Molecular-level understanding of ice crystal surfaces by advanced optical microscopy

*Ken Nagashima[1], Gen Sazaki[1], Ken-ichiro Murata[1], Yoshinori Furukawa[1]

1. The Institute of Low Temperature Science, Hokkaido University

Ice is one of the most abundant crystals on the earth, and hence the molecular-level understanding of ice crystal surfaces holds the key to unlocking the secrets of a number of fields. We and Olympus Engineering Co., Ltd. have developed laser confocal microscopy combined with differential interference contrast microscopy (LCM-DIM), by which we succeeded in the direct visualization of 0.37-nm-thick elementary steps [1] on ice for the first time with enough spatial and temporal resolution. Subsequently, the direct observations of spiral steps on ice basal faces revealed the double-spiral-step structure [2], the migration distance of water molecules adsorbed on a terrace [3], and the temperature dependence of the step kinetic coefficient [4].

On the other hand, we could also visualize the quasi-liquid layers (QLLs) on ice crystal surfaces [5], which are covered with thin liquid layers even below the melting point (0˚C). The direct observations of QLLs revealed the appearance of two types of QLLs with different morphologies [5,6], the appearance temperatures and partial pressure of water vapor [6-8], the inducement of the formation of QLLs by strain [9], and the characteristic velocities of QLLs [10]. Further details of QLLs will be presented in "A-CC28: Glaciology" sessions.

In addition, we also found that atmospheric acidic gas (hydrogen chloride gas) strongly induced the appearances of droplets on ice surfaces (further details will be presented in "A-AS06: Atmospheric Chemistry" session). The droplets were observed in the temperature range of -15.0 ~ -1.5˚C, where no QLL appears in the absence of HCl gas [11]. The HCl induced droplets were embedded into ice crystals by growth of ice crystals [12]. These results show the possibility that ice crystals can store large amount of gas components as fluid inclusions.

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