as log I/I_0 versus λ^3 fell on straight lines broken only at the Br K absorption edge. The values listed in Table 1 are the mean of 3–5 readings. Although the mean values are given to 0·1, the individual readings in some cases varied by as much as ±0·6 from the mean values. The large difference in transmission between these two films for Cu and longer wavelengths facilitates the use of the multiple-film technique (Robertson, 1943; Iball, 1954). The Kodak No Screen film is faster than the DuPont Type 508 by a little more than a factor of 2. Additional pertinent data have been published (Seeman, 1950; VanHorn, 1951).

Table 1. *Film transmission*

		Transmission (%)	
Radiation	Wavelength (Å)	Eastman No Screen	DuPont Type 508
Ag $K\alpha$	0·56	82·9	93·2
Mo $K\beta$	0·63	77·0	90·7
Mo $K\alpha$	0·71	70·3	88·5
Cu $K\beta$	1·39	33·8	63·8
Cu $K\alpha$	1·54	23·8	54·9
Ni $K\alpha$	1·66	17·5	48·4
Co $K\alpha$	1·79	11·8	41·3
Fe $K\alpha$	1·94	7·2	32·8
Cr $K\alpha$	2·29	1·7	17·6

References

Acta Cryst. (1956). **9**, 520.
IBALL, J. (1954). *J. Sci. Instrum.* **31**, 71.
PARRISH, W. (1956). *Philips Tech. Rev.* **17**, 269.
PARRISH, W. & KOHLER, T. K. (1956). *Rev. Sci. Instrum.* In the Press.
ROBERTSON, J. M. (1943). *J. Sci. Instrum.* **20**, 175.
SEEMAN, H. E. (1950). *Rev. Sci. Instrum.* **21**, 314.
VANHORN, M. H. (1951). *Rev. Sci. Instrum.* **22**, 809.

Acta Cryst. (1956). **9**, 972

New twinning systems in magnesium.

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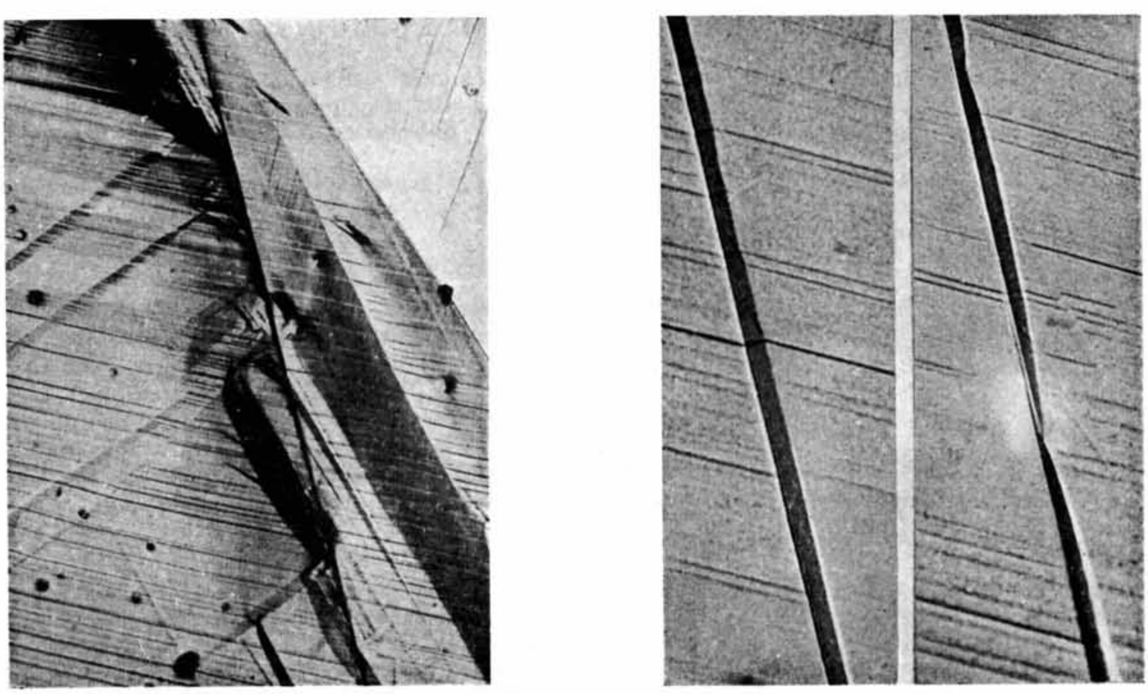
Deformation mechanisms in polycrystalline high-purity magnesium after tensile straining have been studied by Hauser, Starr, Tietz & Dorn (1955) and more recently by Roberts (1955). Of particular interest in this latter work were the observations of 'irrational twin-like markings', deformation structures which had several twin-like characteristics. Using a stereographic one-surface consistency analysis (Cahn, 1953), it was found that these



(*a*) (*b*)

Fig. 1. (*a*) Needle-like {30$\bar{3}$4} twin and other deformation modes after 0·5% strain. 200×. (*b*) Same grain as (*a*) but showing the twin-like nature of the needle. 1500×.

markings had their pole loci at 53°±2° from the basal pole on ⟨11$\bar{2}$0⟩ zones. Since the 53° intersection is almost midway between {10$\bar{1}$2} and {10$\bar{1}$1} it appeared that the twins were either irrational or of higher indices than any seen to date in a hexagonal metal.

Work similar to the above is nearing completion on a large-grained magnesium-base solid-solution alloy containing 2·5% aluminum. The c/a ratio for this alloy is 1·624, the same as that for pure magnesium. A specimen was electropolished and the orientation of twenty-five grains was obtained by the standard back-reflection X-ray technique. After tensile straining, trace-angle measurements of deformation markings were made, the pole loci of the markings were plotted stereographically and analyses were performed by the consistency or pole locus method (Cahn, 1953). Markings whose occurrence was rare generally preferred to nucleate in areas of high local bending. This would be expected since they have never been observed in single-crystal experiments. Unlike the behavior of cubic metals, new deformation mechanisms must come into play when one passes to the polycrystalline aggregate of hexagonal metals. The propensity of these markings to occur on the more restricted 'inside' grains intrinsically prevents the use of two-surface analyses.

After 0·5% total strain, one grain of the specimen showed a particularly good example of an irrational twin-like marking which indexed at 55° to the basal plane on a ⟨11$\bar{2}$0⟩ zone. In Fig. 1 (a), the needle-like structure crossing the grain at a slight angle from the horizontal is the marking in question. Also present in the grain are basal slip, four sets of {10$\bar{1}$2} twins, reoriented basal slip within some of the twins and kink boundaries. At low magnification, the needle-like structure could be mistaken for a fine scratch or crack, but at higher magnification (Fig. 1(b)) its twin-like nature is apparent. It should be noted that the shearing angle of the basal slip lines crossing the twin is quite large, 30° in most areas and as much as 35° in others. (Basal slip lines in a {10$\bar{1}$2} twin are deviated a maximum of 3° 50′ by the twinning motion.) The experimental evidence of consistency shows the twinning plane is of a ⟨11$\bar{2}$0⟩ zone. Using conventional notation, if the composition plane K_1 for this twin is irrational, the shearing direction η_1 is rational and must be ⟨11$\bar{2}$0⟩. However, in such a case, basal slip lines would not be sheared by the twinning action. Since a large deviation was observed, K_1 must be rational. A logical choice for K_1 (within the experimental error) is {30$\bar{3}$4}, which makes an angle af 54° 50′ with the basal plane. If it is assumed that the plane of shear is {1$\bar{2}$10} (the same as that for {10$\bar{1}$2} twinning), the atomic movements in forming a {30$\bar{3}$4} twin are easily derived (Fig. 2). To minimize congestion, the movements in forming only alternate basal planes in the twin are shown; remaining basal planes are formed in a manner identical to that of their respective underlying planes. The movements are very regular; after a uniform shear one third of the atoms are in their final positions and the balance require only minor systematic readjustments to reach them. The model predicts that the angle between the basal planes in matrix and twin will be 70° 50′. When the previously measured 35° maximum shearing angle is converted stereographically to its true angle, a measurement of 70°±3° is obtained. The extreme narrowness of these twins and their tendency to act as crack loci at low macroscopic strain levels are probably associated with the large shear required in their formation.

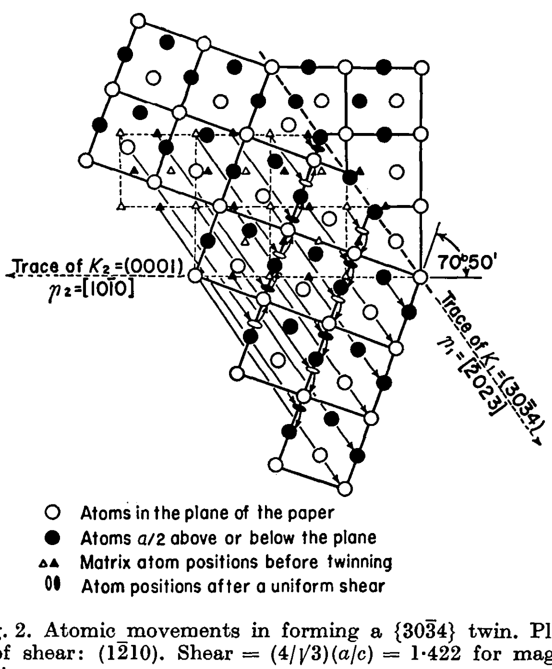


Fig. 2. Atomic movements in forming a {30$\bar{3}$4} twin. Plane of shear: (1$\bar{2}$10). Shear $= (4/\sqrt{3})(a/c) = 1{\cdot}422$ for magnesium.

Evidence for another twinning system has been obtained at higher strain levels in the same specimen. Thin twin lamellae very similar in appearance to that shown in Fig. 1 were found in several grains. Their only consistent stereographic analyses were intersections at 74±2° from the basal pole on ⟨1$\bar{1}$00⟩ zones. This corresponds closely to twinning on a {11$\bar{2}$1} plane, which makes an angle with the basal plane of 72° 53′. Twinning on this plane has also been observed in the hexagonal metals titanium (Rosi, Dube & Alexander, 1953) and zirconium (Rosi, unpublished). The atomic movements in forming a {11$\bar{2}$1} twin have been derived by Hall (1954), who gives K_1 = (11$\bar{2}$1), η_1 = [$\bar{1}\bar{1}$26], K_2 = (0001) and η_2 = [11$\bar{2}$0]. The shear is a/c = 0·616 for magnesium; every atom when sheared uniformly by this amount reaches its final position without further readjustment. It is interesting that the confirmed or most probable atomic-movement models of all three twinning systems {10$\bar{1}$2}, {30$\bar{3}$4} and {11$\bar{2}$1} in magnesium predict a contraction in the 'a' direction and an expansion in the 'c' direction, and the sense of shear is the same in all three cases.

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References

Cahn, R. W. (1953). *Acta Metallurg.* **1**, 49.

Hall, E. O. (1954). *Twinning and Diffusionless Transformations in Metals.* London: Butterworths.

Hauser, F. E., Starr, C. D., Tietz, L. & Dorn, J. E. (1955). *Trans. Amer. Soc. Met.* **47**, 102.

Roberts, C. S. (1955). *WADC Technical Report* 55–241.

Rosi, F. D., Dube, C. A. & Alexander, B. H. (1953). *Trans. Amer. Inst. Min. (Metall.) Engrs.* **197**, 257.