

MARTENSITIC TRANSFORMATION IN A SPLAT COOLED  
METASTABLE Au-47.5 AT. % Cd ALLOY

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The present investigation was undertaken to study the effects of liquid quenching on the martensitic transformation of an Au-47.5 at. % Cd alloy. The equilibrium slow cooled alloy of this composition forms a  $B_2$  ordered  $\beta$ -phase (1,2) above about 65°C. Below this temperature the alloy transforms martensitically into an orthorhombic  $\beta'$ -phase which is twin related (3). The  $\beta$ -phase retains a high degree of long range order even at its melting point (4). It has been reported (5) that solid state quenching produces an anomalous martensitic transformation in this alloy. An unusual property of the alloy is that the equilibrium vacancy concentration extrapolated to the melting point is nearly 1 at. % (4). That is, the defect concentration is about an order of magnitude higher than that for most pure metals.

In pure metals, high densities of vacancies can be quenched-in by liquid quenching (7,8). Also, liquid quenching could possibly produce some change in the long range ordering parameter of the  $\beta$ -phase. Therefore, it is of interest to study the role of such structural defects on the relative stabilities of the parent and the martensitic phases in a splat cooled alloy.

Experimental Procedure

Appropriate amounts of high purity (99.999%) gold and cadmium were vacuum melted and thoroughly homogenized in sealed quartz capsules. The alloy ingots were then cut into splat charges of approximately 50 mg. each.

The samples were splat cooled by using a vertical shock tube apparatus (9,10). Splats were deposited on copper substrate at room temperature. A Phillips EM-200 electron microscope was used to study the splat samples.

## Results

### (a) As Quenched Alloy

Within 10 minutes of splat quenching the samples were examined under the electron microscope. The characteristic martensitic structure of the slow cooled alloy, below about 65°C, was completely absent. The micro-structure showed fine equiaxed grains of varying sizes. A characteristic basket weave type mottled structure was observed within the grains. The average spacing between the periodic striations of this mottled structure was of the order of 20 to 30 Å. Also some black spot condensation loops and extended dislocation boundaries were observed. Typical examples of these can be seen in the central grain as shown in FIG. 1(a).

Selected area diffraction patterns obtained from various grains unambiguously showed the structure to be the  $B_2$  superlattice characteristic of the  $\beta$ -phase. The diffraction patterns always showed extensive streaking along  $\langle 112 \rangle$  type directions. X-ray diffraction analysis shows that the relative superlattice to fundamental line intensities are somewhat larger than that for a slow cooled bulk sample.

### (b) Martensitic Transformation in the Metastable $\beta$ -Phase.

The metastable  $\beta$ -phase was observed to transform martensitically under the influence of a strong electron beam intensity. The martensitic plates appeared and disappeared, following an exact sequence, when the electron beam intensity was increased or decreased respectively. The formation sequence is shown in FIGS. 1(a) through 1(h).

The general nature of the nucleation and growth of such martensite can be summarized as follows:

- (1) Nucleation sites are usually (a) grain boundaries, (b) intersection of laths at an adjacent grain boundary and (c) occasionally dislocations within the grain.
- (2) Dislocation boundaries appear to impede lath growth temporarily.
- (3) Laths grow independently of each other yet maintain an uniform thickness and spacing.

(4) Laths grow lengthwise and some with tapered growing tips.

(5) The steps in the growth of a lath are: (a) Slow dislocation motion resulting in a diffuse area having the final shape of the lath, (b) formation of internal stacking faults and/or micro twins and finally (c) some growth in thickness and general sharpening up of internal structures.

At room temperature the metastable  $\beta$ -phase transforms isothermally to the orthorhombic martensitic phase in about 2 to 3 days. After this reversal the  $\beta$ -phase can only be obtained by heating above the  $A_s$  temperature ( $\sim 80^\circ\text{C}$ ).

#### Discussion and Conclusions

The ordering reaction cannot be suppressed by splat quenching, indicating that the relaxation time for ordering is shorter than the quenching time. It might also imply a high degree of short range order in the liquid phase. The observed increase in superlattice intensity could tentatively be explained by invoking a preferential sublattice vacancy.

The retention of the metastable  $\beta$ -phase at room temperature is most likely caused by the excess lattice defects. In  $\beta$ -brass radiation damage is known to suppress the martensitic reaction (11).

Periodic growth faults as well as extremely fine twins could produce the observed heavy  $\langle 112 \rangle$  streaking. Since the final martensitic structure is twin related, it is interesting to consider the splitting of twinning dislocations into  $a/3 [112]$  sessile components giving rise to the stacking faults on  $\{112\}$  planes (12). Further detailed studies are presently carried out to analyze the crystallography of this transformation.

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(a)



(b)



(c)



(d)

FIG. 1 (a)-(d). Transmission electron micrographs of a sputter cooled Au-47.5 at.% Cd alloy. (a) shows mottled structure and dislocations. FIGS. (b) through (d) show martensite growth sequence. The markers in micrographs (a) and (b) are 0.5 microns.



(e)



(f)



(g)



(h)

FIG. 1 (e) - (h) Transmission electron micrographs showing martensite nucleation and growth in the metastable  $\beta$ -phase. Magnification in FIGS. (b) through (h) are the same.

## DISCUSSION :

- R. Maddin : Did you confirm that the boundary was a dislocation boundary by contrast analysis ?
- K. Mukherjee : Yes, we did and the large dislocation boundary shown in the micrograph is indeed a dislocation boundary.
- A. Guinier : What is the origin of the diffuse striations in two perpendicular directions visible before the start of the martensitic transformation?
- K. Mukherjee : These striations are apparently related to the streaking in electron diffraction pattern observed both in the splat cooled metastable  $\beta$ -phase as well as in the bulk slow cooled  $\beta$ -phase just before the actual martensitic transformation. It is indeed an interesting possibility that we are observing very, very fine scale stacking faults on  $\{112\}$  planes produced by a/b  $\{112\}$  sessile components by the twinning dislocation. Whether these stacking faults act as martensitic embryos, has to be confirmed by further experimentation.
- N.J. Grant : In the lower right hand there is a martensitic colony at a different angle from the major martensitic streak. Have the geometries of these martensitic colonies been determined ?
- K. Mukherjee : Please notice that the angle between the two colonies that you point out is about the same as that of another two sets in a different grain (central grain). We believe that these are the two crystallographic variants as we see them here. We have not yet completed crystallographic studies, we are in the process of doing so.