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Nucleation Enhancement Studies on Aqueous Salt Solutions

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Abstract

Techniques favoring the formation nucleation in water such as static electric discharge, salt (NaCl) addition, and surface "roughness" (viz., indents on the ice tray surfaces) on the nucleation temperature of super-cooled water were demonstrated. Aluminum electrodes of flat end were employed for static electric discharge. Concentration of salt in water sample was varied from 0.0 % (w/w) to 5 % (w/w). Experimental studies showed that for technically smooth surfaces, the static electric discharge technique results in the formation of nucleation sites in distilled water around -2°C to -3°C, while the experiments conducted without static electric discharge showed the formation of nucleation sites around -8.2 °C. Increase in salt concentration up to 1% increased the nucleation temperature of distilled water from -8.2 °C to about -1.8 °C. However, high salt concentration of above 2 % (investigated up to 5%) brings down the probability of getting a distinct nucleation point. Experiments revealed that the nucleation temperature was also significantly enhanced by providing indents on the surface of the container (ice trays).

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*Keywords:*Nucleation enhancementof water; static electric discharge; salt solution; surface indents

1. Introduction

Freezing of water starts with sub-cooling which leads to super-saturation. Nucleation is the beginning of phase transition which is characterized by a sudden jump in temperature. Nucleation normally starts at nucleation a site. The techniques influencing the formation of nucleation in water such as ultrasonic bombarding, addition of foreign particles, applying electric discharge, making surface rough, etc. have been investigated by many researchers [1-7].

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Hozumi et al. [1-2] demonstrated that discharge of static electric charge in the super-cooled water brings up the nucleation temperature to -3°C. It was observed that the shape of electrode influence the magnitude of electric static discharge.The degree of super cooling for freezing is lower for the anode with flat end surface than the one with sharp edge.For applied voltage of 50V, The probability of early freezing is more for flat end cathode than the flat end anode. Hozumi et al. [2] have investigated the effects on electrode material on the freezing phenomenon. The probability of early freezing were Al≅Cu>Ag>Au>Pt>C. Shichiri and Nagata [3] have reported the relationship between the ionization tendency of metals and freezing from the anode.Piucco et al. [8] experimentally studied the effect surface roughness on nucleation behaviour of water. It was observed that increased surface roughness favours early nucleation. Nucleation is also affected by the surface properties inside roughness, angle of contact and surface energy of material of the solidification vessel [5, 8-11].

The common problem faced by the household refrigerator is the delay in the start of nucleation (even the nucleation does not begin at about -6°C). Static electric discharge and surface roughness techniques can be used to short out this problem without affecting the COP of the refrigerator. Ultrasonic bombarding also helps the formation of early nucleation but due to the higher investment cost and complexity in adopting the technique, this method cannot be recommended in domestic refrigerator. In this paper, the effects of salt concentration, static electric discharge, and surface roughness (in the form of macroscopic indents on the technically smooth surfaces of container) on the nucleation temperature of distilled water has been studied. The combined effects of salt concentration and static electric discharge on nucleation temperature of distilled water has also been investigated. During the experiments, the salt concentration has been varied from 0% to 5% (w/w) to cover different types of water samples used in the refrigerator.

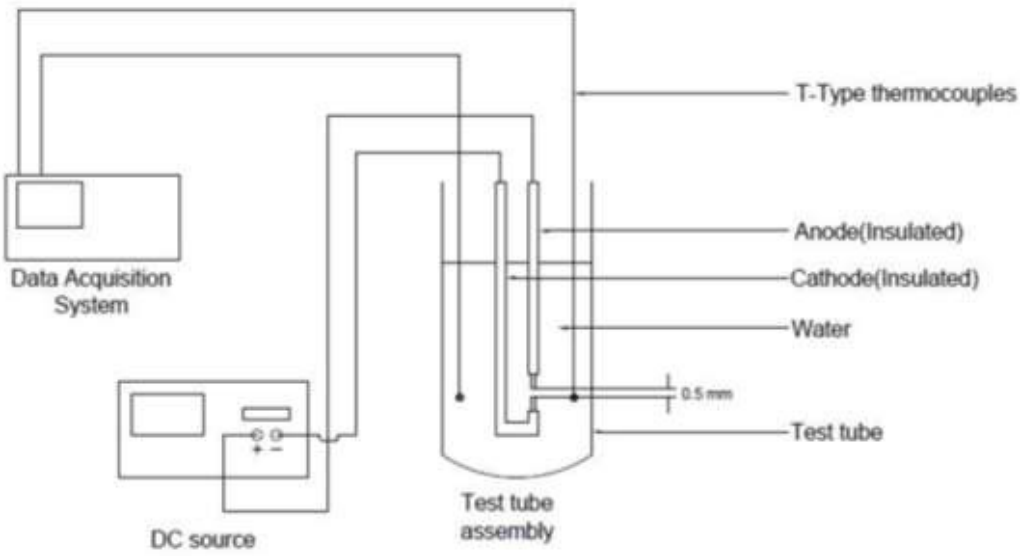

Fig.1 Systematic diagram of experimental setup for study of static electric discharge effect

2. Details of experimental setup

Fig. 1 shows the schematic of the experimental set up employed for studying the effect of static electric discharge on nucleation of the super-cooled water sample. The set up consists of a test tube of 20 ml, aluminum electrode assembly, T-type thermocouples, DC power source, and data acquisition system. Water sample of 10 ml was taken in the test tube having outer diameter 15 mm. Aluminum electrodes having diameter 1.5 mm with flat end surfaces were chosen (flat end electrodes were used because the probability of freezing in the case of the flat end