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Structure of Ice Grown on High-Voltage Conductors

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ABSTRACT

The purpose of this study was to investigate possible effects of an electric field on the structural parameters of ice grown under conditions similar to those which generate accretions on the conductors of overhead power lines. Specific ice samples were made from high-purity D2O droplets, 15 μm in mean volume diameter, which were frozen onto a rotating conductor held at –12°C while it was subjected to ± 15 kV.cm-1, +22 kV.cm-1 or nonenergized electric fields. Neutron diffraction measurements on the samples were taken on the DUALSPEC diffractometer at Chalk River Laboratories in Canada. Rietveld analysis of the diffraction profiles indicates that growing ice samples in a high electric field have small but significant effects on the unit cell volume and the parameters.

INTRODUCTION

Earlier studies carried out on ice accretion on high-voltage conductors showed that the physical appearance of ice was closely related to the electric field strength at the surface of the conductors and also to the polarity of the applied voltage (Farzaneh and Laforte, 1994; Teisseyre and Farzaneh, 1990). The visual aspect of ice accreted from supercooled droplets in the above-mentioned studies showed the formation of ice-treeing under both negative and positive voltage polarities. For negative applied voltages above 10 $kV.cm^{-1}$, the amount of ice accreted was much lower than that accreted under positive voltage for the same magnitude of applied field at the surface of the conductor. In addition, the presence of an electric field reduced the density of accreted ice. The effect of a positive field was less pronounced than that of a negative field. This difference in the physical aspect of ice was attributed to the corona wind and the freezing of the supercooled droplets along the corona streamers (Phan and Laforte, 1981), although there is no direct proof of this assumption.

As concerns the effects of an electric field on the freezing of water droplets, most previous studies have been related to the influence of an electric field upon ice nucleation in atmospheric cloud and the morphological aspects of ice (Prupracher, 1973; Rouleau, 1968; Evans, 1973; Farzaneh and Laforte, 1992). Due to the number of physical phenomena and electric parameters acting simultaneously on individual supercooled droplets, the process of ice formation in the presence of an electric field and corona discharge constitutes a complex problem.

The large number of possible atomic arrangements of ice, which depend on temperature and pressure, has always fascinated scientists. High-density amorphous ice is one of these atomic arrangements (Floriano et al., 1986). Even the structure of the well-known classical ice Ih has not yet been fully solved as concerns the disorder mean square displacements of the atoms, especially protons or deuterons (Kuhs and Lehmann, 1986).

The main purpose of the present study was to investigate possible effects on the crystallographic parameters of ice caused by growth under positive and negative electric fields. As the proton is expected to play the main role in the structural changes induced by an electric field, neutron diffraction measurements are the most appropriate technique for investigating such effects. Due to the large incoherent neutron scattering cross-section of hydrogen, the samples must be made using heavy water, D_2O.

SAMPLE PREPARATION

The specific ice samples, made from very fine supercooled droplets, 15 μm in mean volume diameter, of high isotopic purity heavy water (D_2O), were accreted on the surface of a soft stainless steel conductor, 1.6 cm in diameter, which was placed along the axis of a metallic cylindrical cage, 11.7 cm in diameter (Fig. 1). In order to accumulate a uniform ice thickness, the conductor was rotated at 1 rpm by a driving motor. The pneumatic nozzle used to produce the fine droplets was placed in a heated plexiglass box to prevent the freezing of D_2O vapour at the outlet of the nozzle. Before starting the icing process, the conductor was subjected to either a negative or a positive electric field. For comparison purposes, a reference sample was made with no voltage applied to the conductor. All the processes of ice accretion on this conductor were carried out in a cold chamber where the air temperature was controlled at –12° ± 0.5°C. DC voltage was provided by a constant

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