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Mechanics of Freezing-Empowered Self-Catapulting of Water Droplets

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ABSTRACT

Despite the remarkable progress of anti-icing and deicing technologies in the past decades, it remains a grand challenge to dislodge freezing water from a solid surface without consuming external energy. Herein, we propose a strategy to dislodge freezing water from solid surfaces just by leveraging its volume expansion resulting from the phase change from water to ice. The implementation of this energy-saving strategy relies on a simple micropillar-based gadget on the surface, termed freezing-empowered droplet catapult (FEDC), whereby the work done by the volume expansion of a freezing droplet accreted on it can be harvested and stored as elastic energy, and subsequently released in due course to catapult the freezing droplet away from the surface. Mechanics-based modelling is carried out to reveal the necessary conditions of occurrence for the self-catapulting of freezing water droplets on a FEDC, yielding a phase map that manifests the necessary synergy among the characteristic dimensions and stiffness of the FEDC as well as the volume of the droplet in triggering its self-catapulting. Our study not only demonstrates the feasibility of an energy-saving strategy for shedding off freezing droplets from solid surfaces, but also provides a quantitive guideline for the design of the gadget for implementation, paving the way to a new technology for controlling ice accretion on solid surfaces with zero consumption of external energy.

KEYWORDS

Ice adhesion; interfacial mechanics; deicing; energy-saving; functional surfaces

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