

THE DEVELOPMENT OF THE TEXTURE OF
(112)[$\bar{1}\bar{1}\bar{1}$] ROLLED Al, Cu AND AgC.A. Verbraak
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(Received December 10, 1973)

I Introduction

It is generally known that face centered cubic metals exhibit two different types of rolling textures. The first type of texture, which is observed in Ag and most F.C.C. alloys with a relatively high content of alloying element (the alloy type texture) is described as $\{110\}\langle 112\rangle$. Most F.C.C. elements except Ag, have a texture which is called the copper texture. The crystallographic description of this texture is not so straightforward. In the literature a great number of different notations are suggested (1,2). Most theories about the development and the transition of the textures in F.C.C. metals adopt as the most important component of the Cu-texture: $\{112\}\langle 111\rangle$. Extensive reviews of these theories have been given by Hu, Cline and Goodman (3) and Bunge (4). More recently a very comprehensive review was given by Kalland and Davies (5). The main problems in all these theories are the origin and the stability of this $\{112\}\langle 111\rangle$ texture component. The present paper reports the results of an investigation on the stability of this orientation in single crystals of Al, Cu and Ag.

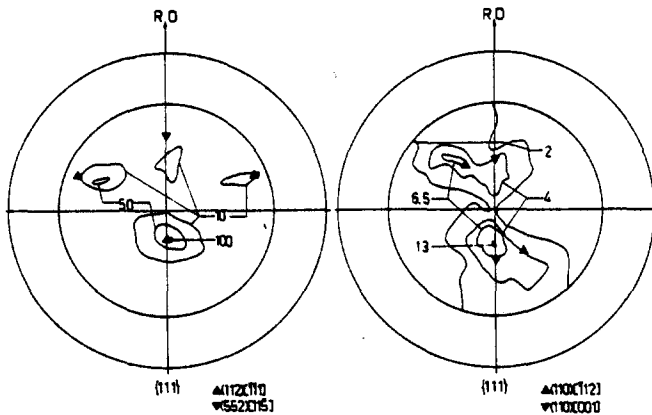
II Experimental Procedure

The single crystals used in the experiments were obtained from Metals Research - England. They were made of Cu 99.999 pct., Al 99.999 pct., and Ag 99.9999 pct. Specimens of $15\times 10\times 8$ mm and with orientation $(112)[\bar{1}\bar{1}\bar{1}]$ were cut from the single crystals with the aid of a Metals Research sparking machine. These specimens were inserted in polycrystalline material, in such a way that during the rolling operation the $\{112\}$ planes were in free contact with the rolls. The planes perpendicular to the rolling direction and the transversal direction were in tight contact with the polycrystalline material. In this way the single crystal is forced to deform in the same manner as the polycrystalline material. Rolling reductions of 30-50-70-80-90-95-98-99 and 99.5 pct. were studied. Each reduction was carried out in ten equal steps. After each of these reductions the changes in texture were measured with a back-reflection Philips texture goniometer with a pitch of 2.5° . The results were represented in conventional pole figures,

restricted to an angle of 70° from the rolling plane normal.

III Results

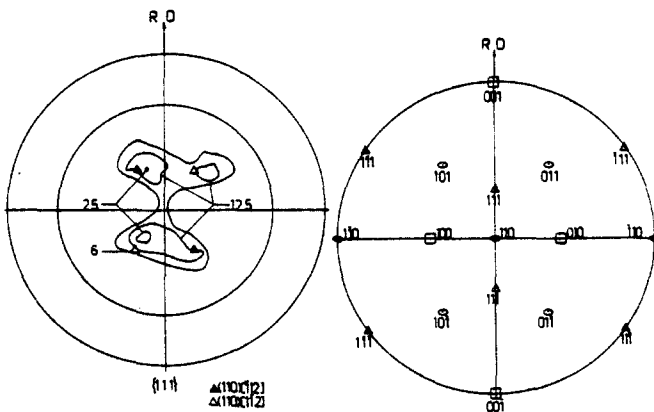
III.1 Silver The texture development in silver single crystals, rolled on the (112) plane in the $[11\bar{1}]$ direction is completely determined by twinning and slip on the octahedral planes. Already after 30 pct rolling reduction the (552)[115] twin texture is formed, and partly rotated towards the (011)[100] texture, due to slip on the $(11\bar{1})$ plane of the twin component (fig 1)



Left: Fig. 1. 111 pole figure of the 30 pct deformed Ag single crystal.

Right: Fig. 2. 111 pole figure of the 50 pct deformed Ag single crystal.

This texture is definitely not stable, from fig. 2, the pole figure of after 50 pct rolling reduction, it is evident that this texture rotated around the rolling plane normal, towards $(110)[1\bar{1}2]$. At 70 pct rolling reduction also the opposite rotation, towards the $(110)[\bar{1}12]$ texture is observed. These rotations lead very clearly to the alloy type texture, as can be seen from the pole figure of the 95 pct deformed specimen (fig. 3).

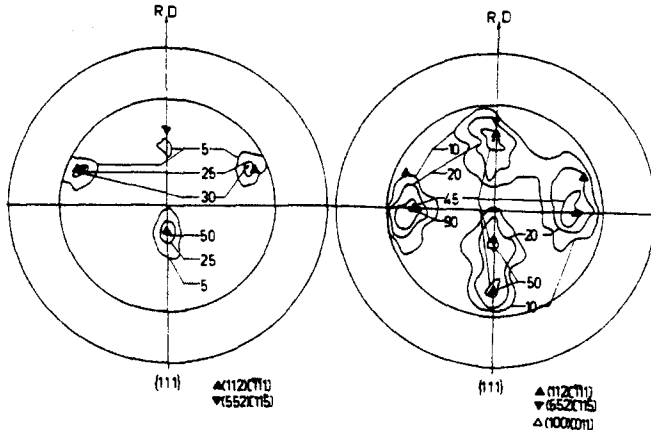


Left: Fig. 3. 111 pole figure of the 95 pct deformed Ag specimen.

Right: Fig. 4. (110) standard stereographic projection.

In similar experiments of W. Heye (6) the rotation $(110)[001] \rightarrow (110)[\bar{1}12] + (110)[\bar{1}\bar{2}]$ was not observed until 90 pct rolling reduction. A possible explanation for this discrepancy may be that Heye rolled his single crystals, not inserted in polycrystalline material, leaving the possibility of broadening of the crystal. Broadening of the crystal will occur, when rolled in the $(110)[001]$ direction, because of slip on the systems $(11\bar{1})[101]$, $(11\bar{1})[011]$ and $(111)[\bar{1}01]$, $(111)[0\bar{1}1]$ (fig. 4). These slip directions do not lie in the plane of the rolling-plane-normal and the rolling direction, which is necessary to prevent broadening. Thus the texture transition is completely according to the theory of Wassermann (8).

III.2. Copper It seems that the limit for twinning lies near Cu, with its stacking fault energy of approximately 55 erg/cm² (7) - for Ag: 21.6 erg/cm² -. Twinning occurs at 95 pct rolling reduction, then the $(552)[11\bar{5}]$ texture component is formed (fig. 5). Its role in texture transition, however, is much less important than in the case of Ag. Of much more importance is slip on cube planes - in accordance with the theory of Haessner (10). At reductions of 99.2 pct the $(112)[\bar{1}\bar{1}1]$ texture component starts to rotate in the direction of the $(100)[011]$ texture (fig. 6).



Left: Fig. 5. 111 pole figure of the 95 pct deformed Cu specimen.

Right: Fig. 6. 111 pole figure of the 99.2 pct deformed Cu single crystal.

III.3. Aluminium In Al (stacking fault energy 200 erg/cm² (7)) a similar texture transition is observed at 99.7 pct rolling reduction (fig. 7).

From the standard (112) projection in fig. 8, it can be seen that this rotation of the $\{111\}$ reflections to the $(11\bar{1})$ pole of the figure, as well as the rotation of the 002 reflection to the centre of the pole figure, can be explained by slip on the (001) plane, or by slip on the $(11\bar{1})$ plane of the $(112)[\bar{1}\bar{1}1]$ texture.

Fig. 8 shows (112) standard stereographic projection. The resolved shear stress on this plane, however, is zero. Dillamore and Roberts (9) proposing the cross-slip mechanism, state that slip on this plane is due to intergranular forces. Haessner (10), however, concludes from his experiments that intergranular forces play a role only in the vicinity of the grain boundary. Thus, slip on cube planes may be concluded from the observations mentioned above.

III.4. Recrystallization During the investigations additional orientations were observed

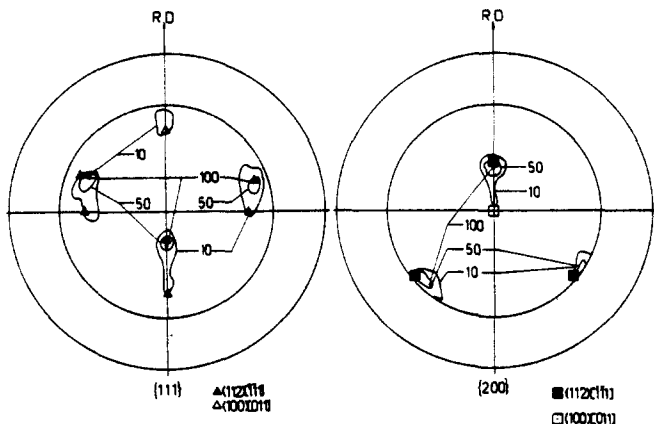


Fig. 7. 111 and 200 pole figures of the 99.7 pct deformed Al single crystal.

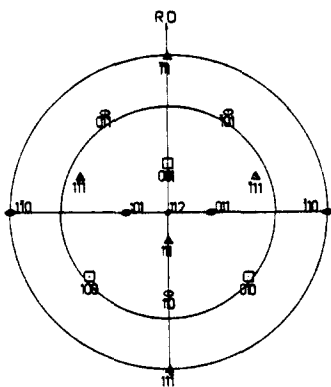
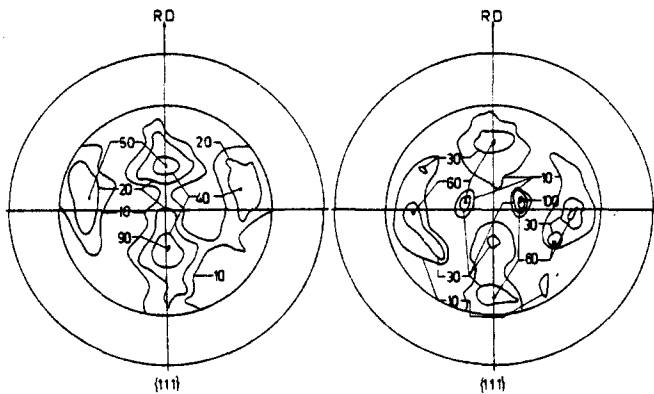


Fig. 8. (112) standard stereographic projection.

in Cu and Ag specimens, some time after rolling, as shown in fig. 9.

Further investigations showed that these changes were due to recrystallization at ambient temperature. It was found that the recrystallization texture component was dominant over the deformation texture component, in about one week after the process of rolling. In this case the orientation which results from recrystallization can be distinguished from the components of the rolling texture. It is doubtful, however, whether the influence of ambient temperature recrystallization was excluded in

all cases reported in literature.



Left: Fig. 9A. (111) pole figure of the 99.2 pct deformed Cu single crystal immediately after rolling.

Right: Fig. 9B. 111 pole figure of the same specimen one week after rolling.

IV Conclusion

From the results obtained so far it can be concluded that the following changes of the (112) [$\bar{1}\bar{1}1$] texture during the rolling process are possible:

- a) In Al (with a relatively high stacking fault energy) it occurs as a result of slip on cube systems, which underlines the theory of texture development of Haessner.
- b) In Ag it is due to twinning, which supports the theory of Wassermann.
- c) In Cu for which the stacking fault energy lies between those of Al and Ag, twinning as well as slip on cube planes are observed as causes.
- d) In Ag and Cu room temperature recrystallization, shortly after rolling causes large changes of the texture.

VI Literature cited

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