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Characteristic Features of the Snow Crystals of Low Temperature Types

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Abstract

Observations of the snow crystals of low temperature types were carried out at Inuvik (68°22′N, 133°42′W), Northwest Territories, Canada from December 25, 1985 to January 23, 1986. In this observation, especially, the correlation between the "Gohei twin", "Sea gull", and "Spearhead" type crystals has been considered based on a number of microphotographs taken by a polarizing microscope. As a result, although we have pointed out that the gohei twin type crystals are two kinds that have tip angle of 56° and 78°, they have another difference besides the difference of their tip angles. Namely, the gohei twin crystals having the tip angle of 56° have a certain kind of finlike appendages along the crystalline boundary of two extended prism planes of the crystals. On the other hand, another twin crystals that have the tip angle of 78° are devoid of finlike appendages along the crystalline boundary. The angles of 13° and 19° between two extended prism planes of the gohei twin crystals pointed out in our previous papers (Kikuchi and Sato, 1984 ; Sato and Kikuchi, 1985) were clarified by the measurement of the tip angles of individual extended prism planes. Furthermore, it was noted that the gohei twin crystals that have the tip angle of 56° are similar to the spearhead type crystals, and the spearhead type crystals were one of the wings of the sea gull type crystals seen from a right angle. However, some parts of the formation mechanisms of snow crystals of low temperature types are obscure and it would be difficult to understand their exact correlation.

1. Introduction

The most typical shapes of snow crystals of low temperature types, that is peculiar shapes (Kikuchi, 1969, 1970), which are known at present are "Gohei twin" (Kikuchi, 1969 ; Sato and Kikuchi, 1985), "Sea gull", "Spearhead" type snow crystals (Kikuchi and Kajikawa, 1979) and so on. Although they were named by one of the authors (K.K.) tentatively, these names appear to be

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accepted in the fields of cloud physics, crystal growth and so on. On the other hand, their respective formation mechanisms except for the gohei twin type crystals have not been clarified. In this paper, therefore, the correlation between the gohei twin, sea gull, and spearhead type crystals has been considered based on a number of microphotographs taken by a polarizing microscope (Kikuchi, 1987).

2. Observations

Snow crystal observations were carried out at Inuvik (68°22′N, 133°42′W), Northwest Territories, Canada from December 25, 1985 to January 23, 1986. Throughout the observations, attention was focused on the degree of tip angle (α), the crossing line of two prism planes of the gohei twin (Kikuchi, 1969, 1970) and spearhead type snow crystals (Kikuchi and Kajikawa, 1979), a supplementary angle of an intersection of the extended prism planes shown in (β) in the previous papers (Kikuchi and Sato, 1984 ; Sato and Kikuchi, 1985), the crystalline structure of wings of sea gull type snow crystals (Kikuchi and Kajikawa, 1979) and so on. For these reasons, microphotographs were taken by inclining the gohei twin and spearhead crystals and cutting the joint of wings of sea gull crystals.

3. Results and considerations

Figure 1 shows one of the typical examples of sea gull crystals. As seen in the figure, each wing grows straight outside. Although throughout the observation period, a number of sea gull type crystals were observed, the wings of all of these crystals were straight, and different from the crystal shapes from the previous expedition when the shapes of the wings showed a upward curve (outside bend from the center nucleus) in relatively high temperature conditions from −20°C to −12°C and a downward curve (inside bend) in relatively low temperature conditions from −20°C to −30°C as interpreted in the previous paper (Kikuchi and Kajikawa, 1979). Figure 2 shows another example which is in close resemblance to the snow crystal of "Very complicated side planes" reported by Nakaya (1954). Especially, it has a number of plate type crystals which grew from frozen cloud droplets collected on the wings of sea gull crystals. These crystals, therefore, were different in their principal axes of the V-shaped crystals reported by Yamashita (1971).

In the previous papers (Kikuchi and Sato, 1984 ; Sato and Kikuchi, 1985), we

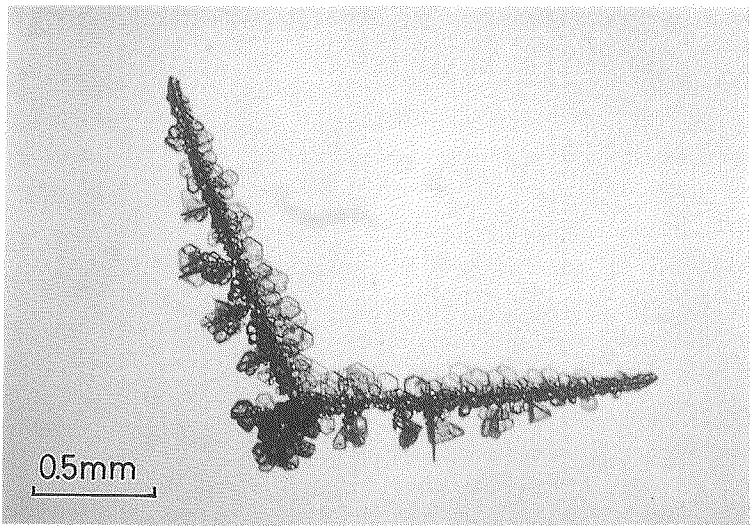


Fig. 1 A microphotograph of typical examples of the sea gull type crystals.

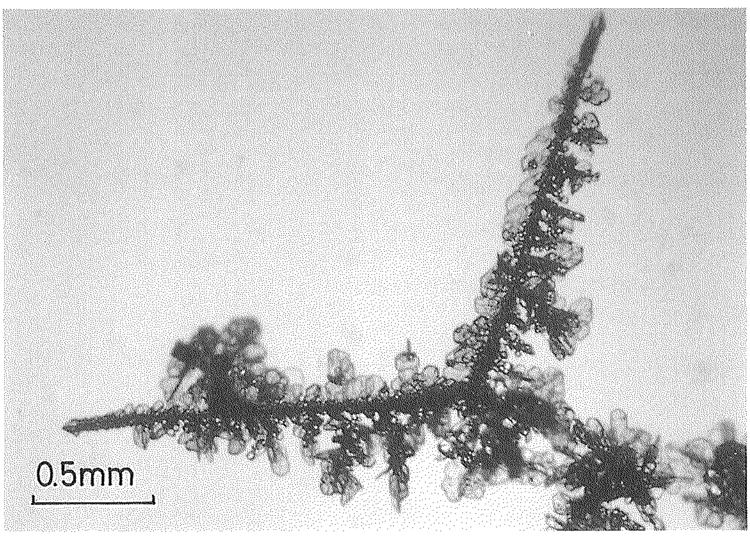


Fig. 2 A microphotograph of typical examples of the sea gull type crystals.

pointed out that the frequency distribution of the tip angles of gohei twin crystals showed a strong maximum at about 78° and 56°. These angles were explained by an assumption in which a crystal took a cubic structure twice on basal planes (0001) of crystals just nucleated in a supercooled cloud droplet. We

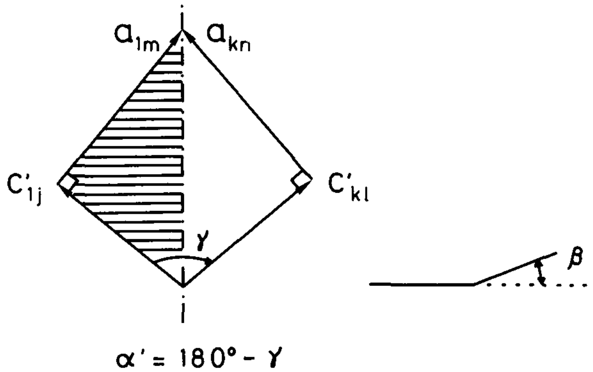


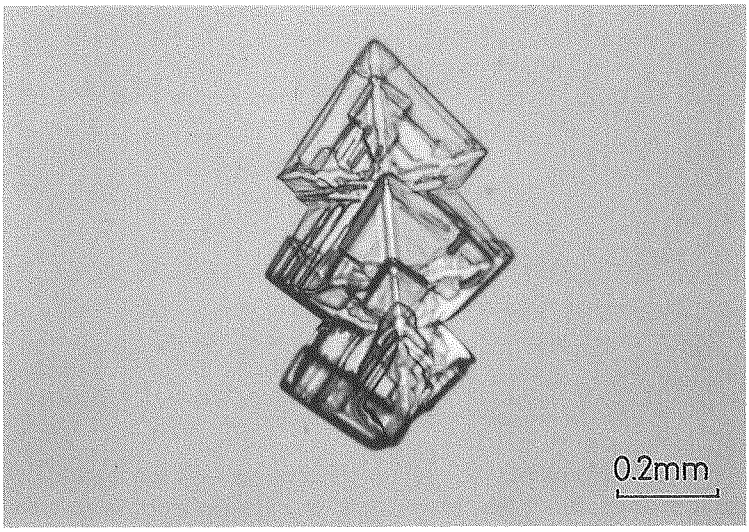
Fig. 3 Angles of α' and β of the gohei twin type crystals (Kikuchi and Sato, 1984).

assumed, however, in an explanation where a combination of two extended prism planes which statisfied the next two conditions could grow as a gohei twin; (1) the supplementary angle $\beta<20°$, and (2) two c-axes are symmetric with respect to the crossing line of two extended prism planes as shown in Fig. 3. Up to that time, however, we did not have any information about the

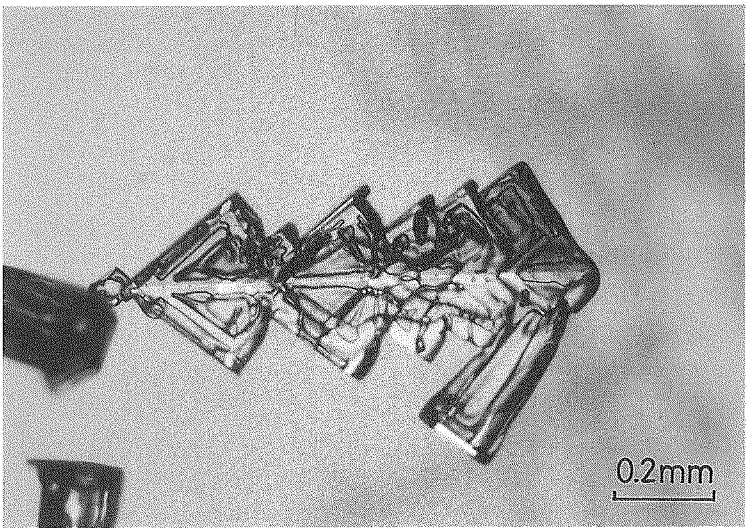
Table 1 Calculation results of the angles of α' and β (Kikuchi and Sato, 1984).

	α'	β
C'_1-C'_1	*56°	19°
	39°	19°
C'_1-C'_2	*66°	11°
C'_1-C'_6	*78°	13°
	32°	16°
	*56°	19°
	39°	19°
C'_1-C'_3	*66°	11°
C'_1-C'_5	32°	16°
	*56°	19°
	39°	19°
C'_1-C'_4	*66°	11°
	*68°	18°
	*56°	19°
	39°	19°

relationship of the tip angle and the supplementary angle, that is, $\beta=19°$ when $\alpha'=56°$, and $\beta=13°$ when $\alpha'=78°$, as shown in Table 1, respectively. Furthermore, although we succeeded in producing the gohei twin crystals artificially in



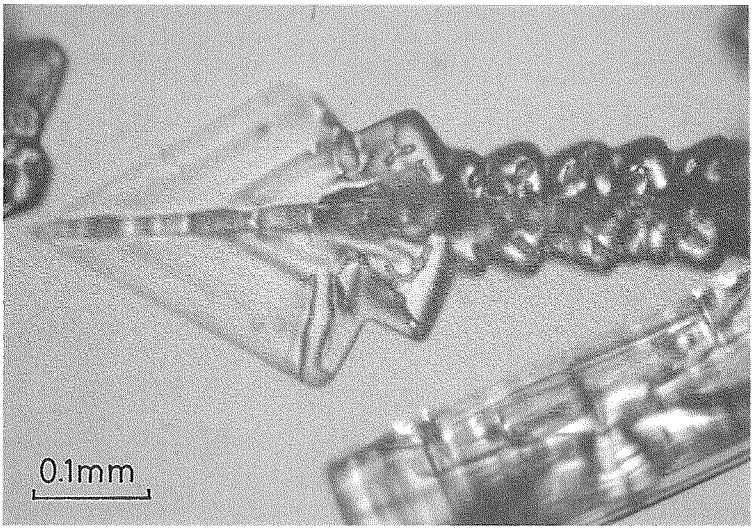
(a)



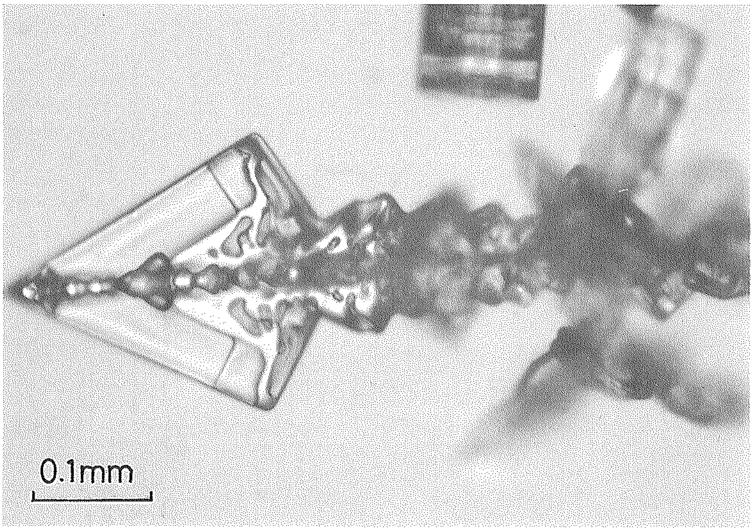
(b)

Fig. 4 Microphotographs of typical examples of the gohei twin type crystals which have the tip angle of 78°.

a newly developed cold diffusion chamber, we could not measure the angle β. On the contrary, it seemed to be a flat angle for β of the gohei twin crystals. Furthermore, we have considered that the gohei twin crystals which have the tip angle α' of 56° and 78° are the same crystals which have a similar formation



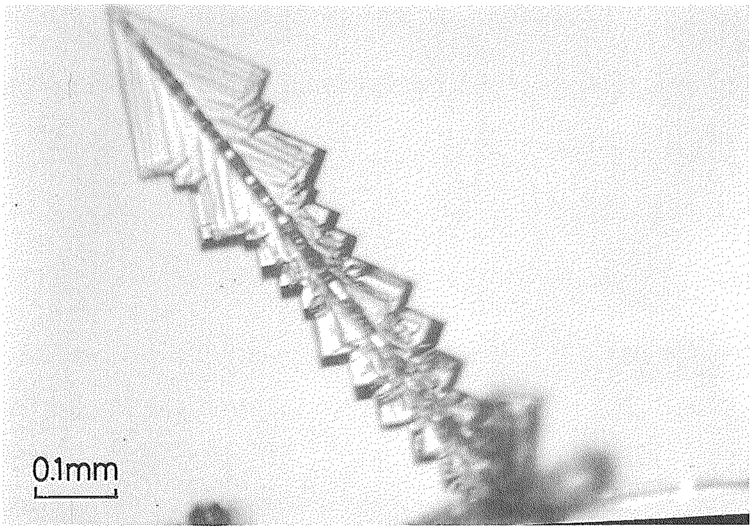
(a)



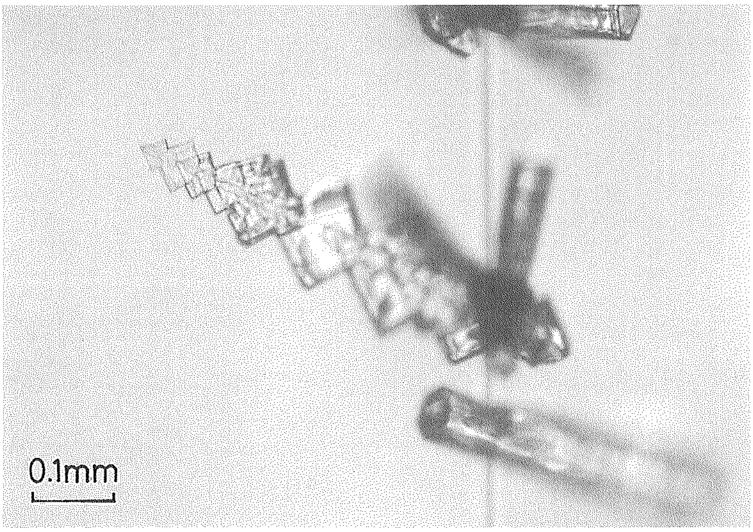
(b)

Fig. 5 Same as Fig. 4 but for the tip angle of 56°.

mechanism except for the difference, that is, 19° and 13° of the supplementary angle β. Scrutinizing these gohei twin crystals anew, it was recognized that they had a clear difference with regards to the crossing line, that is, a grain



(a)



(b)

Fig. 6 Same as Fig. 4 but for the artificial gohei twin type crystals. (a) The tip angle of 56°, (b) 78°.

boundary between two extended prism planes. Figure 4 shows polarizing microphotographs of most typical gohei twin crystals which have the tip angle of 78°. As seen in the figure, the crossing line, that is, grain boundary is very smooth. On the contrary, Fig. 5 shows the most typical gohei twin crystals of the tip angle of 56°. Obviously, the crossing line is wider than the photographs shown in Fig. 4 and it consists of light and dark alternating parts. Thus the

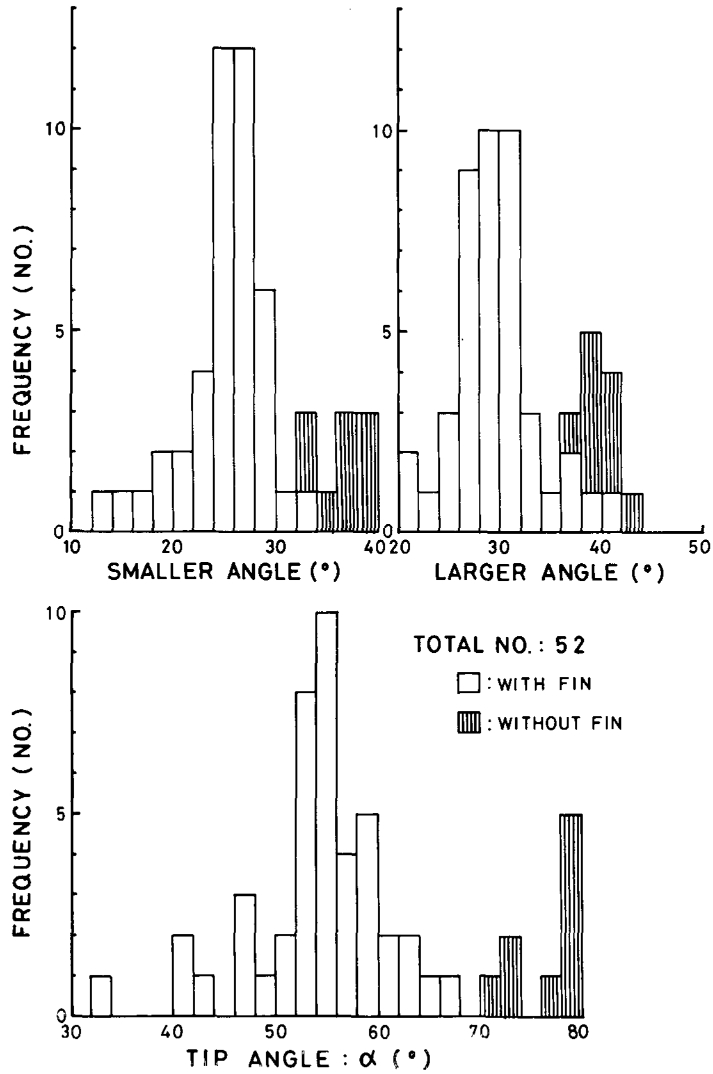
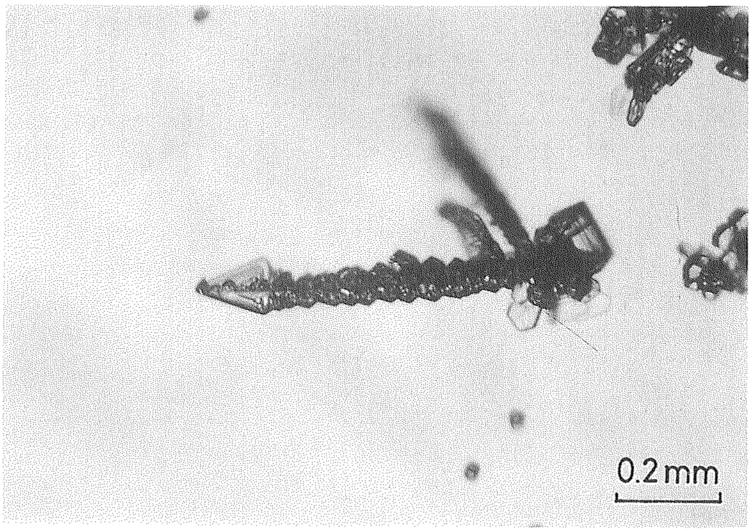


Fig. 7 Frequency distributions of the tip angle α.

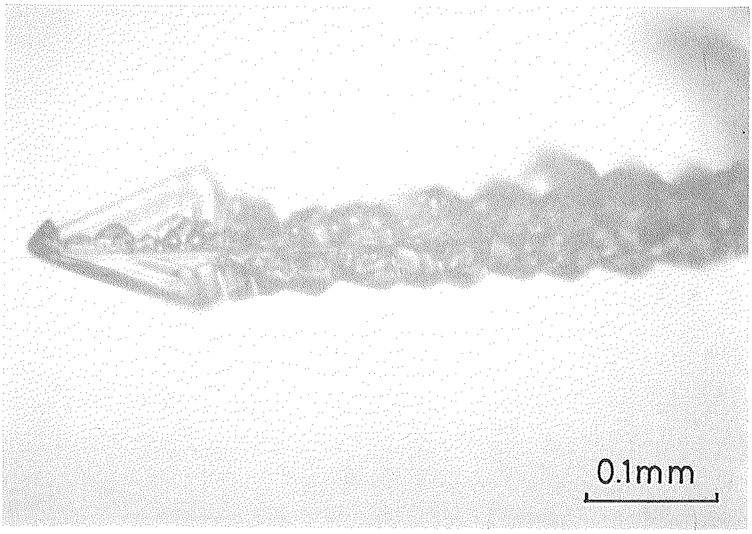
difference of brightness of the crossing line suggests the difference of thickness in the direction parallel to the light axis of the crossing line. The difference of the crossing line of the gohei twin crystals which have the tip angle of 56° and 78° observed in nature was recognized in the gohei twin crystals produced artificially as shown in Fig. 6. Figure 6(a) and (b) shows examples of the tip angles of 56° and 78°, respectively. As seen clearly in the figure, light and dark alternating parts are conspicuous in the crystal of the Fig. 6(a). On the contrary, it is not recognized the difference of brightness in the crystal of the Fig. 6(b).

Regarding the supplementary angle β, on the other hand, it is a very difficult problem to measure the angle β directly, if we use a microscope with a universal stage. Throughout the above examination, fortunately, it dawned on us that there was a some difference between individual angles of the two extended prism planes forming the tip angle α, if the supplementary angle β presented for the gohei twin crystals. Figure 7 shows the frequency distribution of the tip angle α. In this figure, open and stripe histograms show the gohei twin crystals with and without finlike appendages, respectively. In this paper, the difference in thickness of the crossing line was referred to as finlike appendages for the sake of convenience. As seen in the bottom figure, the predominant peaks with finlike appendages and without finlike appendages were recognized at about 56° and 80°, respectively. As pointed out previously, the gohei twin crystals which have the tip angle 56° were with finlike appendages and the crystals which have the angle of about 80° were without finlike appendages. Further, the frequency distributions of the smaller and larger angles showed predominant peaks around 26° and 30° as shown in the upper left and upper right figures, respectively. The difference of 4° of smaller and larger angles between individual angles of the extended two prism planes corresponded to the supplementary angle $\beta=19°$. In contrast, the difference of smaller and larger angles between individual angles of the extended prism planes was very small as shown around 40° in the upper part of the figure. Therefore, the small angles between individual angles of the extended two prism planes corresponded to the supplementary angle $\beta=13°$. In this way, the algle β was clarified by the measurement of the individual angles of each extended prism plane forming the tip angle α.

Subsequently, one of the wings of sea gull type crystals was scrutinized. For that account, sea gull crystals were microphotographed obliquely. Figure 8(a) shows a microphotograph of sea gull crystals and Fig. 8(b) shows a close-up microphotograph of the long wing of Fig. 8(a). As seen in both figures, the finlike appendages named tentatively above were clarified and further the wing



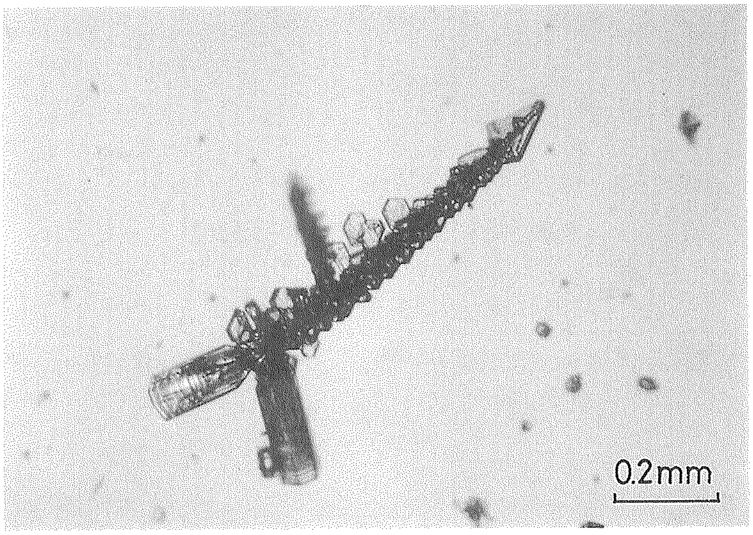
(a)



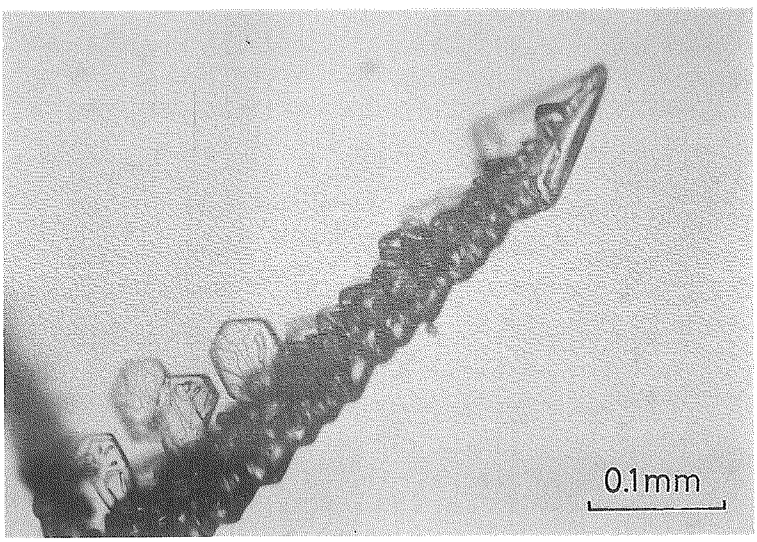
(b)

Fig. 8 Microphotographs of the sea gull type crystals. (a) Low magnification, (b) High magnification.

had a polycrystalline structure divided by the finlike appendages. Similar figures are shown in Fig. 9(a) anb (b). As seen in this figure again, it was recognized that the finlike appendages show a grain boundary and both extended



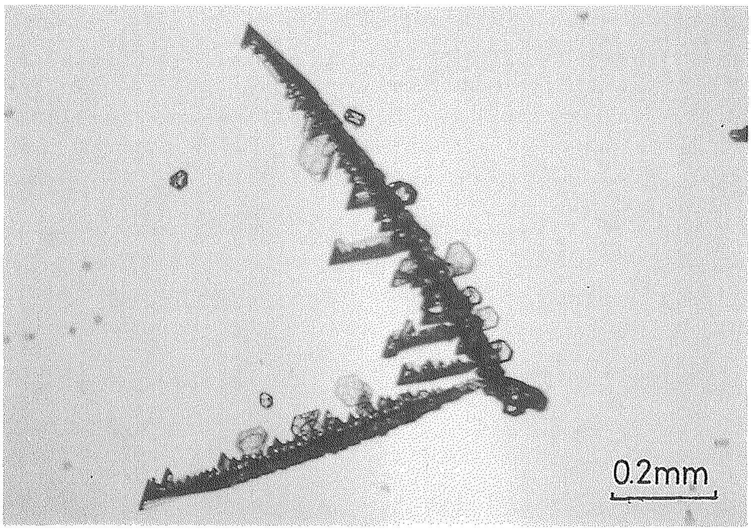
(a)



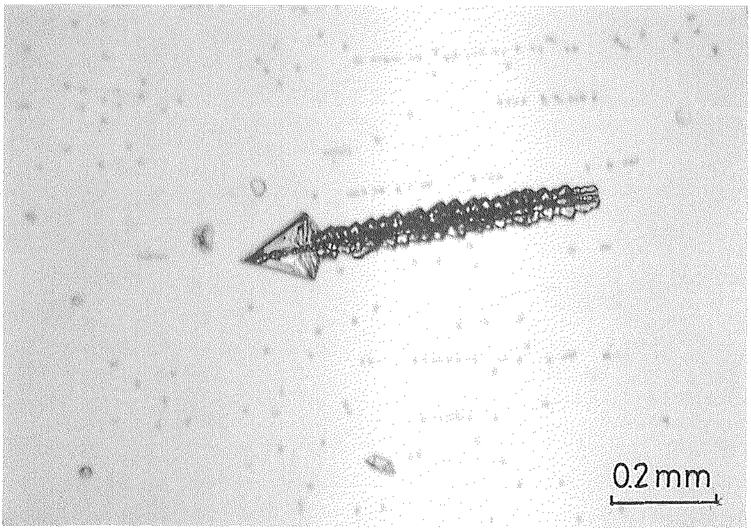
(b)

Fig. 9 Same as Fig. 8.

prism planes have certain angles which show the supplementary angle β. Further, these close-up microphotographs of individual wings as shown in Figs. 8(b) and 9(b) appear to be spearhead type crystals. Next, we attempted to cut two wings of a sea gull crystal, in order to place it horizontally on a glass slide



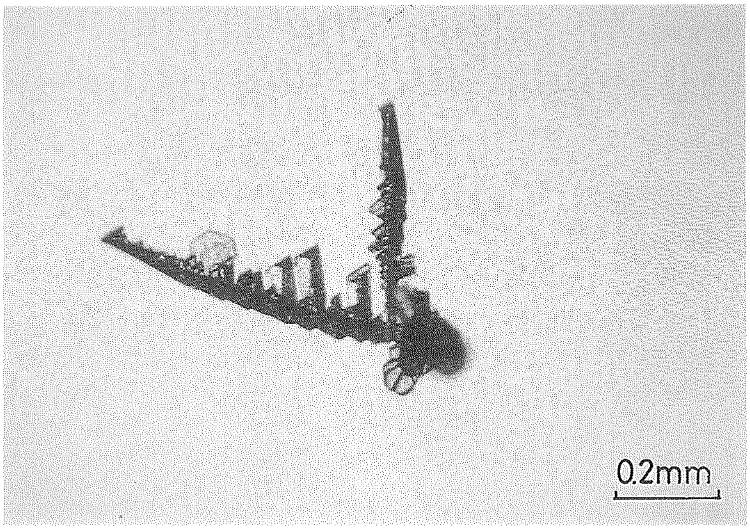
(a)



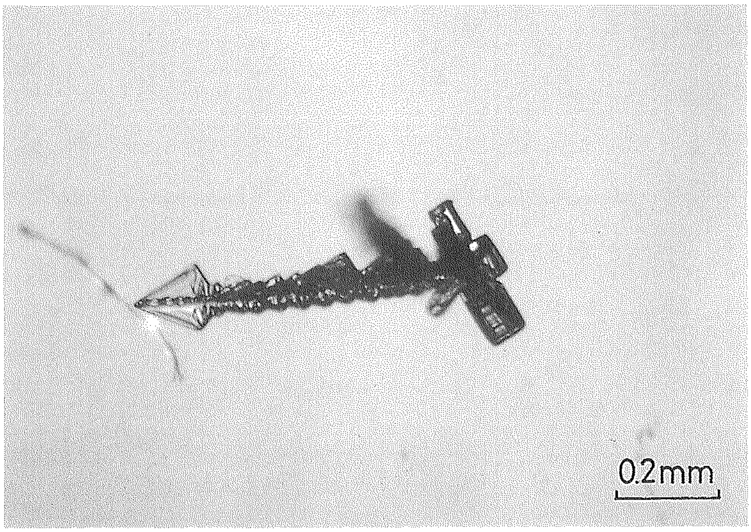
(b)

Fig. 10 Microphotographs of the sea gull type crystals. (a) A whole figure, (b) Shorter wing of (a).

in such a way as to see from a right angle under the polarizing microscope. Figure 10(a) shows microphotographs of a sea gull crystal and the shorter wing of it (b). As seen in Fig. 10(b), the wing of sea gull crystal has a polycrystalline



(a)



(b)

Fig. 11 Microphotographs of the sea gull type crystals. (a) A whole figure, (b) Longer wing of (a).

structure and finlike appendages. Unexpectedly and to our surprise, it was clarified that one of the wings of sea gull crystals was similar to the crystal of spearhead type itself. A similar example was shown in Fig. 11(a) and (b).

That is to say, the spearhead crystal as seen in the Fig. 11(b) is the longer wing itself of the sea gull crystal as shown in Fig. 11(a).

4. Conclusions

The correlation between the gohei twin, sea gull, and spearhead type crystals has been considered based on a number of microphotographs taken by a polarizing microscope during the observation period from December 25, 1985 to January 23, 1986, at Inuvik, Northwest Territories, Canada.

As a result, although we have pointed out that the gohei twin type crystals consist of two kinds that have tip angles of 56° and 78°, they have another difference besides the difference of their tip angles. That is to say, the gohei twin type crystals which have the tip angle of 56° have a certain kind of finlike appendages along the crystalline boundary of two extended prism planes of the crystals. On the other hand, other gohei twin crystals which have the tip angle of 78° are devoid of finlike appendages along the crystalline boundary. The angles of 13° and 19° between two extended prism planes of the gohei twin crystals pointed out in our previous papers were clarified by the measurement of the tip angles of individual extended prism planes. Furthermore, it was noted that the gohei twin type crystals which have the tip angle of 56° are similar to the spearhead type crystals, and the spearhead type crystals were one of the wings of the sea gull type crystals seen from a right angle. However, the finlike appendages along the crystalline boundary as seen in the wings of sea gull type crystals remain unclarified as to their crystalline structures and formation mechanisms.

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