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ABSTRACT

This article reviews the fundamental interfacial mechanisms underlying electrofreezing (promotion of ice nucleation via the application of an electric field). Electrofreezing has been an active research topic for many decades, with applications in food preservation, cryopreservation, cryogenics and hydrate formation. There is substantial literature detailing experimental and simulations-based studies, which aim to understand the complex mechanisms underlying accelerated ice nucleation in the presence of electric fields and electrical charge. This work provides a critical review of all such studies. It is noted that application-focused studies of electrofreezing are excluded from this review; such studies have been previously reviewed in literature. This review focuses only on fundamental studies, which analyze the physical mechanisms underlying electrofreezing. Topics reviewed include experimental studies on electrofreezing (DC and AC electric fields), pyroelectricity-based control of freezing, molecular dynamics simulations of electrofreezing, and thermodynamics-based explanations of electrofreezing. Overall, it is seen that while electrofreezing can enable disruptive advancements in the control of liquid-to-solid phase change, our current understanding of the underlying mechanisms can be significantly improved through further studies of various interfacial effects coming into play.

Keywords: electrofreezing; electric field; ice nucleation; molecular dynamics simulations; pyroelectric effect