

## **Coupled Heat and Mass Transfer During Crystallization of Ice on a Cooled Surface**

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In crystallization from an aqueous solution on a cold surface, during phase transition it is frequently assumed that all of the heat of crystallization is transferred into the cold side (i.e. to the crystal side) and the temperature values of both sides (crystal side and the liquid side) of the interface are equal. To understand the crystallization phenomena better, this work aims to investigate the crystal growth from an aqueous solution on a cooled surface theoretically and experimentally in terms of irreversible thermodynamics aspect for (i) estimating the magnitude of the temperature jump at the crystal - liquid interface, (ii) quantifying the effect of the coupling of heat and mass transport and (iii) showing the error one may do using this assumption. Thus, ice formation is taken as an example case and different ice growth regimes (parabolic, linear and dendritic) are distinguished depending on the growth conditions using irreversible thermodynamics. A quartz growth cell is designed and constructed for this crystallization experiments. The cell underneath surface is cooled via a heat exchanger. Data is collected during crystallization on the heat exchanger surface at varying supersaturations. Thermo Liquid Crystal is used to detect the temperature profile at a micro scale both in the solution and under the ice crystals. To define the fluxes and forces of the system, the excess entropy production rate for heat and mass transport into, out of and across the interface (between ice surface and liquid) is used. The method describes the interface as a separate (two-dimensional) phase in local equilibrium. Coupled heat and mass flux equations from non-equilibrium thermodynamics are defined for crystal growth and solved taking the advantage of the Onsager equations. Temperature jumps, coupling coefficients and transfer resistivities at the interface of a growing ice on a cooled surface for each ice growth regimes are defined. The approach of ice growth from coupled heat and mass flux equations, which is first time described for the ice liquid-solid interface, is compared with other growth theories. Using the knowledge gained, calculation of the minimal driving forces needed for ice crystallization in the different growth regimes is possible. As practical application, understanding the different ice regimes' growth phenomena would allow the prevention of undesired ice formation (scaling) on the cooling units which eventually pursue the production of scale-free heat exchangers.