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Time dependent change of tip velocities of a dendritic ice crystal in growing from supercooled water

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We measured the growth rates of secondary branches of a dendritic ice crystal growing from supercooled heavy water in both microgravity and 1g conditions. We have analyzed recorded sequences of images of microgravity experiments that were carried out 134 times in the International Space Station(ISS) and measured the growth rates of both the tip of a primary dendrite and the basal faces of an ice crystal growing from supercooled heavy water in the range of supercooling from 0.03 to 2.0 K and found that the steady state primary tip velocity agrees with the dendritic growth theories [1,2] of dimensionless supercooling for $\Delta > 0.002$ (=0.16 K) when the growth on the basal face is not zero [3]. In contrast to steady-state primary tips motion, the measured data show that the tip growth rates of secondary branches are not constant with time and almost half of that of the primary tip in the initial stages and subsequently decrease with time for the small undercooling region < 1.0 K. The time dependency of tip growth rates of secondary branches is different for microgravity and 1g conditions. For the larger undercooling, the time dependency can depend on the position on the main stem.

Furthermore, we extracted the contour images of a dendritic ice crystal from images and examined the pattern matching of extraction contours around the tips of both primary and secondary branches. The dendrite tip of the ice crystal is composed of two distinct tip radii, R1 and R2. The tip radius R1 is parallel to the basal plane, while the tip radius R2 is perpendicular to the basal plane. The contour images corresponding to R1 show that the radii do not change with time and the radii tips of secondary branches agree with that of the primary tip. As a result, we expect that all radii R1 of dendritic tips have the same value and determined by supercooling, nevertheless the tip velocities of secondary branches are different from the primary tip velocity.

Finally, we calculate a critical value of the interfacial stability parameter [2,4] using the data obtained from both the ISS experiments and 1g experiments and show these two sets of the values are fairly separated. The critical value in 1g decreases with increasing dimensionless supercooling, while the value in microgravity is almost constant because of no natural convection. This result is almost the same as the analysis for succinonitrile experiments having four fold symmetry [4] and agrees with the Interfacial Wave (IFW) Theory [2]. We also discuss the occurrence of side branches and the asymmetric with respect to the main stem.

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Significance statement

The growth rates of secondary branches of a dendritic ice crystal growing from supercooled water are not constant with time. On the other hand, the radii of secondary branches parallel to the basal plane do not change with time and they agree with the primary tip radius.

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