SOME CHARACTERISTICS OF DEFORMATION TWINS IN CRYSTALLINE MERCURY*

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Deformation twins have been produced at liquid air temperature by bending mercury single crystals of square cross-section and by indenting flat large-grained polycrystals. The twins all belong to the anomalous Type II mode, reported earlier, which has an irrational composition plane near $\{\bar{1}35\}$. They interact amongst themselves and with slip to produce several characteristic features. Thus four crystallographically distinct types of twin interaction arise. One of these, which is termed complementary, is particularly abundant due to a series of crystallographic accidents which enable the strains at the twin intersection to be accommodated almost exactly by a single slip system. These complementary interactions can also occur repeatedly to produce networks of twins. Nine possible interactions between slip and twin boundaries can occur in mercury. The possibility of slip penetrating the boundary in these cases is examined and the resulting twinning dislocations which are responsible for twin growth are discussed. It is concluded that at low temperatures only one of these reactions, which produces groups of four unit twinning dislocations can occur, and this has been conclusively observed in two distinct situations. Facets and indentations in twin boundaries are also investigated and found to have a characteristic crystallographic habit. The structure of this interface is studied in detail and shown to have a semi-coherent nature. The observations are compared with similar features associated with deformation twins in other metals.

QUELQUES PROPRIETES DES MACLES DE DEFORMATION DANS LE MERCURE CRISTALLIN

Des mâcles de déformation ont été produites à la température de l'air liquide en courbant des monocristaux de mercure de section carrée et en entaillant des polycristaux plats à gros grains. Les mâcles appartiennent toutes à un mode anormal du Type II, étudié précédemment, et qui a un plan de composition irrationnel proche de $\{\bar{1}35\}$. Elles interagissent entre elles et avec le glissement, présentant ainsi plusieurs propriétés caractéristiques. De cette facon, il apparaît quatre types d'interaction de mâcles, cristallographiquement distincts. L'un d'eux, qui est nommé complémentaire, apparaît particulièrement souvent, car il est du à une série d'accidents cristallographiques qui permettent aux déformations à l'intersection des mâcles de s'adapter presque exactement par un système de glissement simple. Ces interactions complémentaires peuvent aussi se produire de façon répétée pour produire des réseaux de mâcles. Neuf interactions possibles entre le glissement et les joints de mâcles peuvent se présenter dans le mercure. Les auteurs examinent pour ces différents cas la possibilité du glissement traversant le joint, ainsi que les dislocations de mâcle résultantes, qui sont responsables de la croissance des mâcles. Ils concluent que, aux basses températures, une seule de ces réactions peut se produire, celle qui donne des groupes de quatre dislocations de macle, et ceci a été observé de façon concluante dans deux situations distinctes. Les facettes et les entailles dans les joints de mâcles ont été également étudiées et semblent présenter un accolement cristallographique caractéristique. La structure de cette interface est étudiée en détails et paraît être de nature semi-cohérente. Les observations sont comparées aux propriétés analogues associées aux mâcles de déformation relatives à d'autres métaux.

EINIGE CHARAKTERISTISCHE EIGENSCHAFTEN VON VERFORMUNGSZWILLINGEN IN KRISTALLINEM QUECKSILBER

Verformungszwillinge in Quecksilber wurden bei der Temperatur der flüssigen Luft durch Biegen von Einkristallen mit quadratischem Querschnitt und durch Indentation flacher, großkörniger Polykristalle erzeugt. Die Zwillinge gehörten alle zu dem schon früher gefundenen Typ II, der eine irrationale Habitusebene in der Nähe von $\{\bar{1}35\}$ hat. Sie wechselwirken miteinander und mit Gleitversetzungen und erzeugen charakteristische Kennzeichen. So werden vier kristallographisch verschiedene Zwillingswechselwirkungen beobachtet. Eine davon, genannt komplementär, erfolgt besonders häufig, da die Spannungen an den Zwillingsschnittlinien auf Grund eines kristallographischen "Unfalls" fast vollständig durch ein einziges Gleitsystem akkomodiert werden können. Diese komplementären Wechselwirkungen können auch wiederholt auftreten und so Zwillingsnetzwerke bilden. In Quecksilber können neun mögliche Wechselwirkungen zwischen Gleit- und Zwillingsgrenzen stattfinden. Die Möglichkeit, daß in diesen Fällen Gleitversetzungen die Zwillingsflächen durchdringen wird untersucht und die entstehenden, für das Zwillingswachstum verantwortlichen Zwillingsversetzungen werden diskutiert. Es ergibt sich, daß bei tiefen Temperaturen nur die Reaktion stattfinden kann, die Gruppen von vier Zwillingsversetzungen erzeugt und diese Reaktion wurde in zwei Fällen eindeutig beobachtet. Flächen und Indentationen in Zwillingsgrenzen wurden ebenfalls untersucht; sie zeigen ein charakteristisches kristallographisches Verhalten. Die Struktur dieser Grenzflächen wird ausführlich untersucht und es wird gezeigt, daß sie semi-kohärent ist. Die Beobachtungen werden mit ähnlichen Ergebnissen über Verformungszwillinge in anderen Metallen verglichen.

1. INTRODUCTION

In a previous paper[1] we showed conclusively that deformation twins in crystalline mercury belong to the Type II twinning mode[2] with $K_1K_2\ \eta_1\ \eta_2$ elements given by '$\{\bar{1}35\}$' $\{\bar{1}11\}$ $\langle\bar{1}21\rangle$ '$\langle 0\bar{1}1\rangle$', the magnitude g of the twinning shear being 0.633. Here the indices are given relative to the face centred rhombohedral cell of axial angle 98°22′, to which the structure is most conveniently referred. The irrational elements K_1 and η_2, which are indicated by apostrophes are functions of the cosine c of this angle, which is given approximately by $c = -\frac{1}{7}$. Earlier work had shown that the slip plane of crystalline mercury[3] is the closest packed plane $\{11\bar{1}\}$, the predominant slip direction being $\langle 1\bar{1}0\rangle$, although slip in the close packed $\langle 011\rangle$ direction also occurs, especially near the melting point.

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These investigations have now been extended in order to study the structure and mobility of coherent and incoherent twin boundaries and the phenomena associated with interactions between slip and twinning. Two types of experiment, both of which involve complex stresses and are thus likely to result in interactions of this kind were adopted. The first of these used flat polycrystalline specimens which were deformed at liquid air temperature by carefully tapping the surface with a pre-cooled brass rod. Secondly single crystals of 6 mm square cross-section were deformed at liquid air temperature by four-point bending. Many of these crystals twinned, the appearance of the twins, which initially were typically between 1 μ and 10 μ in thickness, being accompanied by audible clicks. Subsequent thickening was silent and apparently continuous, maximum thicknesses being approximately 100 μ. Our detailed observations on these twins and those in the flat specimens are the subject of the present paper.

2. RESULTS

2.1. *Twin interactions*

There are six variants of the '$\{\bar{1}35\}$' mercury twinning mode and thus fifteen pairs of twins which may be involved in an interaction. However, only four distinct crystallographic situations occur and these can be conveniently characterised by means of the line of intersection of the operative twinning planes. These are in all cases irrational but, using the approximation $c = -\frac{1}{7}$, become $\langle 211\rangle$, $\langle 433\rangle$, $\langle 455\rangle$ and $\langle 11, 8, 7\rangle$. The corresponding acute angles between the associated twinning planes are 35°, 89°, 28° and 62° respectively. In practice all four interactions are observed in the deformed flat specimens. However, the $\langle 211\rangle$ interaction, which is illustrated clearly on the flat specimen shown as Fig. 1, tended to predominate and was the only interaction observed in the single crystals which were subjected to bending, including the specimen shown in Fig. 2. Indeed this interaction is a characteristic feature of deformed mercury[4] and can operate repeatedly to produce beautiful networks of twins.

The predominance of the $\langle 211\rangle$ twin interaction is due primarily to this direction lying in the $\{\bar{1}11\}$ slip plane, which is the conjugate twinning plane of both participating twins. In addition the $\langle 01\bar{1}\rangle$ slip direction in the $\{\bar{1}11\}$ plane and the two relevant twinning directions are all approximately orthogonal to the $\langle 211\rangle$ direction. Indeed, on letting $c = -\frac{1}{7}$, these approximations are eliminated and the geometry of the intersection for the case of two twins of equal thickness is as shown in Fig. 3(a). Alternatively, on letting c take its exact value, the discrepancies are as given on the small section of the standard 111 mercury stereographic projection, in the region of the $\langle 211\rangle$ pole, shown in Fig. 3(b). The result of this series of crystallographic accidents is that the plastic strains associated with the twin intersection can be accommodated almost exactly by slip on the conjugate twinning plane. In the present paper pairs of twins with this crystallographic relationship are termed complementary.

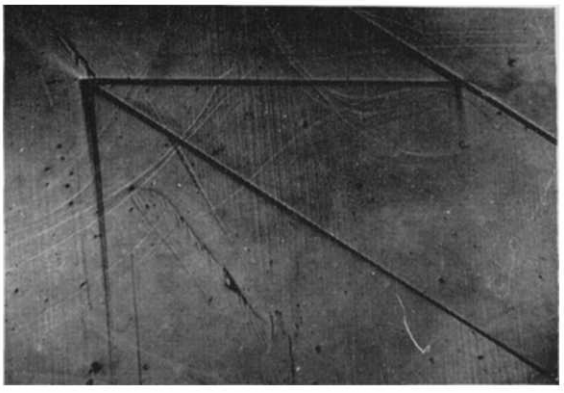

FIG. 1. Micrograph of an indented flat mercury specimen showing straight slip lines and complementary twin interactions. Note particularly the accommodation slip at the twin interactions. (×70).

The accommodation of the strains involved in complementary twin intersections is illustrated schematically by Fig. 3(c), (d) and (e). In the first of these diagrams the two regions of parent material which are to be sheared into different twin orientations are

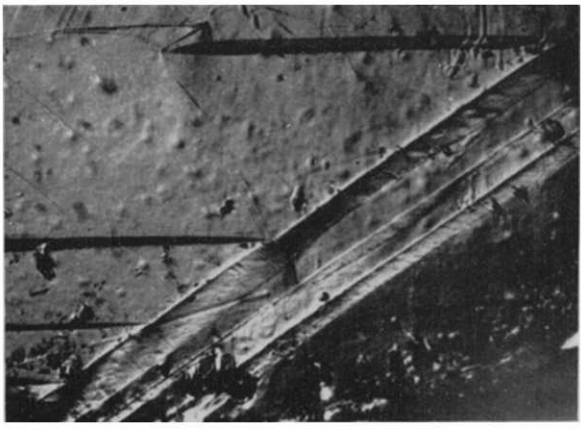

FIG. 2. Micrograph of the upper face of a bent single crystal of mercury showing straight slip and two sets of parallel twins. Of particular interest is the slip induced inside the large twins, near the regions where it has impeded the growth of the series of twins on the second system, and the subsequent propagation of this slip across the twin boundary. Note also the ridges in some of the twin boundaries. (×45).

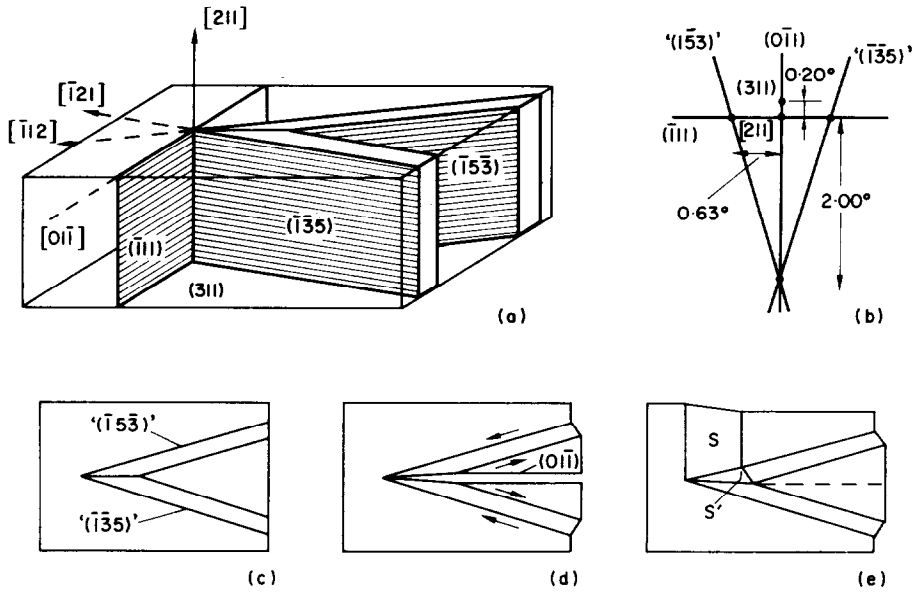

FIG. 3. The geometry of complementary twin interactions. Diagram (a) shows the geometry for the approximate case in which c, the cosine of the rhombohedral angle, equals $-\frac{1}{2}$. The two twin planes then have the rational forms ($\bar{1}35$) and ($\bar{1}5\bar{3}$) and they both intersect the ($\bar{1}11$) slip plane in the [211] direction. In addition all three shear directions [$\bar{1}21$] [$\bar{1}12$] and [01$\bar{1}$] lie in the (311) plane, which is perpendicular to [211]. The deviations from this situation, which arise on letting c equal its observed value of -0.1454, are shown on a region of the standard mercury stereogram near [211] in diagram (b). The way in which the shape deformation associated with complementary twin interactions is accommodated is shown schematically in diagrams (c), (d) and (e). Note particularly the sense of the twinning shears in (d) and the accommodating slip S and S' in the parent and in one of the twins respectively in (e).

outlined. Then, in the second diagram the shears have occurred and are accommodated schematically by a crack along the $\{01\bar{1}\}$ mirror plane, which bisects the pair of twins. Finally this crack is closed by a band of slip S in the parent material. This slip shear can occur on either side, or indeed both sides of the twin intersection and is very clearly shown in the micrograph reproduced as Fig. 1. However, as indicated in Fig. 3, due to the twinning shears being unidirectional only acute-angled intersections occur between twins of equal thickness. Similarly, intersections between complementary twins of unequal thickness result in appropriate changes in thickness of one of the twins as shown in Fig. 1.

Two features of complementary twin intersections are of particular interest. Firstly, the slip shear propagates across one of the twin boundaries to form a triangular region of slip inside the twin, as shown schematically in Fig. 3(e). Several good illustrations of this type of morphology are present in the micrograph of the flat crystal in Fig. 4. It is an important example of possible interactions of slip and twins which are discussed fully in Section 2.2. Secondly the well-defined incoherent interface between the two participating twins, again clearly shown in Figs. 1 and 4 is very striking. It is derived from the parent $\{01\bar{1}\}$ mirror plane and has indices of the form $\{\bar{1}\bar{1}3\}$. These two planes play an important role in the formation of incoherent boundaries on twins in mercury which are fully discussed in Section 2.3.

2.2. *Interactions between slip and twins*

The three different variants of the $\{11\bar{1}\}$ mercury slip plane are related to a given '$\{\bar{1}35\}$' twin in three distinct ways. In addition each of these planes contains three possible slip directions, one variant of $\langle 1\bar{1}0\rangle$ and two variants of $\langle 011\rangle$. Thus, in general nine different interactions between slip dislocations and twin boundaries are expected to occur. Some details of the characteristics of these interactions are summarised in Table 1 for the case of the '($\bar{1}35$)' twin variant. In particular, we quote): 1) the indices of the planes and directions in the twin which are derived from the parent slip planes and directions as a result of the twinning shear, (2) the lines of intersection of the slip planes and the twin boundary, and (3) the magnitudes, in units of the $\{\bar{1}35\}$ interplanar spacing, of the steps in the boundary produced by the interactions. These steps will be termed extrinsic twinning dislocations to distinguish them from the steps known as intrinsic twinning dislocations[1]

FIG. 4. Complementary twin interactions on an indented flat crystal of mercury. The two sets of twins are approximately vertical and approximately horizontal, the latter having very small surface tilts and hence being in weak contrast. The other twins and the accommodating slip produce marked contrast effects. Note particularly the light triangular regions at the twin interactions, where the accommodating slip penetrates the near vertical twins, as shown schematically by the region S' in Fig. 3(e). Also of interest are the well-defined indentations in the twin boundaries, which are analysed in Section 2.3 of the text. (×60).

TABLE 1. The nine interactions between slip and the '$(\bar{1}\bar{3}5)$' twin

	h_P	$2u_P$	d_P	h_T	$2u_T$	d_T	'n'
1		$[01\bar{1}]$			$[0\bar{1}1]$		4
2	$(\bar{1}11)$	$[110]$	'$[211]$'	$(\bar{1}11)$	$[\bar{1}\bar{1}0]$	'$[\bar{2}\bar{1}\bar{1}]$'	2
3		$[10\bar{1}]$			$[\bar{1}0\bar{1}]$		2
4		$[1\bar{1}0]$			$[0\bar{1}\bar{1}]$		1
5	$(11\bar{1})$	$[011]$	$[\bar{1}21]$	$(\bar{1}\bar{1}1)$	$[\bar{1}10]$	$[\bar{1}21]$	1
6		$[10\bar{1}]$			$[\bar{1}0\bar{1}]$		2
7		$[10\bar{1}]$			$[0\bar{1}0]$		3
8	$(1\bar{1}1)$	$[011]$	'$[132]$'	$(00\bar{1})$	$[\bar{1}10]$	'$[\bar{3}10]$'	1
9		$[110]$			$[\bar{1}\bar{1}0]$		2

The indices of the slip planes h and the Burgers vectors of the slip dislocations u are given relative to parent and twin bases P and T respectively. In addition the lines of intersection d of the slip planes and the '$(\bar{1}\bar{3}5)$' boundary and the approximate magnitude 'n' of the zonal twinning dislocations resulting from the interactions are quoted.

which must be present in an otherwise perfect rational $\{\bar{1}\bar{3}5\}$ plane to produce the irrational twin boundary. Examples of single, double, triple and quadruple steps arise but in practice the multiple steps will certainly dissociate into groups of unit twinning dislocations. Table 1 shows that the $(1\bar{1}1)$ slip plane is transformed into a $\{001\}$ plane in the twin so that the associated dislocations will have great difficulty in penetrating the boundary. However, the other two slip planes retain their $\{11\bar{1}\}$ character. In addition the Burgers vectors of the dislocations in these planes remain either $\frac{1}{2}\langle 1\bar{1}0\rangle$ or $\frac{1}{2}\langle 011\rangle$. Thus the corresponding six interactions are likely to occur in practice. However, the present series of experiments was carried out at liquid air temperature where $\langle 011\rangle$ slip is uncommon. Therefore, only interaction 1 of Table 1 which involves $\langle 1\bar{1}0\rangle$ slip in both parent and twinned structures might occur under these conditions.

Two distinct situations demonstrating the occurrence of interaction 1, involving $\langle 1\bar{1}0\rangle$ slip on the conjugate twinning plane, have been isolated. The first of these involves complementary twin interactions. It is illustrated in the micrograph of Fig. 4 and schematically in Fig. 3(e). The slip shear which accommodates the strains at these twin intersections is observed to pass through the twin boundary to form a triangular region of apparently homogeneous shear inside one of the twins. This is labelled S' in Fig. 3(e). The groups of four unit twinning dislocations which will be produced by this mechanism will of course distribute themselves in the twin boundary to further relieve the small local stresses particularly from slip on only one side of the interaction as shown for example in Figs. 1 and 4. The second situation in which interaction 1 has been observed to occur is when the growth of a twin is halted by an existing twin. The stress concentration associated with the twin interaction can then cause slip to occur inside the first twin. If this slip is on the conjugate twinning plane it is observed to penetrate the opposite twin boundary, using interaction 1, and propagate into the parent material. In this case the associated twinning dislocations cause a change in the width of the twin. An example of this type of interaction is shown in Fig. 2 where a series of parallel twins meets a larger pre-existing twin and produces the appropriate slip dislocations. Unfortunately, no conclusive experimental evidence for the other interactions listed in Table 1 has been obtained. Indeed many observations were made of slip lines which apparently ended at or near twin boundaries, suggesting that these interactions do not occur in practice. These slip lines were in many cases associated with characteristic ridges

in the interfaces as shown in Fig. 2. Twin growth did not appear to occur from such boundaries.

2.3. *Incoherent twin boundaries*

Many of the twin boundaries observed in these experiments contained well-defined incoherent facets. One example of this type of feature, is the common interfacial plane of the two twins comprising a complementary twin interaction. It is illustrated in Figs. 1 and 4. A second case arises when twins terminate abruptly in the interior of a crystal as shown by the example in the micrograph of Fig. 5. Note that in this case the end of the twin consists characterstically of two well-defined incoherent facets. Finally we shall discuss the indentations and facets on twin boundaries which are otherwise planar. Examples of these are clearly seen in Figs. 4 and 5.

Complementary twin intersections in which the common plane of the two twins has indices $\{\bar{1}\bar{1}3\}$ relative to both twin bases and derives from a $\{01\bar{1}\}$ plane in the parent, gives a clear guide to the form of these features. These two planes are less than 3° apart and have very similar atomic structures. Thus, an interface between parent and twinned material in which either a parent $\{01\bar{1}\}$ plane is almost parallel to $\{\bar{1}\bar{1}3\}$ of the twin or vice versa can be accommodated comparatively easily and have a low energy. Indeed all of the incoherent boundaries examined in detail are consistent with this hypothesis.

For example the morphology of the twin tip shown in Fig. 5, can be readily explained using this model.

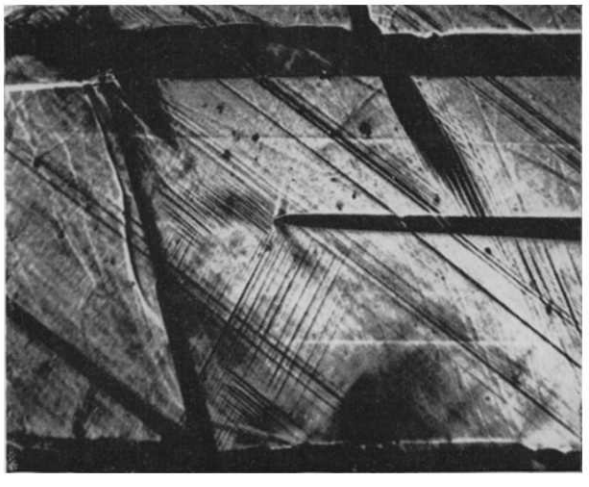

FIG. 5. Deformation traces on a flat specimen of crystalline mercury. Three sets of slip traces and two sets of twins are present. Note in particular the facets on the twin tip at the centre of the micrograph and defining the indentations in the upper boundaries of the horizontal twins. (×135).

Thus, the upper and lower incoherent facets in the micrograph have indices $(01\bar{1})$ and $(\bar{1}\bar{1}3)$ respectively when referred to the twin basis and $(\bar{1}\bar{1}3)$ and $(01\bar{1})$ respectively when referred to the parent. These planes all contain the [211] direction, which is the common line of intersection of the "$(\bar{1}\bar{3}5)$" and '$(\bar{1}5\bar{3})$' complementary twin pair and the $(\bar{1}11)$ slip plane. The angle between the facets at the twin tip, when measured relative to either parent or twinned material, is approximately 32° but because the corresponding planes are misaligned by nearly 3° some accommodation effects are expected. However, these will be much smaller than the effects associated with the termination of the twinning shear itself and should not be significant. Examination of the slip traces at the tip of the twin in Fig. 5 does indeed illustrate these effects clearly. Well-defined facets associated with nine indentations in twin boundaries, some of which are shown in Figs. 4 and 5, were also examined in detail and in all cases were consistent with the crystallographic forms described above.

The structure of these facets is fascinating and shows that they are more correctly termed semi-coherent rather than incoherent. This is illustrated by Fig. 6, which shows the $\{01\bar{1}\}$ and $\{\bar{1}\bar{1}3\}$ lattice planes superimposed, with the common $\langle 211\rangle$ directions parallel. Note that the $\{\bar{1}\bar{1}3\}$ plane may be obtained from the $\{01\bar{1}\}$ arrangement by means of an expansion perpendicular to $\langle 211\rangle$ and that this expansion is given, to within 0.15 per cent, by the rational fraction 2/11, so that thirteen unit cells in the $\{01\bar{1}\}$ plane have approximately the same area as eleven unit cells in the $\{\bar{1}\bar{1}3\}$ plane. The result of this special relationship is that the incoherent twin boundary which the $\{01\bar{1}\}$ and $\{\bar{1}\bar{1}3\}$ planes define has a particularly simple structure. It may be considered to consist of a single set of interfacial dislocations parallel to the common $\langle 211\rangle$ direction and with a spacing of $6\frac{1}{2}$ $\{01\bar{1}\}$ cells or equivalently $5\frac{1}{2}$ $\{\bar{1}\bar{1}3\}$ cells as shown in Fig. 6. It is interesting to note that these interfacial dislocations are closely related to the conventional $\frac{1}{2}\langle 01\bar{1}\rangle$ edge slip dislocation lying in the $\{\bar{1}11\}$ conjugate twinning plane. Additional dislocations of this kind may also be present in the interface in the form of steps on either the $\{01\bar{1}\}$ or $\{\bar{1}\bar{1}3\}$ plane or both and thus eliminating the predicted angle of approximately 3° between the planes. The exact structure of the interface will thus depend on its specific orientation but essentially the arrangement of atoms on either side of the boundary will be as shown in Fig. 6. These interfaces thus have a particularly simple structure and a correspondingly small energy. Probably more significant however is the fact that the interfacial dislocations are

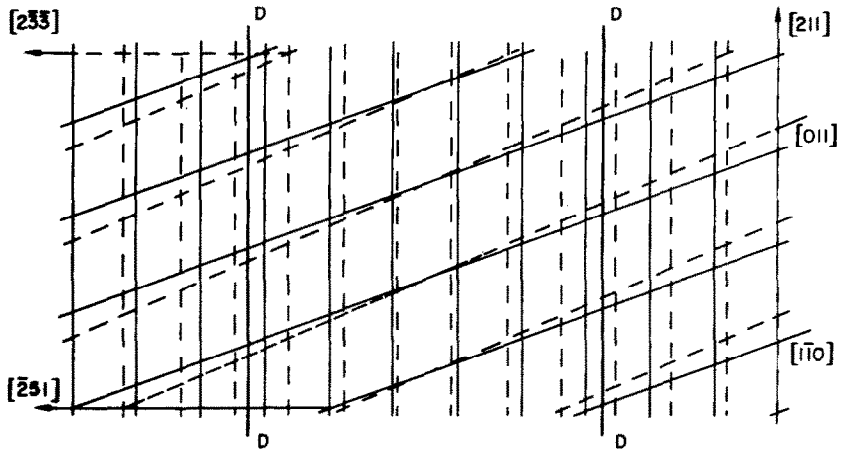

FIG. 6. Superimposed plots of the (01$\bar{1}$) and ($\bar{1}\bar{1}$3) lattice planes of crystalline mercury, represented by broken and continuous lines respectively. The common [211] directions of the two planes are drawn parallel and coincide to within 0.15 per cent at either side of the diagram. The [2$\bar{3}\bar{3}$] and [$\bar{2}$51] directions are both normal to [211] and lie in the (01$\bar{1}$) and ($\bar{1}\bar{1}$3) planes respectively. These planes also contain the [011] and [1$\bar{1}$0] directions respectively. The locations of the two interfacial dislocations representing this part of the boundary are shown by the bold lines labelled *D*.

effectively of the same type as those necessary to accommodate the strains associated with the facets. Therefore, again because of a series of crystallographic accidents the characteristic facets in the boundaries on {01$\bar{1}$} and {$\bar{1}\bar{1}$3} planes are particularly favourable.

3. DISCUSSION

The original aim of the work described in the present paper was to investigate the structure and mobility of twin boundaries in crystalline mercury. It was hoped that this would clarify the apparently anomalous occurrence of the '{$\bar{1}$35}' Type II twin mode in preference to an alternative compound mode,[1] which involves a smaller shear strain. In practice we have confirmed that the crystallography of all the observed twins is consistent with the '{$\bar{1}$35}' mode. It is likely that this result is partly due to the simple structure of the '{$\bar{1}\bar{3}$5}' twin boundary, with its associated intrinsic and extrinsic twinning dislocations and the series of crystallographic degeneracies which have been described in the present paper. These characteristics are particularly surprising for a twinning mode in a crystal of comparatively low symmetry which involves irrational elements. However, the complete exclusion of the alternative modes remains a mystery and demands further investigation.

The structures of the twin boundaries considered here are intermediate in complexity between simple boundaries, such as coherent {111} twin interfaces in f.c.c. metals, and general grain or interphase boundaries. It is usual to interpret boundaries of this kind in terms of coincident lattice points[5] but the significance of this approach for structures of low symmetry where no lattice points coincide exactly is not clear. We have therefore preferred to concentrate on the two-dimensional matching at the interface rather than an obscure three-dimensional superposition of two crystals of different orientation. A more attractive method of studying the structure of these boundaries would be to determine, using an appropriate interatomic force-law for mercury, the equilibrium positions of the atoms near the boundary. This procedure has already been successfully used to investigate simple faults and dislocations in f.c.c. metals[6] and a suitable force-law for mercury has been developed by Weaire,[7] using the pseudopotential theory of metals. However, before applying the method to mercury it seems wiser to first investigate some less symmetric boundaries in cubic metals.

Further experimental work on the deformation of crystalline mercury is continuing[4,8,9] and in particular a detailed study of slip at temperatures near the melting point has been initiated. This will include deformation of specimens previously strained at liquid air temperature to produce twins, which will facilitate an investigation of interactions between ⟨011⟩ slip and twins complementing the results on ⟨1$\bar{1}$0⟩ slip presented here. It is also hoped that we shall be able to make some direct observations of dislocations in mercury using both X-ray topography and electron microscopy but the technical difficulties involved in these projects are considerable.

An interesting aspect of the experimental result for mercury presented in this paper is that they are similar to results on twins in other materials despite the fact that the crystallography is basically more

complex. Thus the complementary twin interactions in mercury appear superficially to be similar to interactions, observed in α-uranium[10] and b.c.c. metals[11,12] but in these cases little or no accommodating slip need accompany the twins. In hexagonal close packed metals[13] twin intersections occur, but involve considerable distortion of the surrounding material, several accommodating mechanisms being operative. By comparison the mercury interaction is particularly elegant a single slip process providing almost exact accommodation. Again the twinning dislocations in mercury, produced by interactions between slip and irrational twin boundaries have essentially the same structure as those in rational composition planes in other metals although, strictly, the Burgers vectors of twinning dislocations in irrational interfaces, of infinitesimal interplanar spacing should themselves be infinitesimal. Theoretical treatments of interactions between slip and Type I twins[14] are well-established and the cases of Type II twins and the non-classical twins introduced by Bevis and Crocker[15] have also been discussed.[14,16] However, it is only recently that direct experimental information on these interactions has been obtained[17,18] and it would be particularly pleasing to be able to carry out similar work on mercury. Indentations and facets on twin boundaries are also a common feature of twins in b.c.c.[12] and other metals[19] but in these cases the boundaries are either non-crystallographic or controlled by operative slip planes. Again the almost perfect matching of quite distinct crystallographic planes at the corresponding boundaries in mercury provides a much more elegant description of these features. The most direct comparison that can be made between the mercury twins and deformation twins in other materials is however with the Type II twins in α-uranium.[10,20] It is indeed most encouraging that the model of the mercury '{$\bar{1}35$}' twin boundary proposed in our earlier paper[1] has been successfully adopted by Daniel and Lesage[21] in considering both the '{197}' and '{172}' twin boundaries in α-uranium.

The main contribution of the work described here has thus been to document and interpret in detail some of the features of the '{$\bar{1}35$}' mercury twins, rather than to explain the occurrence of this mode. It has been shown that these features are controlled by a sequence of crystallographic accidents. These result for example in many irrational planes and directions being approximately parallel to each other and thus enabling accommodation effects to occur which would otherwise be impossible. These particular degeneracies do of course only apply to the specific structure of crystalline mercury and are not directly applicable to other materials. They therefore demonstrate the dangers of formulating and adopting general crystallographic theories which cannot be used to consider special cases of this kind.

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