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EFFECT OF TRACE ELEMENTS ON PRECIPITATION IN Al-Cu ALLOYS UCRL-19137

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The addition of small amounts of Cd, In and Sn to the Al-Cu alloys is known[1] to strongly influence the aging process. The formation of θ' is favored at the expense of θ". In the present study a series of Al-4Cu alloys with and without additions of Cd, In and Sn, and a commercial 2021 Al-alloy containing 6.3% Cu, 0.15 Cd and 0.05 Sn were investigated by transmission electron microscopy and diffraction. The ternary alloys had either 0.12% Cd or 0.05% Sn or In.

The structures obtained after aging for 24 hours at 163° are shown in fig. 1. The 2021 Al-alloy shows particles of ~ 500Å diameter with large strain fields [Fig. 1(a)]. The ternary Al-4Cu-0.05 Sn alloy also showed [Fig. 1(b)] similar θ' particles, but of slightly larger diameter (~ 770Å), after identical aging treatment. On the other hand the binary Al-4Cu alloy contained mixtures of θ" (average dia. ~ 330Å) and θ' [Fig. 1 (c)] after the same aging treatment. The size and distribution of the θ' precipitates in 2021 Al-alloy appear to be similar to the θ" in the binary, and their strain fields are also very similar. This suggests that the θ' particles in 2021-Al alloy and also in the ternary alloys are probably coherent at this aging temperature. Coherency could be maintained in θ' by Cd, In or Sn atoms segregating at the interface. This possibility is in accord with the diffraction pattern. (fig. 2). The presence of {100} {300}, etc., θ' spots (including spots at x fig. 2b) could be explained if some of the 0, 1/2, 1/4 or 1/2, 0, 3/4 sites in θ' structure [the unoccupied sites," ref. (2)] are occupied by Cd, In or

Sn atoms. To maintain coherency it may be that more of such sites near the θ'-matrix interfaces will be filled than in the interior and so it may not be necessary to assume a different interface structure (as in ref. 1). An alternative interpretation of the pattern (fig. 2) involves double diffraction, although dark field analysis of possible double diffraciton spots has been inconclusive, so we prefer the above explanation.

A comparison of the sizes of θ' particles in the various alloys shows that they are much smaller in the 2021-Al alloy compared to the other ternary alloys. This suggests that the growth rate of θ' in 2021-Al alloy containing maximum supersaturation of Cu and also Cd and Sn is the slowest. This can be explained if one assumes that in the alloys containing trace elements, the growth of the precipitate is controlled by the movement of Cu-vacancy-Cd (or In or Sn) clusters to it, as suggested by Noble.[3] In the 2021-Al alloy the clusters may be of Cu-Vac-Cd-Sn, which may be larger in size compared to the clusters in the ternary. Thus, the larger cluster size may be responsible for the smaller particle diameter in 2021-Al alloy compared to other ternary alloys.

In all the alloys containing trace elements θ' precipitates are uniformly distributed [figs. 1(a) and (b)] and no nucleation on dislocations is observed. In binary Al-Cu alloys heterogeneous nucleation of θ' on dislocations is well known. The presence of Cd, In or Sn atoms at the interface of θ' may reduce its surface energy and hence favor homogeneous nucleation even at lower temperatures.

Fig. 3 shows the presence of both θ' and θ" precipitates in the

Al-4Cu-0.05 In alloy after aging for 24 hours at 163°C. The θ precipitates are much bigger than the θ" as clearly seen in dark field. For the same aging treatment the Al-4Cu-0.05 Sn alloy does not show any θ" and only θ' is seen [fig. 1(b)]. This may be due to a greater binding energy between vacancy and Sn atoms than with In atoms.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Figure 1. (a) Dark field micrograph of matrix reflection in 2021-Al alloy, θ' only.

(b) Bright field micrograph of Al-4Cu-0.05 Sn alloy, θ' only.

(c) Bright field micrograph of Al-4Cu alloy showing both θ" and θ' (marked by arrow) precipitates.

All were aged for 24 hours at 163°C.

Figure 2. (a) Selected area diffraction pattern from an area similar to Figure 1(a) but aged for 12 hours at 190°C. The c/a ratio for the θ' precipitates is ~ 1.5.

(b) Explanation of the pattern in (a).

Figure 3. (a) Al-4Cu-0.05 In alloy aged for 24 hours at 163°C showing both θ' and θ" precipitates.

(b) Selected area diffraction pattern of (a). The reflections due to θ' and θ" are indistinguishable.

(c) Dark field of the streak [encircled area in (b)], showing mainly θ' precipitates. The θ" precipitates reverse contrast faintly.

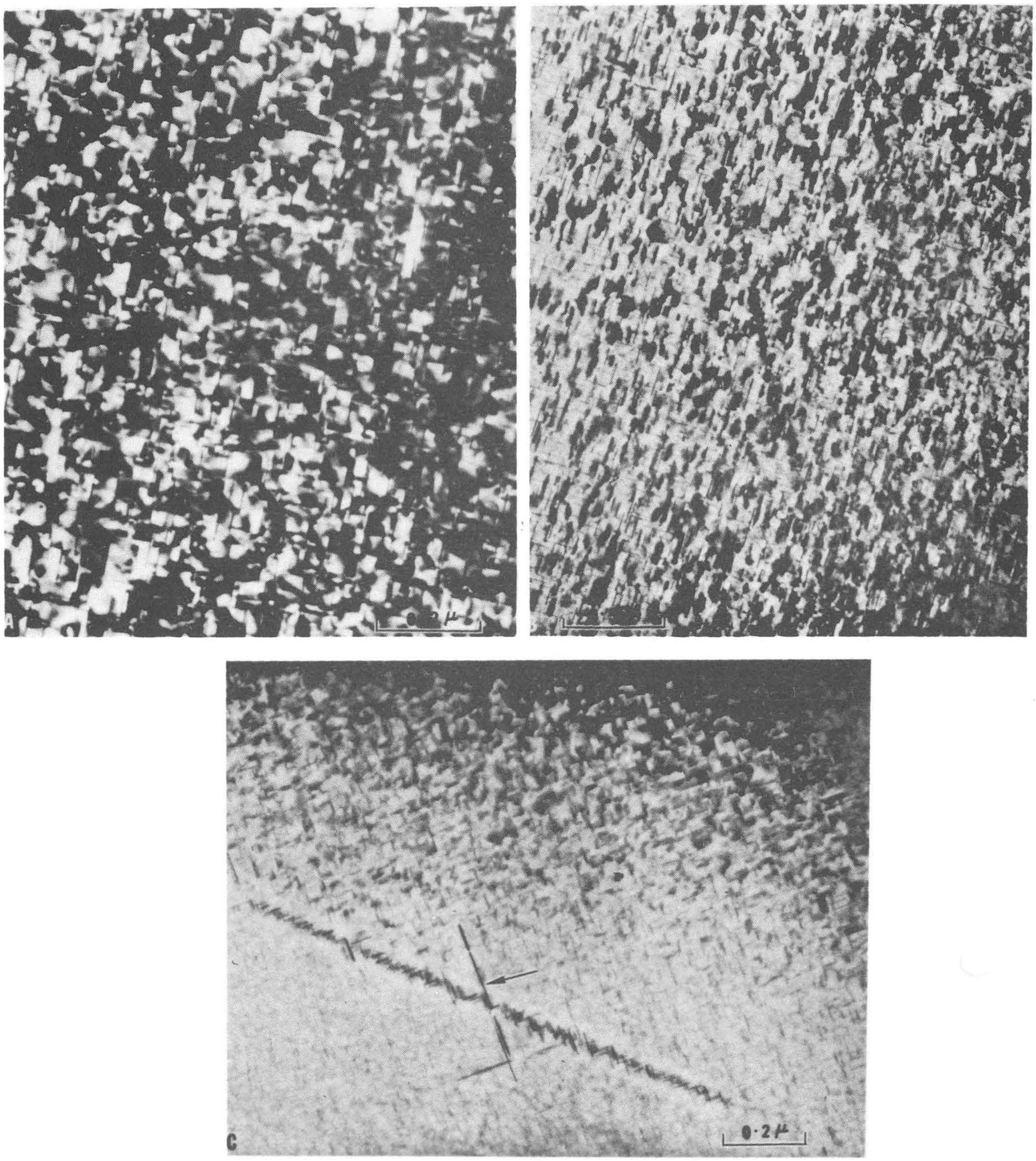

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Figure 1

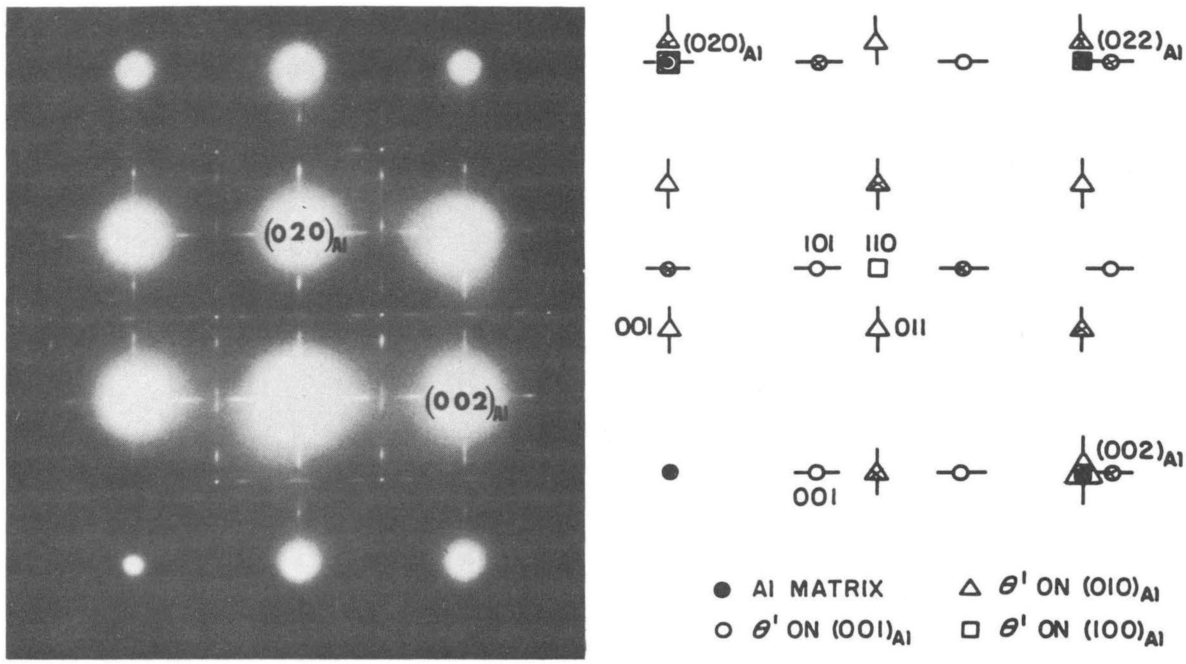

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Figure 2

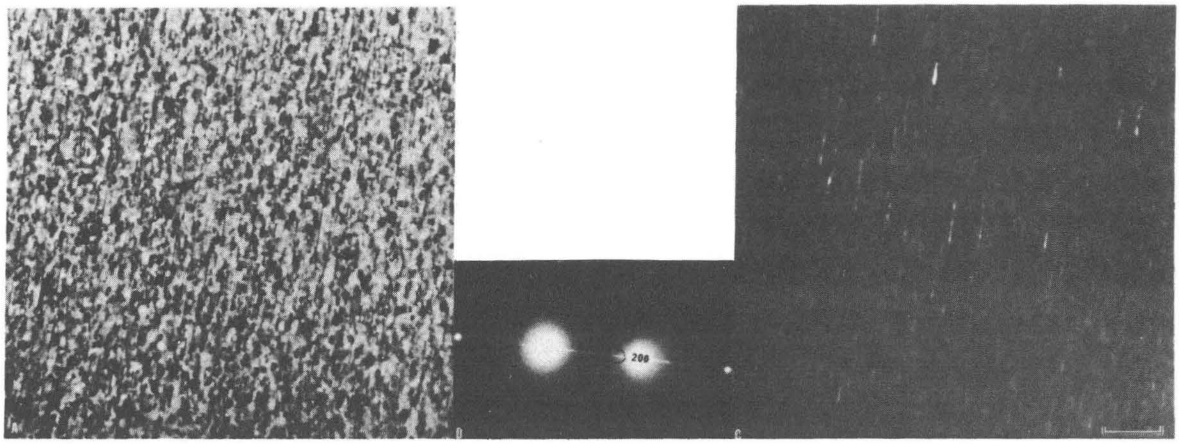

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Figure 3

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