A new electrochemical property of ice: negative charge transport triggered by reactions of surface OH radicals with electrons

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The electrochemical behavior of water ice is of particular interest in astrophysical chemistry and atmospheric chemistry. Much research has shown that the ice can be a p-type semiconductor due to the conduction of excess protons along the hydrogen bonds. In contrast to positive charges, the conductivity of negative charges due to the relay of hydroxide ions (OH^-) in ice has not been verified. We have recently observed the negative charge conductivity of ice simultaneously exposed to UV and electrons at temperatures below 50 K [1]. The phenomenon can be explained by the following processes: (1) production of OH radicals on ice surface by UV irradiation, (2) electron attachment to OH radicals, and (3) the produced OH^- induce the sequence of proton abstraction from surrounding H_2O. To confirm the above processes, we additionally measured the density of surface OH radicals using a novel technique, a combination of photostimulated desorption and resonance-enhanced multiphoton ionization [2].

Figure 1(a) shows the temporal variation of the negative currents through H_2O ice at 10 K. One can see the increase in negative currents during simultaneous exposure to UV and electrons. A transient peak initially formed by electron irradiation may be attributed to the leakage of electrons through pores or cracks in ice. Meanwhile, as shown in Figure 1(b), the density of surface OH radicals decrease upon electron exposure. The results suggest that the surface OH radicals are consumed via electron attachment to the radicals to produce OH^-. We consider that the negative currents are subsequently induced by the relay of OH^- in ice at low temperatures.

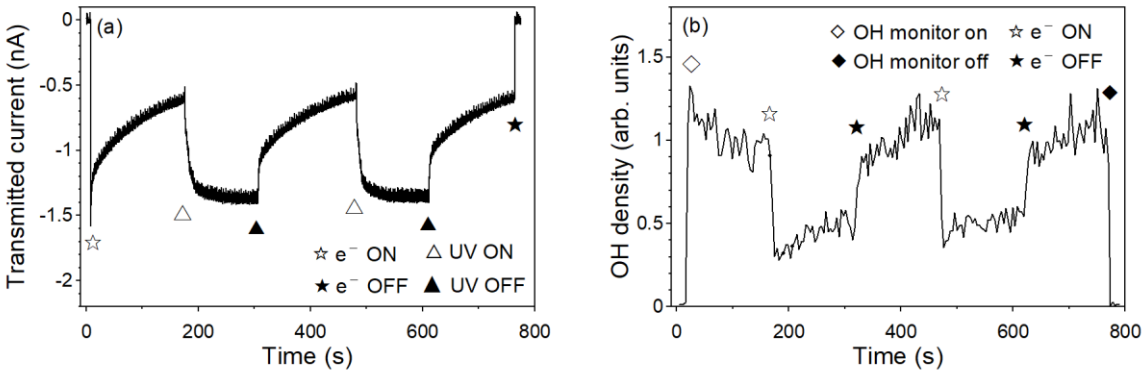

Figure 1 (a) Temporal variation in negative currents through H_2O ice at 10 K upon repetitive UV irradiation with continuous exposure to electrons. (b) Temporal variation in OH radical densities on ice at 10 K upon repetitive electron irradiation with continuous exposure to UV.

References

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[2] K. Kitajima, Y. Nakai, W.M.C. Sameera, M. Tsuge, A. Miyazaki, H. Hidaka, A. Kouchi, N. Watanabe, 2021, JPCL, 12, 704.