Fluorine-Free Oil Repellency: Material and Structural Design for Oil-Repellent Textile Surfaces

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Abstract

The substitution of per- and polyfluoroalkyl substances (PFAS) in textile finishing requires a clear distinction between durable water repellency (DWR), for which effective fluorine-free technologies are already available, and genuine repellency against oils and other low-surface-tension liquids. For the latter, the surface energies achievable with fluorine-free chemistries are intrinsically limited. Current research is therefore shifting from the search for a direct chemical substitute towards approaches combining surface chemistry with hierarchical and re-entrant structures to kinetically stabilise non-wetting states.
Our approach explores an additional concept based on hollow silica nanoparticles and functional polymers. The particle size, shell structure, porosity and surface chemistry of the silica nanospheres are systematically varied. Short alkyl chains (C1–C4) were tethered to the particle surface to control molecular organisation and the density of low-energy methyl groups. Water-vapour sorption reveals pronounced differences between unmodified and modified particles. At high relative humidity, unmodified particles take up approximately 40 wt% water, whereas alkyl modification strongly suppresses this uptake. Sorption/desorption hysteresis indicates different water populations, comprising a large fraction associated with capillary condensation and a more strongly bound fraction persisting to considerably lower humidity.

In parallel, latex coatings based on polyacrylate copolymers containing docosyl and poly(dimethylsiloxane) side chains show a measurable kinetic retardation of oil wetting upon incorporation of SiO hollow nanoparticles.
The results demonstrate that fluorine-free oil repellency cannot be considered solely as a question of replacing fluorinated surface chemistry. Molecular organisation, particle architecture, interfacial water and hierarchical surface structure must be considered together. This provides a basis for developing application-specific fluorine-free oil-repellent textile coatings.

Keywords: Oil Repellency, Oil, Repellent Textile Surfaces, substitution of PFAS

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