Preliminary study of radiation-induced morphological alteration to water ice (Ih)

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A large fraction of amorphous solid water is expected to be crystalline phase in protoplanetary disks (PPDs) [1]. Two variant crystal structures of the water ice are potentially formed around the snow line at PPDs: hexagonal ice (Ih), which is produced above 150 K by condensation of water vapor and/or above 140 K by annealing of amorphous solid water (ASW), and cubic ice (Ic), which is produced above 130 K by condensation of water vapor and/or 130 to 140 K by annealing of ASW [2], depend on the temperature of the snow line.

Cosmic rays from a central star irradiate the upper layer of a PPD where gas and dust are decomposed and altered by the high-energy solar wind [3]. The consequence of the radiolysis depends on the physical state and the composition of the dust. In the case of crystalline water, tiny-cavities are formed due to immediate clustering of myriad vacancies generated by diffusion of hydrogen and oxygen atoms from their lattice sites, which are a direct result of the electron-induced radiolysis of water ice [4]. The tiny-cavities produced by radiolysis can serve as additional surface on the water ices.

It is widely supposed that the surface of water ice works as a catalysis for gas-solid phase chemistry in interstellar environments [5]. To understand radiation-induced alterations to water ice, we observed a time-evolution of tiny-cavities in water ice (Ih) with a liquid-cell transmission electron microscopy (LC-TEM). Figure 1 shows a moment of the time-evolutions of tiny-cavities in the ices around −15 °C obtained by a 200 keV TEM (JEM-2100F). The tiny-cavities were discerned their shapes at the beginning of the observation and then clearly recognized in a period of the observation due to a simultaneous disappearance of the mother ice body. We found that the size, the shape, and the evolution path of the tiny-cavities were changed depend on the thickness of the mother ices that was estimated from 17 to 500 nm.

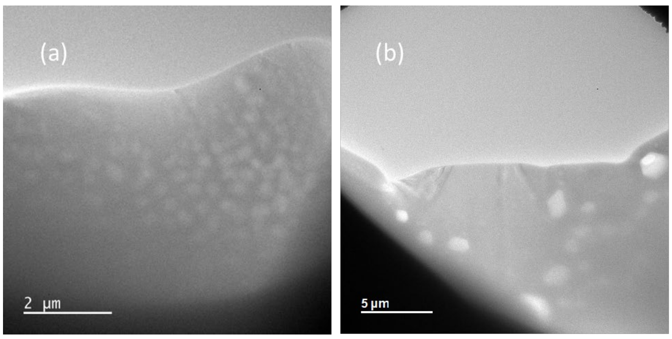

Figure 1: Bright field TEM images of selected frames in each video of tiny-cavities evolution in ice Ih encapsulated between electron-transparent SiN windows. The relative dark fields correspond to ice at a range of the estimated thickness 17 to 35 nm for (a) and 70 to 150 nm for (b). The relative bright fields are possibly filled with gas generated by the radiolysis of the ice.

References

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