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Passive Snow Repulsion: A State-of-the-art Review Illuminating Research Gaps and Possibilities

Per-Olof Andersson[a]*, Bjørn Petter Jelle[ab], Zhiliang Zhang[c]

[a]*Departement of Civil and Environmental Engineering, Norwegian University of Science and Technology (NTNU), NO-7491 Trondheim, Norway*
[b]*Departement of Materials and Structures, SINTEF Building and Infrastructure, NO-7465 Trondheim, Norway*
[c]*Departement of Structural Engineering, Norwegian University of Science and Technology (NTNU), NO-7491 Trondheim, Norway*

Abstract

Building integrated photovoltaics (BIPV) are becoming more common every day. They are used everywhere, from the cabin in the mountains to the modern apartment building, and with more common use, strengths and weaknesses begin to reveal themselves more and more. In the regions of the world experiencing a colder climate, ice and snow coverage presents a challenge to productivity, BIPV resilience and longevity. Mechanically clearing snow and ice wears down the installations more quickly and may present a hazard to the people carrying out the clearing. Several research studies have been presented regarding the passive repulsion of ice and frost, while the repulsion of snow remains largely unexplored. This study aims to concisely present a review of what has been published in the field regarding snow repulsion and illuminate the research gaps and thus pave the way for future research. The snow aspect is illuminated by employing strategies previously applied to icephobicity research. A special emphasis is put on the comparison between microstructured, nanostructured and hierarchically structured surfaces as these constitute the basis of most icephobic (pagophobic) strategies.

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Keywords: Snow; Icephobic; Snowphobic; Frigophobic; Pagophobic; Chionophobic; Building integrated photovoltaics; BIPV; Microstructure; Nanostructure; Hierarchical structure; Review; State-of-the-art

* Corresponding author. Tel.: +47 92284661
E-mail address: per.olof.andersson@ntnu.no

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1. Introduction

Removing snow and ice from building integrated photovoltaic (BIPV) installations is a necessary step to maximize electricity production through the winter months in regions that experience significant snowfall. This is an activity that can be accompanied by a risk of personal injury (e.g. from falling off a slippery roof) and of damaging the modules with various tools. A BIPV solution with a surface that passively sheds snow would effectively eliminate this risk and ensure continuous production throughout the year. Also, the risk of irreversibly damaging an integrated part of a building envelope is potentially expensive to rectify, making the passive clearing of snow and ice that much more important.

A lot of recent work has been carried out in the field of passively de-icing surfaces [1–5] and the terms icephobic and pagophobic were invented to describe these surfaces. Passive snow repulsion or shedding, however, is a largely unexplored area. In this study, possible strategies are explored and recent research reviewed in order to illuminate challenges and future research opportunities. In keeping with scientific tradition, snowphobic surfaces will hereafter be referred to as chionophobic surfaces (chion = snow (Greek)).

2. Ice versus snow

While significantly different phenomena, ice and snow accumulation are intimately related. As reviewed in a previous study [6], ice will commonly accumulate via a liquid stage whether it be glace, frost or rime. This makes the successful application of a superhydrophobic surface, a realistic potential solution. Snow differs from ice in that it is comprised of an agglomeration of snow crystals, liquid water and air; all in varying relative quantities. This gives snow a wide range of physical characteristics depending on composition and ambient conditions. Snow crystals also come in a great variety of morphologies, ranging from simple hexagonal prisms to the more famous dendritic forms [7–10] (*see figure 1*). This further adds complexity to the range of physical behaviour snow can display.

Snow has been defined by Sojoudi et al. [3] as "dry" at temperatures below -1°C to -2°C and "wet" above the same. The same definition was previously made by Glenne et al. [11] but with a limit at 5°C and Pfister et al. [12] observed a limit of snow cohesion at -3°C. This implies some ambiguity as to what can be defined as "wet" and "dry" snow. A more stringent treatment could be as a continuum of compositions containing air, water and snow crystals (*see figure 1*). Each continuum will, however, only be valid for one crystal morphology and can be strongly affected by the level of inter-crystal bonding of the snow.

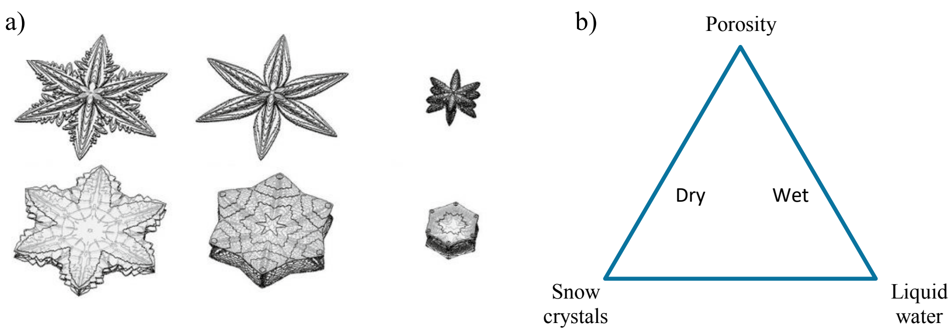

Fig. 1. (a) Snow crystal morphology examples as shown by Kelly et al. [10]; (b) Suggested compositional view of snow depicted as a ternary diagram, yielding a more dynamic definition of "wet" and "dry" snow. (The figure may appear to suggest the existence of porous water, which is incorrect. It is merely a representation of the coexistence of the three components)