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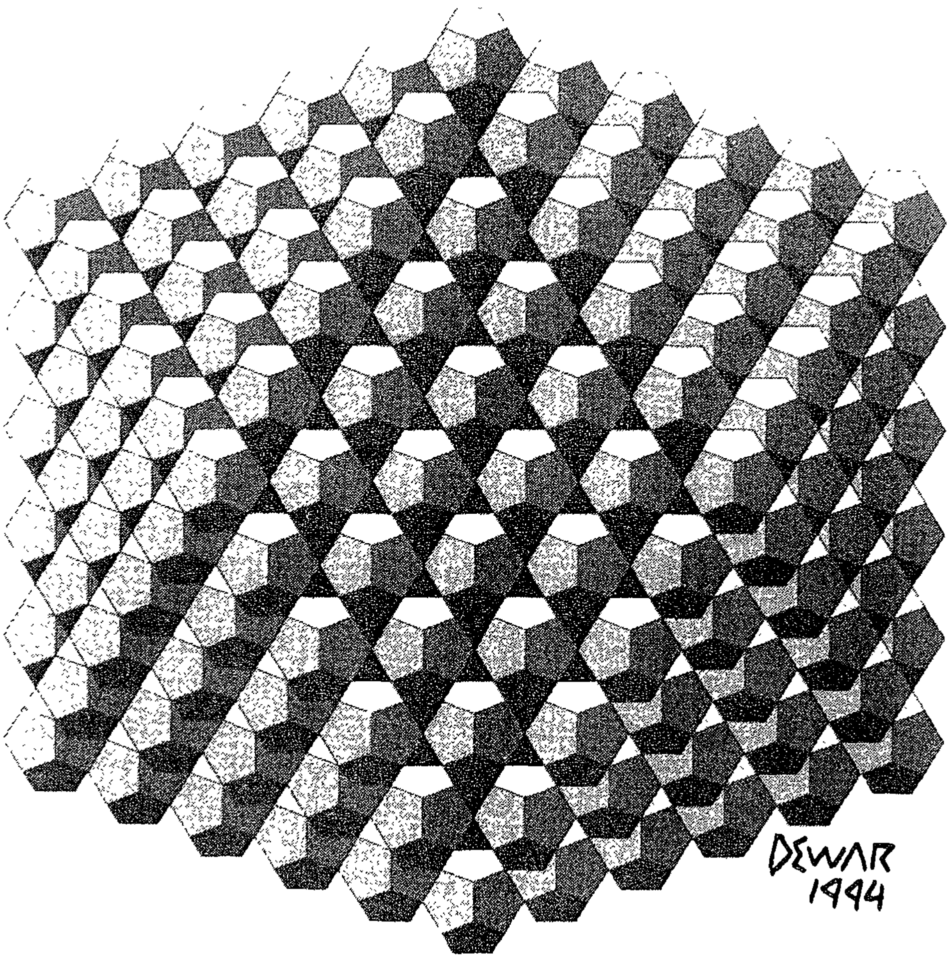

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FORMATION OF PATTERNS IN GROWTH OF NATURAL SNOW CRYSTALS

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It is well known that growth forms of single snow crystals with hexagonal symmetry remarkably depend on the growth condition such as temperature and supersaturation. It should be noted, furthermore, that each crystal changes its external pattern during growth under definite environmental conditions. A spherical single ice crystal of the order of 1-10μm in radius is formed by freezing of a supercooled cloud droplet. Then it grows into a hexagonal prism bounded by two basal and six prismatic faces by adsorbing supersaturated water vapor. The hexagonal prisms further develop into various patterns, e.g., plate, column(prism), dendrite, needle etc., depending on the growth condition in the cloud. In this presentation the characteristics of morphological changes in growth of single snow crystals and their pattern formation mechanisms will be discussed.

The morphological changes of snow crystals are characterized into two categories. First, basic habit of polyhedral snow crystals bounded by flat faces changes with decreasing temperatures; namely plates to columns at -4℃, columns to plates at -10℃ and plates to columns at -22℃ , as shown in Fig.1. Kuroda and Lacmann(1982) proposed a new interpretation of the habit change based on the viewpoint of surface melting and surface roughening which should occur on basal and prismatic faces of ice crystals at different temperatures respectively. After that an ellipsometric study of the ice surface structure has been carried out by Furukawa *et al.* (1987), and it was found that surface melting occurs at -2 ℃ on basal face and at -4℃ on prismatic face. Measured temperature dependencies of the thickness of quasi-liquid layer, which is a melted layer along the surface, are qualitatively in good agreement with theoretical prediction. Recent molecular dynamics simulations for the surface structures of ice crystals carried by Nada and Furukawa(1994) also suggest that the surface melting on each surface may occur at different temperatures. However the transition

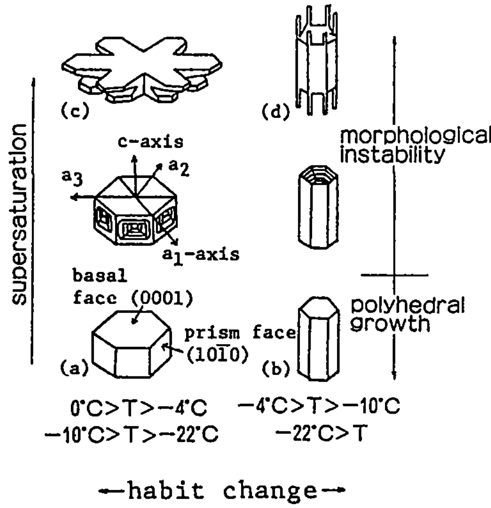

Fig. 1 Schematic representation of variation of growth patterns of single snow crytsals with growth conditions (temperature and supersaturation).

temperatures of surface melting obtained by the expenment and simulation are different from those assigned for the theoretical interpretation of habit change.

On the other hand, plates of snow crystals change to sector plates and then to dendrites with increasing supersaturation at the temperature range between -10 and -22℃ These characteristic changes of growth forms correspond to the development of morphological instability during the growth of polyhedral snow crystals (Yokoyama and Kuroda, 1990). The interaction between the stabilizing factor and the destabilizing factor for the growing flat surfaces (facets) should be consistently considered. The former may be the difference between the surface supersaturation at the edge of surface and that at the center of surface, and the latter is the adjustment of the intervals of growth steps.

Now, let us come back to the snow crystals innumerably falling in the air. Beautiful pictures of snow crystals mislead us to believe that each of the snow crystals possesses a perfect hexagonal symmetry of single crystal (Furukawa, 1993). But most of the natural snow crystals are actually polycrystals of twin type, as shown in Fig.2. Consequently, it is unfair only to consider the pattern formation of single snow crystals. The shapes of snow polycrystals include the twin prism, twelve-branched crystal, plane assemblage of the spatial-type (spatial dendrite), plane assemblage of the radiating-type (radiating dendrite), combination of bullets, crossed-plates and so on. Each component of the snow polycrystal extends in three

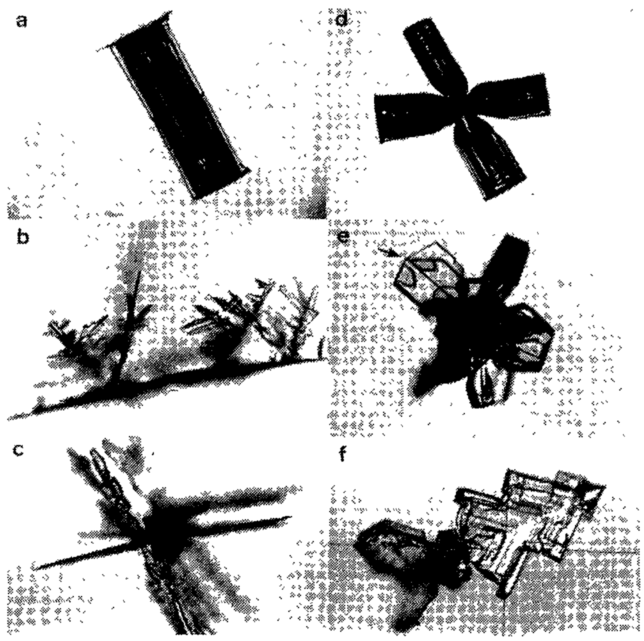

Fig. 2 A variety of snow polycrystals: (a) twin prisms, (b) spatial dendrite, (c) radiating dendrite, (d) combination of bullets, (e) crossed-plates, and (f) peculiar-shaped crystal.

dimensions, excepting the twelve-branched crystal. The morphology and the pattern formation of these snow polycrystals, however, were given but of a scant attention because the difficulty of observation for the three-dimensionally developed crystals was not to be compared with that for single snow crystals.

To clarify the structures of snow polycrystals, the angles between the crystallographic axes of each component were measured for natural snow polycrystals at the beginning. As a result, we found that the c-axes angles between each component of snow polycrystals concentrate at 70° for all types of snow polycrystals excepting the twelve-branched crystal. The mechanism of pattern formation is very consistently explained on the basis of both the grain boundary structure expected by the Coincidence-Site Lattice (CSL) concept and the concept of Ostwald's step rule, which is the formation of a in-stable cubic ice embryo taking the lead in growing the stable ice I_h crystal during the ice nucleation process in the supercooled water droplet. In the presentation, the structures and the pattern formation mechanism of snow polycrystals will be also summarized.

References

Y. Furukawa: in Research of Pattern Formation, ed. R. Takaki, KTK Scientific. Pub., 111(1994).

Y. Furukawa, M. Yamamoto and T. Kuroda: J. Crystal Growth, 82(1987)665.

T. Kuroda and R. Lacmann: J. Crystal Growth, 56(1982)189.

H. Nada and Y. Furukawa: in The Structure of Surfaces IV, ed. X. Xie *et al.* World Scientific Pub., (1994)543.

E. Yokoyama and T. Kuroda: Phys. Rev., 41(1990)2038.