technology, smart textiles, and self-cleaning devices has accelerated the search for substrate-independent and highly durable water-repellent materials. Among various surface modification strategies, superhydrophobic surfaces have attracted significant attention due to their ability to effectively repel water droplets, prevent ice accretion, and resist corrosion. Conventional liquid-phase coating techniques often suffer from severe limitations, including solvent dependency, pore clogging, poor conformality, and lack of mechanical flexibility, which restrict their application on complex micro/nanostructured surfaces. Furthermore, most superhydrophobic coatings rely heavily on permanent rigid substrates, limiting their integration into self-supporting and flexible architectures. To overcome these intrinsic challenges, this study presents a novel, eco-friendly, and solvent-free approach for fabricating self-supporting, ultra-thin superhydrophobic organic/inorganic nanocomposite films by synergistically integrating Soft Lithography and Initiated Chemical Vapor Deposition (iCVD) techniques. In this strategy, sacrificial templates with micro/nano-scale surface roughness were initially fabricated using highly water-soluble Polyvinyl Alcohol (PVA) replicated from p600 and p1000 sandpapers via Soft Lithography. Subsequently, a conformal polymeric thin film composed of perfluorodecyl acrylate (PFDA), 2-ethylhexyl acrylate (EHA), and acrylic acid (AA) was deposited in a single step over the rough PVA templates using an iCVD process. Atomic Force Microscopy (AFM) analysis revealed that the nano-roughness (RMS) of the synthesized films is strongly governed by the thermal reaction conditions; an optimal filament temperature of 215°C and substrate temperature of 20°C yielded the most uniform and smooth film with roughness of 14.06 nm, whereas higher filament temperatures (250°C) significantly increased nanoscale surface roughness up to 31.78 nm. Following the iCVD coating, the sacrificial PVA template was completely dissolved in pure water, yielding a freestanding, highly flexible, ultra-thin polymer film without leaving chemical residues. The synergy between the micro-roughness and the conformal low-surface-energy fluoropolymer coating supported the Cassie-Baxter wetting state, resulting in high water contact angles (CA>150°) exhibiting superhydrophobic character. This work provides a versatile and sustainable framework for manufacturing transferable and substrate-free superhydrophobic for advanced engineering applications.

Keywords: Initiated Chemical Vapor Deposition (iCVD), Self-support Soft Lithography, Superhydrophobic, Water repellency