

Fig. 7. Top surface of (110) [110] [110] aluminum crystal after 24% thickness reduction, showing absence of deformation bands. Slip plane traces are noted in margin.  $\times 280$

With regard to crystal 7, (111)[112], the lower hardening may result from lattice reorientation, again lowering the  $M$  value. Brick and Williamson<sup>(11)</sup> have found that a (111)[112] brass crystal rotates to a (110)[001] position after an 80% reduction by rolling. It may be noted that  $M = \sqrt{6}$  for (110)[001], which is smaller than the value of  $M = 3\sqrt{6}/2$  for (111)[112]. Hence if lattice rotation did not occur in the present (111)[112] sample, use of a smaller value of  $M$  would Bishop and Hill<sup>(4)</sup> is used (see Ref. 7) instead of theory. (If a value of  $M = 1.35\sqrt{6}$  as derived by fall within the single crystal group. However, they do soften in their (111)[112] brass crystal.

Secondly, the two polycrystalline samples, 8 and 9, measurements, Brick and Williamson<sup>(11)</sup> also noted a

have raised its  $\tau$ - $\gamma$  curve in Fig. 5. Using hardness

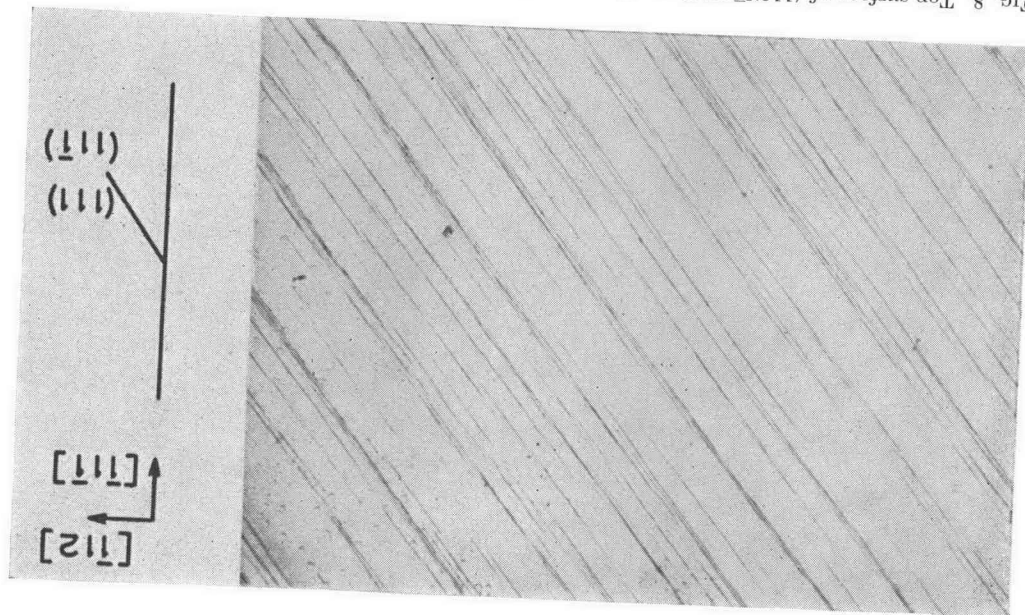


Fig. 8. Top surface of (110)[112] Permalloy crystal after 50.5% thickness reduction, electropolished, and then further deformed lightly. No constraint on  $\epsilon_z$ . Slip plane traces consistent with predicted  $-a_2$ , (111)[101], and  $b_2$ , (111)[011] slips.  $\times 140$

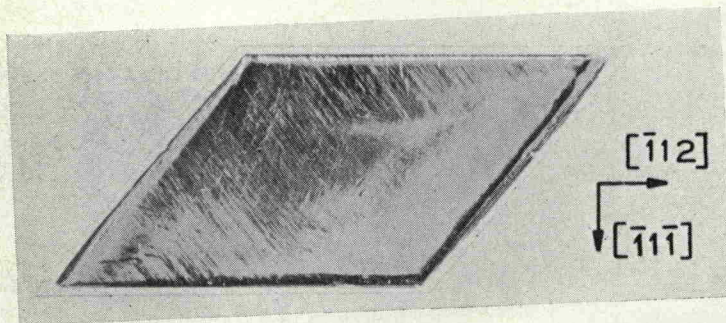


FIG. 9. Top view of (110)[112] Permalloy crystal of Fig. 8 after 50.5% thickness reduction. Transformation of the initially rectangular shape to a parallelogram indicated presence of  $\epsilon_{yz}$ .  $\times 2.70$

$M = 1.44\sqrt{6}$  for the present study, the  $\tau$ - $\gamma$  curves would lie higher still. This would accentuate the possible grain size strengthening effect even more.) It may be noted that the difference between samples 8 and 9 in the cooling rate. Sample 8, slowly cooled after a 1000°C anneal, has a much higher yield stress probably as a result of ordering.

Finally, in the case of (110)[112] straining (crystal No. 2), a value of  $M = \sqrt{6}$  was used in Fig. 5. This corresponds to the two-slip system ( $-a_2$  and  $b_1$ ) operation and leads to the strain equations (11), instead of activating additional slip systems ( $-d_1$  and  $d_2$ ) to conform with equations (6). The two-slip system operation is confirmed by metallographic observation of slip traces on the specimen surface, Fig. 8. In addition, the initially rectangular geometry is changed to a parallelogram after straining, Fig. 9, indicating

the presence of the  $d\epsilon_{yz}$  term (equation (11)) associated with the predicted two-slip system operation. A detailed analysis<sup>(12)</sup> of the shape change has likewise confirmed that the deformation can be accounted for almost exclusively by the two predicted slip systems  $-a_2$  and  $b_1$ .

By placing a (110)[112] crystal between rectangular polycrystalline blocks during compression,  $d\epsilon_{yz}$  was suppressed. As a result, all four slip systems ( $-a_2$ ,  $b_1$ ,  $-d_1$  and  $d_2$ ) were found to operate in accordance with analysis, see Fig. 10.

At first glance, the fact that  $-d_1$ , (111)[011] and  $d_2$ , (111)[101] can be activated at all seems surprising. The slip plane normal (111) of these two slip systems is perpendicular to the compression axis (see Fig. 2) and hence the resolved shear stress is zero on this basis. In actuality, however, if the shear strain  $d\epsilon_{yz}$  resulting

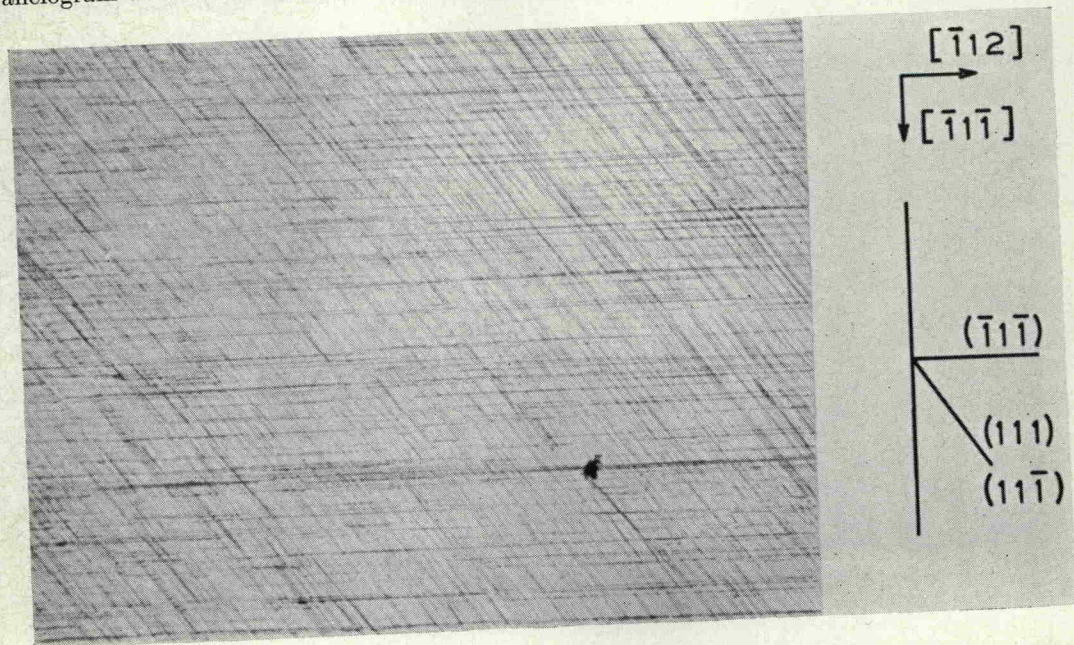


FIG. 10. Top surface of (110)[112] Permalloy crystal after 13% thickness reduction. Strain  $\epsilon_{yz}$  was suppressed by placing the sample between polycrystalline blocks. Note additional slip traces consistent with predicted new systems  $-d_1$ , (111)[011] and  $d_2$ , (111)[101].  $\times 140$