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# HREM STUDIES ON TWINNING BEHAVIOUR OF EUTECTIC SILICON IN UNMODIFIED AND Sr-MODIFIED Al-Si ALLOYS

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The addition of trace amounts of sodium or strontium to commercial Al-Si alloys promotes a massive increase in twin density in the eutectic silicon which is associated with a change in morphology of the silicon phase from a flake to a fibrous form.[1,2] In the flake form the internal twins are always parallel to external faces of an individual flake as in Fig. 1a,[3] resulting in a consistent <112> growth direction by the twin-plane reentrant edge (TPRE) growth mechanism.[4] In the fibrous form the high twin density promotes a zigzag alternation of <112> growth directions, as in Fig. 1b, with a net <001> growth axis,[2] so that twins can be parallel to any of four <110> axes. In the flake form all twins lie in a single <110> zone. The essential morphological features of flake and fibrous growth are conveyed in two dimensions by Figs. 1a and 1b. HREM has been employed in the present study to investigate further the nature of the twinning in eutectic silicon of flake and fibrous morphologies.

Al-12.7 wt % Si eutectic alloys with, and without, 0.05% Sr were vacuum cast from Al and Si each of 99.999% purity, and Al-5 wt % Sr master alloys of 99.9% purity. The cast billets were re-melted and unidirectionally solidified at a rate of 50 micron/s. Thin foil specimens taken from longitudinal and transverse cross-sections of the solidified alloys were prepared by a method described elsewhere[3], by electropolishing followed by ion-beam thinning. HREM was performed with a JEM-4000EX operated at 400kV.

An HREM image of a segment of flake-type silicon is shown in Fig. 2. In accordance with the TPRE growth pattern (Fig. 1a), the image shows parallel twin boundaries along the same {111} plane. Each boundary extends along <112> and is parallel to the flake surface. The HREM micrograph in Fig. 3 was taken from a segment of a typical silicon fiber and reveals two {111} twinning systems in the same fiber. The boundaries extend along two different <112> directions. The crystals in Fig. 3, as labelled, correspond to crystals of twin group AB and BC of Fig. 1b. This implies that a TPRE growth has occurred along a zigzag alternation of <112> directions of the fiber. Another feature of this micrograph is the branching of two parallel twins by a band of stacking faults. The role of these stacking faults in the overall growth mechanism of silicon is not clear and further work on this question is in progress.

In summary, the results of this investigation confirm that the growth mechanisms of silicon revealed by the atomic arrangements in the flake and fibrous silicon are in complete agreement with those established by previous TEM studies.[2,3] The presence of the stacking faults in twin planes of fibrous silicon offers some insight into the rôle of Sr in the crystal growth of silicon. It suggests that during crystallization, the Sr atoms present in the melt upset the stacking of silicon in some way allowing the twin boundaries to appear and disappear randomly. This probably explains why the twin density in the silicon fiber is greatly enhanced in Sr-modified alloys.



References

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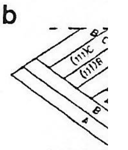
1b



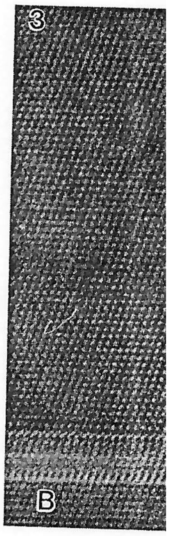



Fig. 1. (a)
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Si, alterna
TPRE growth
Fig. 2. HREM
segment in
50°C/cm, lo
Fig. 3.HREM i
in Al-12.7%

References

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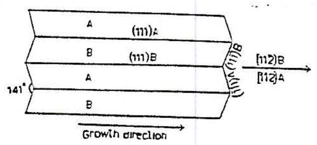
5. This work has been conducted at the HREM Facility in the Center for Solid State Science at Arizona State University, supported by NSF Grant DMR-86-11609.

1a

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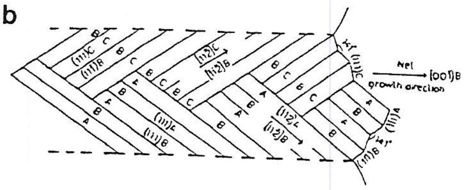


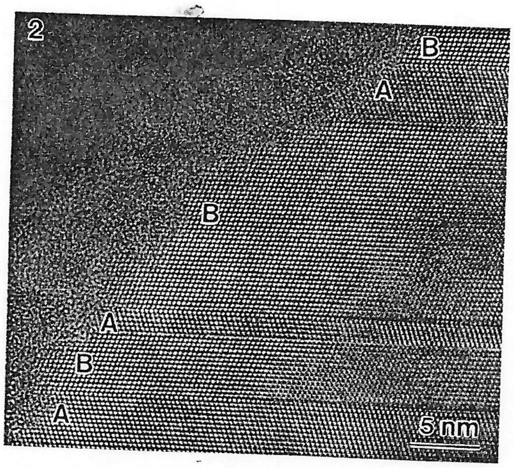


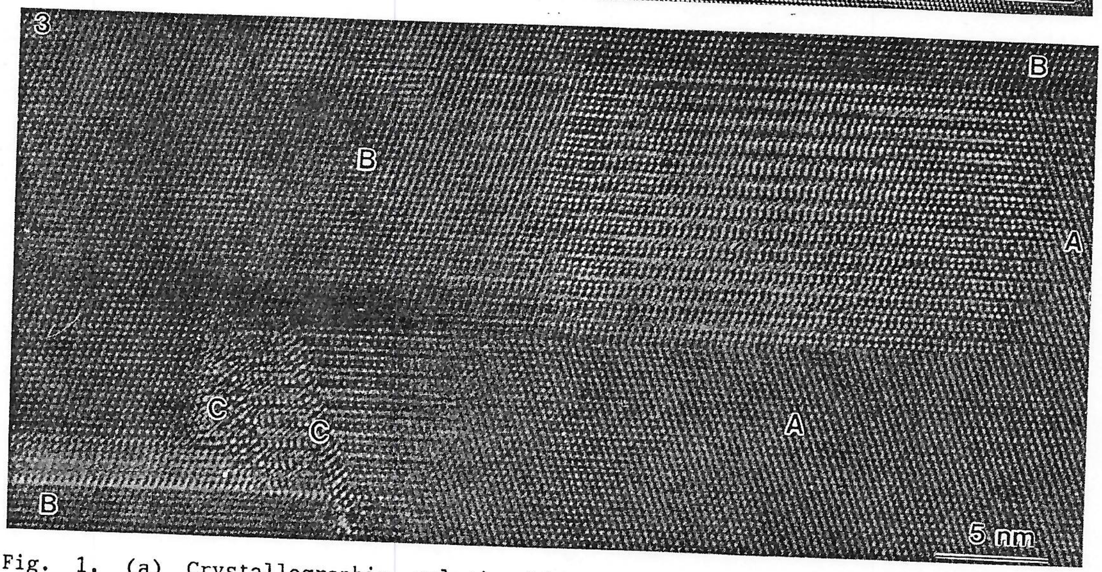


Fig. 1. (a) Crystallographic relationships of twinned crystals in unmodified eutectic Si growing by TPRE mechanism. (b) Fibrous growth in Sr-modified eutectic Si, alternate internal branching of constituent crystals A, B and C by twinning. TPRE growth in alternating <112> directions.
Fig. 2. HREM image with incident beam parallel to {111} twinning planes of Si flake segment in Al-12.7% alloy (growth rate v = 50 micron/s, temperature gradient G = 50°C/cm, longitudinal section).
Fig. 3.HREM image with incident beam parallel to {111} twinning planes of Si fiber in Al-12.7% Si -0.05% Sr alloy. See text for explanation of labels A, B and C.