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PRECIPITATES IN AN Al-Ge ALLOY

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AN ATOMIC RESOLUTION STUDY OF PRECIPITATES IN AN Al-Ge ALLOY

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The difficulty of precipitating germanium in dilute aluminum-germanium alloys is due to a large difference in crystal structures (face-centered cubic and diamond cubic) accompanied by a substantial volume expansion of 36%. A great variety of precipitate morphologies and orientation relationships are observed.[1-4] A frequently found morphology is that of <100> needles. By selected area diffraction and Moiré fringes it has been established that <100> Al and <110> Ge are parallel along the needle axis.[4] The typical aspect ratio of about 100 has made it difficult in the past to investigate the cross-sectional shape and internal structure of these needles, although some indications of internal twinning were found in plates.[5] In the present work, the Berkeley Atomic Resolution Microscope was used to examine needles in cross section by imaging along the <110> Ge <100> Al needle axis.

In the large number of high-resolution images recorded the particles were found to exhibit a fascinating variety of cross-section morphologies, internal and interface structures, and orientation relationships, even though only needles with <110> Ge || <100> Al were examined. At least three primary orientation relationships were observed; (a) {111} Ge || {100} Al, (b) {100} Ge || {100} Al and (c) {110} Ge || {110} Al.[4-6] An example of a typical precipitate is shown in Fig. 1. The two longest flat facets are {111} Ge planes parallel to {310} Al while the shorter facets are another set of {111} Ge planes parallel to {100} Al. The primary orientation relationship of this precipitate and the one most frequently found is that given in (a) with monoclinic 2/m symmetry. The shape of this particle also has approximately 2/m symmetry along its axis, but the perfect symmetry is disrupted by the internal twins labelled 1, 2 and 3. The central precipitate and its twin 1 have the same (a) orientation relationship because they are mirror related across the {100} symmetry plane of the matrix. On the other hand, twins 2 and 3 are in a different (secondary) orientation relationship because their twin plane is the {111} Ge plane that is parallel to {310} Al. Note that the corresponding interfaces with the matrix are atomically flat on the Ge side, leading to a stepped appearance on the Al side. Closer examination reveals an apparent stacking fault in the Ge layer next to this interface. Further high-resolution microscopy, especially comparison with other morphologies in the same alloy, is expected to provide additional clues on how these particles grow and how they are accommodated in the matrix.[7]

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7. This work is supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

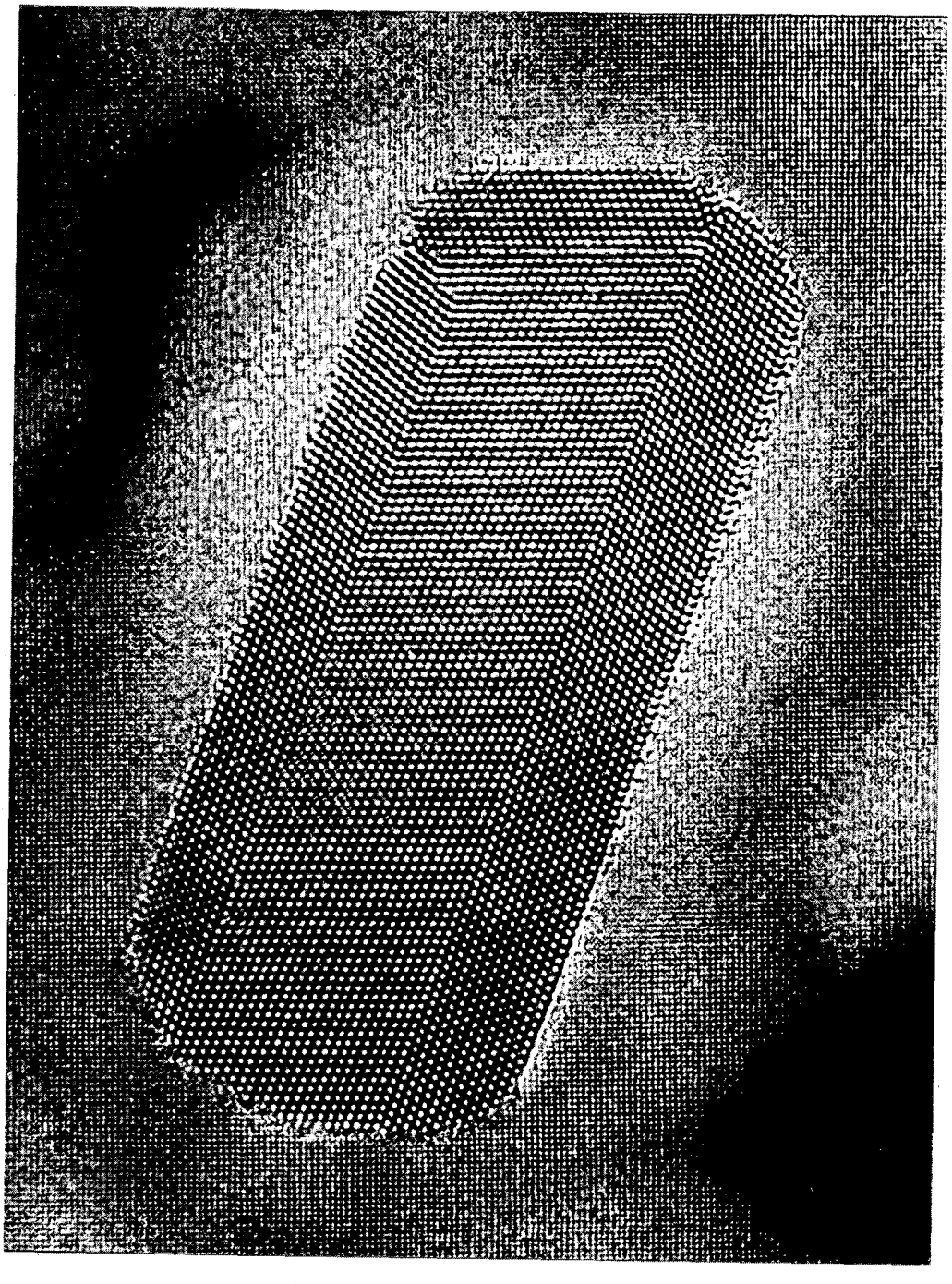

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FIG. 1. -- High resolution image of the needle-or lath-shaped Ge precipitate seen end-on along <110> Ge. The Al matrix is in <100> orientation. Segments 1, 2 and 3 are twin-related to the central part of the precipitate whose orientation relationship is <110> Ge || <100> Al and {111} Ge || {100} Al. The flat interfaces lie on {111} Ge || {310} Al planes.

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