Interfacial molecular dynamics govern frictional dissipation and detachment

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Water friction on solid surfaces gives rise to a variety of important phenomena, including interfacial charging, coating delamination, and surface cleaning[1-3]. Elucidating the molecular mechanisms underlying these effects at water–solid interfaces is therefore of considerable scientific and technological significance. Ice accretion on solids is also ubiquitous, yet the molecular origins of ice friction and detachment remain poorly understood, especially for interfaces with distinct molecular compositions and structural configurations. Given these considerations, our group studies how interfacial molecular dynamics control friction, adhesion, and detachment at water–solid and ice–solid interfaces. We have shown that adaptive polymer interfaces can achieve low friction despite strong adhesion by dissipating stress through rapid, reversible chain deformation and stepwise desorption. We further discovered an explosive fracture mode of adhered ice under quasi-static cooling, governed by ice grain size and thermomechanical stress accumulation. Building on these insights, we developed a polar-bear-inspired deformable coating for wind turbine blades that enables spontaneous ice shedding under real icing conditions. Field trials on utility-scale turbines demonstrated substantial improvements in power output and shutdown reduction. Together, these studies provide a molecular-to-engineering framework for designing low-friction, self-deicing interfaces and coatings for cold-environment applications.

Keywords:
interface, interfacial molecular dynamics, water friction, ice adhesion

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