ELECTRICAL CHARACTERISTICS OF DRIFTING ARCTIC ICE IN THE FREQUENCY RANGE 100 Hz–1 MHz

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Abstract

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ELECTRICAL CHARACTERISTICS OF DRIFTING ARCTIC ICE IN THE FREQUENCY RANGE 100 Hz–1 MHz

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In recent years the drifting ice of the Arctic has become the object of detailed study. The present work is devoted to a discussion of the electrical characteristics of drifting Arctic ice in the low-frequency range.

In papers ([1–3]), investigations of the electrical characteristics of saline synthesized ices in alternating fields are discussed. In papers ([4,5]), the authors give electrical characteristics of the ice of the Sea of Okhotsk and Arctic seas, measured in the range 0.1-30 MHz under laboratory conditions. The characteristics obtained in the cited works agree poorly with one another, and therefore they cannot be extended to drifting Arctic ice, which possesses a specific temporal and spatial distribution of physical properties (temperature, salinity, density).

Fig. 1 and Fig. 2

Fig. 1. Typical temperature dependences of ε' and ρ. Sample salinity $S = 5.4$‰, $f = 1$ kHz

Fig. 2. Dependence of ε' of Arctic ice on salinity at various temperatures. $f = 1$ kHz

The authors of this paper carried out year-round investigations of the electrical characteristics of Arctic ice in 1965–66 at the drifting scientific research station "North Pole 13-f." The investigations were carried out on young and pack ice with the aid of special flat capacitors. The ice samples studied were extracted from various depths of the ice cover and frozen onto nickel-plated electro-

···the plates of a capacitor having guard rings were cooled to air temperature and then placed in closed thermos vessels. The temperature dependence of the electrical characteristics was investigated by two bridges. The errors in measuring capacitance did not exceed 10%, and those in resistance, 15%. Temperature was monitored with an electric thermometer with an accuracy of $\pm 0.2°$. A check showed that the nonuniformity of the temperature distribution in the sample during the measurements, which lasted several hours, did not exceed the accuracy of temperature determination.

The salinity of a sample was determined with an electrical salinometer calibrated in values of chlorinity. The effective values of the dielectric constant ε' and of the specific volume resistivity ρ were calculated from the formulas

$$\varepsilon' = C_x/C_0, \qquad \rho = R_x S/h,$$

where C_0, C_x, R_x are, respectively, the geometrical capacitance and the measured capacitance and resistance of the capacitor with the area of the guarded electrode S and the sample thickness h.

Figure 1 presents the most typical temperature dependences of ε' and ρ for a sample with salinity 5.4‰ at a frequency of 1 kHz. The observed qualitative course of the temperature dependences, consisting in an increase of ε' and of the specific electrical conductivity $1/\rho$ with temperature, is characteristic of all the measured samples, including those taken from the surface of pack ice and containing a negligible amount of salts. The most characteristic temperature at which a sharp change in the electrical properties of ice is observed is the temperature of precipitation of chlori-

Fig. 3

Fig. 4

Fig. 3. Dependence of ρ of Arctic ice on salinity at different temperatures. $f = 1$ kHz.

Fig. 4. Frequency dependences of ε' of Arctic ice at different temperatures: a –$t = -5°$, b–10°, v–30°C. 1–S = 14‰, 2–10‰, 3–5‰, 4–3‰, 5–1‰, 6–fresh ice (after Eder (6))

sodium, which, depending on the concentration and composition of other salts in the ice, may vary within the range 21.1-22.9 (%).

An increase in the salinity of the ice samples leads to an increase in ε' and a decrease in ρ. Figures 2 and 3 show electrical characteristics averaged over 500 measurements. The scatter of the values relative to the curves shown often considerably exceeded the accuracy of the measurements. This circumstance can probably serve as indirect confirmation of the influence on ε' and ρ of the number, size, and nature of the distribution of inhomogeneities inside the sample and in the near-electrode layer. No frequency dependence of the specific volume resistance within the scatter of its values was found. The frequency dependences of the dielectric permittivity of drifting ice are similar to the anomalous dispersion of freshwater ice (Fig. 4).

The effective electrical characteristics obtained reflect the properties of drifting ice located in the electric field of the capacitor and having direct contact with its electrodes. The complexity of the mechanism of polarization of sea ice is explained by its multicomponent nature. It may be assumed that for saline ice in general, and for drifting ice in particular, several polarization mechanisms are characteristic: **interlayer** polarization within the volume of the ice, **dipole-relaxation** polarization of freshwater ice crystals, **ion-relaxation** polarization of the salts present in the ice, and **structural** polarization. The accumulation of volume charges in the near-electrode layer and the accompanying adsorption and electrochemical processes occurring directly on the surface of the electrodes must lead to near-electrode polarization, introducing an additional electrical capacitance between the electrodes, the magnitude of which may significantly exceed the capacitance determined by the dielectric permittivity of the ice. All these effects lead to extremely large values of the effective dielectric permittivity; the most substantial influence is probably exerted by near-electrode polarization.

The characteristics we obtained agree satisfactorily with the characteristics obtained in works ([3],[4]).

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CITED LITERATURE

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Note: Figure translations are in progress. See original paper for figures.