Electric Currents due to Stress-Activated Positive Hole Charge Carriers in Ice

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ABSTRACT

Jupiter's satellite Europa, whose surface is composed of ice with a possible water ocean beneath, could conceivably serve as an abode for extraterrestrial life. This and other icy celestial bodies may contain organic macromolecular solid material that is produced when surface ices are exposed to ultraviolet radiation and/or electrical energy. Tidal and tectonic stresses or meteorite impacts in icy crusts may produce electrical discharges, which would provide the energy for in-situ synthesis of the organic solids. This electrical energy can be provided by positive hole charge carrier activation. Positive holes exhibit properties such as the ability to flow out of the stressed ice volume, building up electrical potential gradients and forming electrical currents. (1,2)

BACKGROUND

Experiments on rock samples that were stressed under uniaxial compression have also shown a propensity for charge production due to defects in their crystal lattice structure which allow the propagation of positive charges within the material (1). In ice impact experiments, electrical charges were produced both during and after the impact episode. Generation of electric polarization of ice has been noted under non-uniform strain conditions, owing to defects in the ice crystal structure, known as Bjerrum and ionic defects (3) . By incorporating additional molecules into the ice crystal lattice, like hydrogen peroxide, a chemical formed by ionization of water, additional defects are formed, which may increase the electrical potential.

Hydrogen peroxide appears on the icy surface of Jupiter's moon Europa, according to NASA's Galileo spacecraft. Hydrogen peroxide is formed constantly on Europa as Jupiter's energetic particles smash apart molecules on the surface to produce new chemicals, a process called radiolysis (4).

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EXPERIMENT

In this study, hydrogen peroxide (H_2O_2)-doped and plain ice samples were stressed at various temperatures and the resulting electrical currents generated were measured.

Figure 1 provides the experimental matrix.

Temperature	Hyd. Peroxide Concentration 0%	0.03%	0.30%
-10°C	A	B	
-78°C	C	D	E
-196°C	F	G	H

Figure 1. Experimental Matrix

Hydrogen peroxide concentrations and temperatures were varied to discover their effect on the generation of current. Hydrogen peroxide concentrations simulated levels consistent with those encountered in Earth's waters and also higher levels that may be found on other celestial bodies.

Temperatures were varied to simulate those encountered on Earth (-10°C and –78°C) and also in deep space (–196 °C). Samples of ice were initially cast in a cold room (-10°C) then either tested at that temperature or further frozen using dry ice (-78°C) or liquid nitrogen (-196°C).

The samples were then subjected to a uniaxial compressive stress and the currents generated were monitored via electrodes implanted on each side of the specimen mold. The configuration of the testing apparatus is provided in Figure 2.

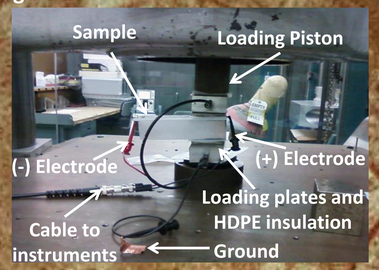

Figure 2. Experiment Setup

The physics behind the phenomena of generating current by compressing ice is shown in Figure 3. Upon stressing the ice samples, charges are generated which flow out of the stressed area to the end of the sample, where they are recorded by the electrodes.

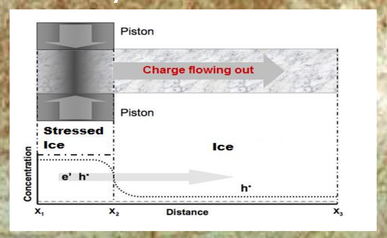

Figure 3. Physics behind phenomena

RESULTS

The data was analyzed and some conclusions may be drawn from this study:

1. Pure ice without hydrogen peroxide does not produce as much current as does ice with it.
2. Liquid nitrogen temperatures (-196°C) may be too low for a current to flow in the samples or the problems associated with making and testing the specimens did not allow for good measurement.
3. At dry-ice temperature (-78°C), both concentrations of hydrogen peroxide produce a current that in most cases appears related to the load.
4. Current-producing events in static ice, and/or during the loading process, may be caused by cracking along fracture lines or grain boundaries on which some charge separation has occurred.
5. Noise in the measurement of the electrical currents made it difficult to have good repeatable results. An improved sample preparation and testing setup would be helpful in reducing this noise.

Stressing the ice generally created positive electric currents which is in agreement with findings by Petrenko and Whitworth (1999) who stated that "electric currents are carried in ice by the motion of protons, rather than electrons." Freund et. al. (1994) described a similar relationship of the concept of positive holes in a rock matrix (peroxy defects) having been shown to produce positive electric current under loads and thermal stresses. Figure 4 provides a representation of good data showing a correlation of increasing current with load. An evaluation of the effects of temperature and hydrogen peroxide concentration showed a general increase in the maximum current change with increasing hydrogen peroxide concentration. Temperature effects on the maximum current change were less conclusive, due in part to a poor electrical response of the -196° samples which made an analysis of this effect difficult.

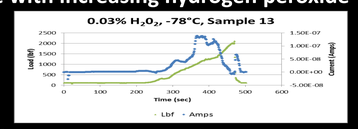

Figure 4. Ideal plot of current vs. load

CONCLUSIONS

The study has shown that it is possible to generate electric currents from ice samples and with increasing concentrations of hydrogen peroxide, the current levels also increased. On a larger scale, such as may be found on icy celestial bodies, the generation of electrical currents by tidal, tectonic, or meteorite impact may provide the sufficient energy to jump start the synthesis of organic compounds and provide the building blocks necessary for life. Additional experiments to confirm any of these interpreted relationships should be done in the future.

References

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