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RECOVERY AND STACKING FAULTS OF α Ag-Sn ALLOYS*)

Harsono Wirjosumarto**)

R I N G K A S A N

Penggeseran puncak difraksi sinar-X dapat dipergunakan untuk menentukan temperatur pemulihan dari logam-logam dengan struktur kubus berpusat sisi. Dengan cara tersebut dapat ditentukan bahwa serbuk kikiran dari α Ag-Sn pulih kembali pada temperatur antara 100° dan 200°C. Diketemukan pula bahwa energi salah tumpuk dari paduan tersebut berkurang dengan bertambahnya konsentrasi timah putih.

A B S T R A C T

X-ray diffraction peak shift can be used to determine the recovery temperature of face centered cubic metals. Using this method it was found that filed α Ag-Sn chips recover at temperature between 100° and 200°C. The stacking fault energy was found to be decreasing with increasing tin content.

INTRODUCTION

Cold deformation process in metal working produces deformed or distorted structure in metal. This cold work struc-

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*) This work was done at the University of Kentucky, U.S.A.

**) Mechanical Engineering Department, Institute of Technology Bandung.

ture can be transformed back into normal structure by annealing. During the annealing, three processes occur, they are recovery, recrystallization, and growth processes. The last two processes are accompanied by microstructural change, therefore they can be detected metallographically. While the first one, which is a nonstructural change process, is relatively difficult to determine.

In this work the temperature during which the recovery process occurs in α Ag-Sn was determined by the use of X-ray diffraction method. From the X-ray peak shift the relation between stacking fault energy and tin content was analyzed.

MATERIAL AND METHOD

Materials

Materials which were used in this work are 5 Ag-Sn alloys with 0.0, 2.9, 5.2, 8.1 and 9.9 wt % Sn.

Sample Preparation

The alloys were made by melting silver granules of 99.99% purity, then adding the required amount of 99.99% purity tin into it. Then ingots were made by remelting the alloys and casting them centrifugally into Vycor glass tube with 3.8 mm inner diameter. This procedure gave a dense, uniform and reproducible ingot structure.

The ingots were then homogenized at 400°C for 48 hours. During the homogenization process each ingot was sealed in an evacuated glass tube to minimize oxydation.

Experimental Method

Cold deformation was introduced to the samples by filing homogenized ingots into chips. Chips of each alloy were then annealed at room temperature, 100°C, 150°C, 250°C and 350°C for one hour. One sample for each alloy was fully annealed at 400°C for 6 hours.

X-ray diffraction patterns of the samples, which cover (111) and (200) peaks were made and the differences in Bragg angle of the two peaks were measured. These X-ray diffraction patterns were made with Cu-Kα radiation on a General Electric diffraction unit.

RESULT AND DISCUSSION

The differences in Bragg or 2θ angle between (111) and

(200) peaks, which will be designated with Δ2θ, were plotted against the annealing temperature. This relation is shown in Figure 1. This figure indicates that the value of Δ2θ for the

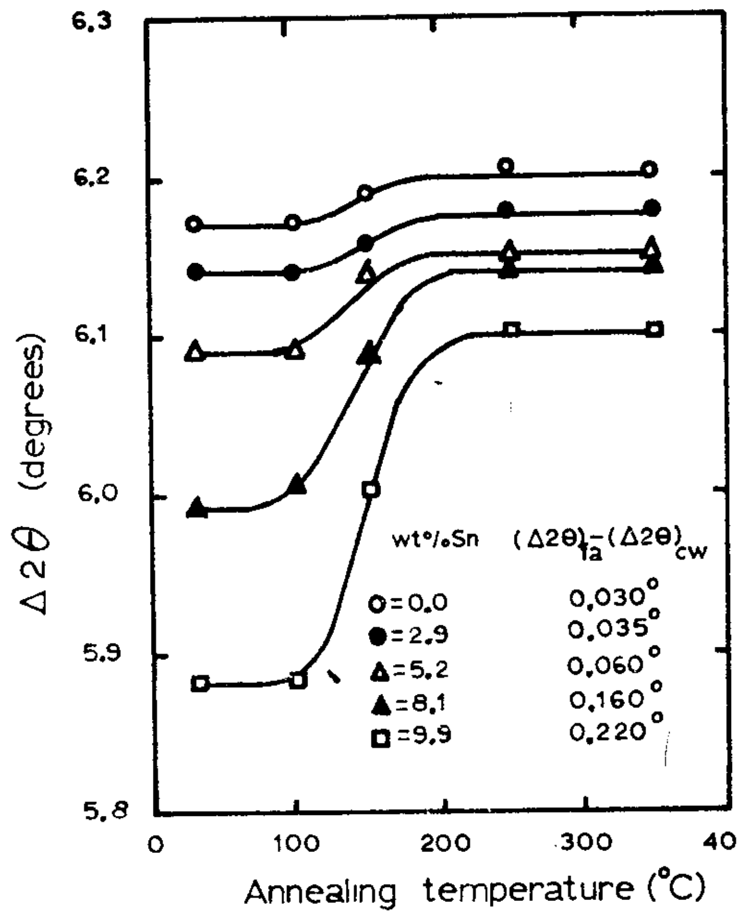

Figure 1

X-ray diffraction peak shift of
cold-worked α Ag-Sn alloys

as cold worked and annealed samples are different. This phenomenon is explained in the following.

α Ag-Sn alloy is a face centered cubic (FCC) metal. It has been known that in most FCC metal, plastic deformation is accomodated by slip between the slip planes. In FCC metal the slip plane is the (111) plane and there are three differently oriented slip planes, which are usually designated as a, b and c. Therefore the stacking sequence of these slip planes in FCC metal is . . . a b c a b c . . . etc. Further, it also has been known that the atomic arrangement of the slip plane in hexagonal close packed (HCP) metal is exactly the same as that of FCC metal. The difference between these two structure lies only on the stacking sequence of their slip plane. In HCP metal the sequence is . . . a b a b . . . etc.

During the deformation, FCC metal may undergo a complete slip, a partial slip or a mixture of both of them. In the case of complete slip, the deformed metal keeps its stacking sequence, while in the case of partial slip the orientation of the slip plane changes with respect to each other. This partial slip therefore may transform plane a into b or c, plane b into a or c and plane c into a or b position, so that . . a b a b . . or HCP stacking sequence may appear in the deformed FCC metal. This fault is called stacking fault.

From the above explanation it can be concluded that deformation may transform part of FCC metal into HCP structure in the form of stacking fault. Consequently X-ray peak position of the deformed FCC metal might move slightly toward the peak position of HCP metal. This peak shift is the $\Delta 2\theta$, which was detected and measured in this work.

Figure 1 also indicates that the $\Delta 2\theta$ value of the cold worked samples changes abruptly toward the value of fully annealed sample at temperature between 100° and 200°C. This means that at this temperature range the misplaced atoms move toward the normal FCC arrangement. This atomic rearrangement is the recovery process. So it can be concluded that filed α Ag-Sn chips recover at a temperature between 100° and 200°C. This result is in agreement with that of Newton and Ruff(1), in which they found that deformed Ag-Sn with 9 at % Sn starts to recover rapidly at 165°C.

The stacking fault probability was calculated according to the mathematical formulation developed by Warren(2). The equation is as follow:

$$P = \frac{(\Delta 2\theta)_{c.w} - (\Delta 2\theta)_{f.a}}{(45\sqrt{3}/\pi^2)\ [\tan 2\theta_{(200)} + \tfrac{1}{2} \tan 2\theta_{(111)}]}$$

where: P = stacking fault probability
c.w. = cold-worked
f.a. = fully annealed

The values of the calculated stacking fault probability for each alloy were then plotted as a function of the tin content. This relation is shown in Figure 2. From this figure

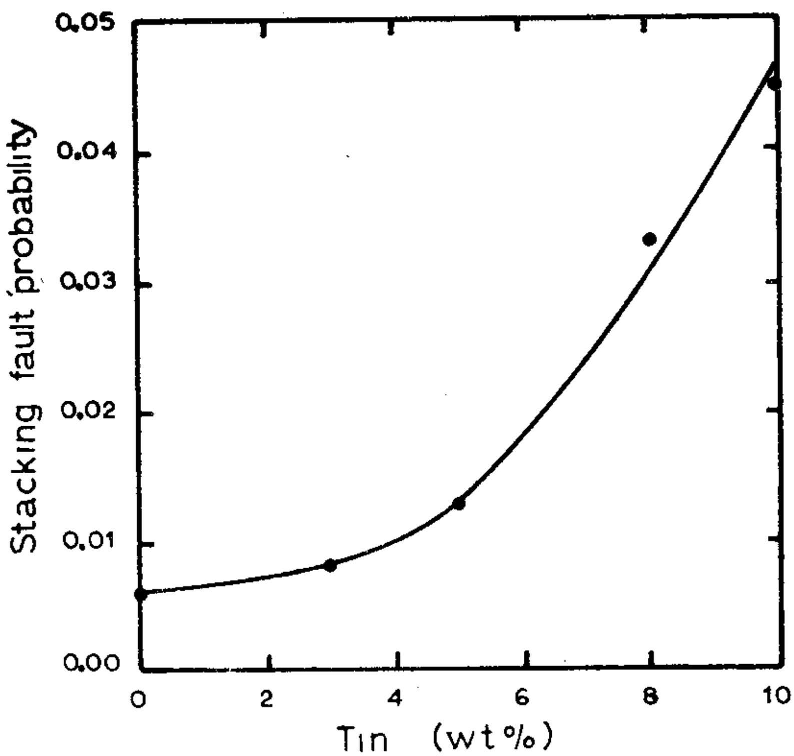

Figure 2

Stacking fault probability of cold-worked α Ag-Sn alloys as function of tin content

it is clear that the stacking fault probability increases with increasing tin content. So it can be concluded that the stacking fault energy decreases as the tin content in the alloy increases. This phenomenon is expected since tin content of more than 10 wt % will produce stable hexagonal close packed structure of β Ag-Sn alloy as indicated by the phase diagram of Ag-Sn system[3]. This result confirms the work of Ruff and Ives[4], in which they used transmission electron microscopy to calculate the stacking fault energy of α Ag-Sn from the dislocation nodes.

CONCLUSIONS

1. X-ray diffraction peak shift could be used to determine the recovery temperature of FCC metals.
2. Filed α Ag-Sn chip recovers at a temperature between 100°C and 200°C.
3. The stacking fault energy in α Ag-Sn alloys decreases with increasing tin content.

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