

(b) Growth patterns

Fig. 12 shows the typical cross-section of the sample from Globe, Arizona. Besides a normal cylinder at A, there are many anomalous ones, including a multi-layer spiral at B, a non-hollowed cylinder at C, two-step growth at D, and an inter-fibril segment at E. Anomalous black and white contrast indicated by the arrows seems to be due to higher order reflexions which are excited simultaneously. It is seen that inter- and intra-fibril parts are well preserved without serious radiation damage, as a result of the precautions referred to in the preceding section. We can see that the inter-fibril sites are generally vacant.

These anomalous growth patterns were rarely seen in the samples from Quebec, Coalinga and Transvaal, while they were often observed in the samples from Globe and Tasmania.

(c) Behaviour of the 7.3 Å fringes

It was reported in the previous paper (Yada, 1967) that all the circumferential 7.3 Å fringes observed were spiral or multi-spiral. Although such spiral structures were found in all the samples studied, it was shown for the first time that a perfectly concentric structure also exists in some samples. In Fig. 13, (a) shows the spiral structure and (b) the multi-spiral one, seen in the sample from Transvaal. Fig. 14 shows the concentric structure in the same Transvaal sample, in which two pairs of through-focused images are shown, and forming the concentricity. It is noted that the upper fibril clearly has concentric structure, though it is a little elliptical in shape. The 4.5 Å fringes corresponding to 020, in the radial direction, are clearly visible in the upper images, while they are scarcely seen in the lower ones. The disappearance of these fringes seems to be caused not by a lack of resolution but by a deviation from the Bragg condition due to the tilting of the 010 layers. Table 2 shows the distribution of the concentric and spiral structures for three samples. It is seen that the percentage of fibrils showing the concentric structure is fairly high, being nearly a half in the Transvaal sample, while it is low for the Coalinga and Tasmania samples. Although the total numbers of cross sections examined are not sufficiently large for statistical analysis, the observed differences seem to be significant and are presumably related to the different growth conditions.

(d) Distribution of diameters

From the histograms for the distributions of the inner and outer diameters shown in Fig. 15, the following points are noted: (1) The distribution of the diameters is considerably different from sample to sample, presumably depending on the growth conditions in each locality. (2) In samples for which the outer diameters are distributed over wide ranges, there is a tendency for the peak position in the histogram to shift to a larger value. In such samples, fibrils both with a very small inner diameter and without the central

void are often observed. The samples from Quebec, Globe and Tasmania, which contain a number of fibrils consisting of a multi-spiral lattice, are classified into this group. (3) The most frequent values of the outer and inner diameters of the samples showing a sharp distribution (Coalinga and Transvaal) are 220–270 Å and 70–80 Å, respectively. The value of 260 Å for the outer diameter obtained by Whittaker (1957), (partly theoretically and partly from X-ray diffraction measurements on a sample from Bell Mine, Quebec), is in good agreement with the present value, but his value of 110 Å for the inner diameter is not. (4) Most fibrils thicker than about 350 Å seem to contain a discontinuous step-growth.

Discussion

(a) Crystal structure

Although Padurow (1950) suggested a triclinic structure for chrysotile, it is thought at present that the principal form of chrysotile is clino-chrysotile, while ortho- and para-chrysotile are less common (Whittaker & Zussman, 1956). The result found in the present experiment that the 4.5 Å fringes are not always parallel to the fibril edge seems to be important in connexion with the crystal structure of chrysotile. The tilting of these fringes is equally compatible with either of the following structures. (1) a helical roll with a rectangular lattice, retaining the monoclinic structure (a clino-chrysotile in which the *a* axis is not exactly parallel to the fibre axis and the *b* axis not exactly perpendicular to the fibre axis) and (2) a straight roll with a non-rectangular lattice (an anorthic structure in which the *b* axis is perpendicular to the fibre axis but the *a* axis is not parallel and the *c* axis not perpendicular to the fibre axis). A choice between these two possibilities could be made if the 2.6 Å transverse fringes corresponding to 200 in the central region of the fibrils were clearly observed. Unfortunately, however, it was difficult to resolve these fringes, as mentioned in the preceding section. However, by a dark field method in which a 200 reflexion is selected by the use of a small objective aperture and the corresponding dark field images compared with a normal bright field image, it is possible to decide which of the helical roll and the straight roll is the true structure.

According to a preliminary test using such a method it appears that the former is the case.* With a model of the helical roll it is quite easy to understand the experimental fact that the tilt angle of the 4.5 Å fringes varies over a range of up to about ten degrees from fibril to fibril, though no periodicity of the angular distribution was observed in the present experiment.

There is still the possibility of a polytype structure. The non-parallel 7.3 Å fringes seen in the synthetic chrysotile (Fig. 9) are the result of such a polytype. This type of structure, however, does not necessarily

* The details will be reported elsewhere.