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THE OBSERVATION OF HELICAL DISLOCATIONS IN SAPPHIRE

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CERAMICS DIVISION

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Technical Report by

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ABSTRACT

Helical dislocations have been found in sapphire for the first time. Lang X-ray diffraction topographs, including a stereotopograph revealing such helical dislocations are shown. The Burgers vectors, in all cases, have been found to be parallel to the $<2\bar{1}\bar{1}0>$ directions as well as with the axes of the helical dislocations.

THE OBSERVATION OF HELICAL DISLOCATIONS IN SAPPHIRE

During the course of investigation of dislocations in sapphire crystals,[1] numerous dislocation reactions of the type

$$[2\bar{1}\bar{1}0] + [\bar{1}2\bar{1}0] + [\bar{1}\bar{1}20] = 0$$

were identified. Each reaction represents a self-pinning point, hence the dislocations involved cannot glide easily. However, a special kind of controlled dislocation climb can take place. If a straight dislocation of predominantly screw character, pinned on both ends, could climb, it would curve and thereby acquire an edge-type component. This type of climb would require a transfer of material and a high activation energy, hence, the implication is that the dislocation will be active only at an elevated temperature. Provided that the climb already described could be realized, then prismatic glide[2] parallel to the Burgers vector can occur as well. In such a case, a dislocation which is pinned on both ends and undergoes limited climb and prismatic glide would curl and, under certain circumstances, may result in the formation of a helicoidal dislocation. Such helical or helicoidal dislocations have been observed, using decoration techniques, in ionic crystals such as CaF_2[3-6] and NaCl.[7,8] A review of the subject of dislocations in ionic crystals in which the mechanism describing the formation of these helices is given by Amelinckx.[9] This is the first time that such helical dislocations have been observed in sapphire (see Figure 1).

Examination of these helices in stereo topographs revealed that the axes of the helical dislocations are parallel with basal plane and in the $<2\bar{1}\bar{1}0>$ directions. Consequently, such a helical dislocation will be mostly of an edge character. Therefore, for the total extinction of the helix, both conditions, $\vec{g}\cdot\vec{b} = 0$ and $\vec{g}\cdot\vec{n} = 0$, must be satisfied simultaneously. Since the helical dislocations are totally extinct in the topographs obtained, using the $\{30\bar{3}0\}$ diffraction planes, the Burgers vectors are parallel to the $<2\bar{1}\bar{1}0>$ directions and also with the axes of the helicoidal dislocations.

Figure 1. An X-ray transmission topograph of a sapphire plate, cut parallel to the (0001) plane, taken in $\bar{3}030$ reflection. The arrow indicates the direction of the Burgers vector with respect to the helical dislocation. This helical dislocation exhibits total extinction in $\bar{3}300$ reflection.
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In sapphire, the helicoidal dislocations having Burgers vectors directions $<2\bar{1}\bar{1}0>$ were identified. It should also be noted that the formation of numerous prismatic loops, originating from the helical dislocations, are frequently observed. (See Figures 2 and 3).

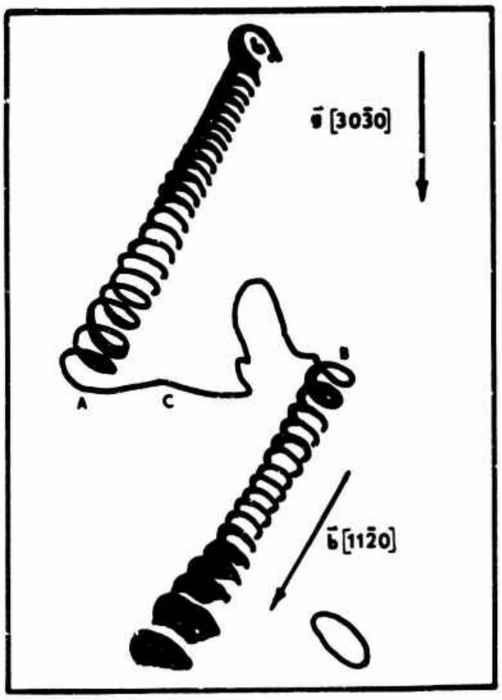

Figure 2. A schematic drawing of topograph a (in Figure 3) showing vectors $\bar{b}$ and $\bar{g}$ properly oriented with respect to the A and B helices. These helical dislocations are connected by dislocation C.
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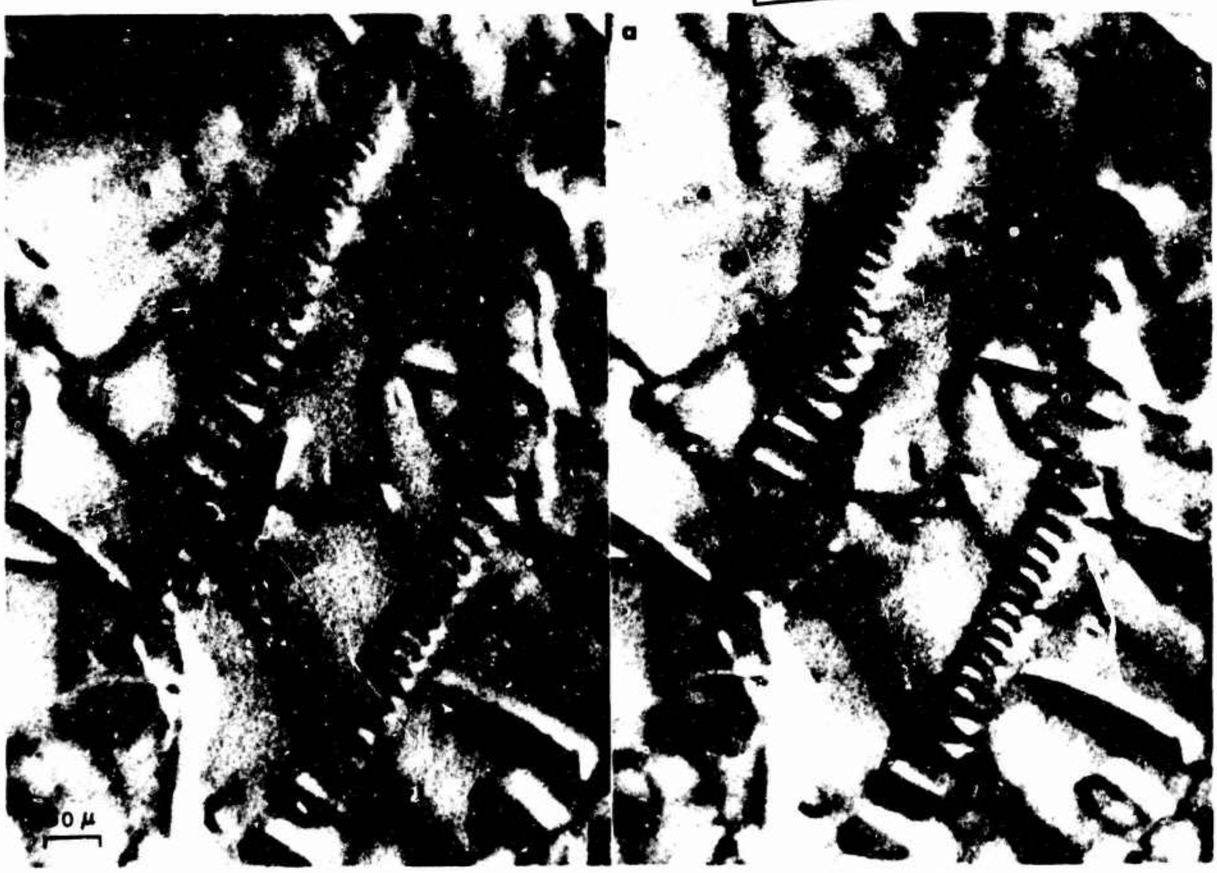

Figure 3. A stereo pair of X-ray topographs where a is in 3030 and b is in 3030 reflection. A pair of basal, helical dislocations is shown interconnected by a dislocation line. Viewed stereographically, the helix on the right is higher than the helix on the left. Note the prismatic loop in the lower right hand corner.
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Hence it may be inferred that the loops, such as have been observed by Lommel and Kronberg[10], could have been formed by a similar mechanism. The magnitude of the Burgers vectors was derived from the topographic study performed on sapphire[1].

A detailed explanation of this work will be presented in the near future.

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