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COMMENT

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Crystal Defects in Evaporated Single Crystal Tin Films*

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Electron microscope studies of imperfections in crystals have been limited primarily to thinned bulk samples. Few studies using evaporated films have been made, owing to the experimental difficulties encountered in making satisfactory specimens. Recently it was shown that single crystals of white tin with a remarkably high degree of crystalline perfection could be made by evaporation under ultra high vacuum conditions[1),2)]. These films ranged in thickness from 1000 Å to 3800 Å and were, therefore, ideally suited for electron microscope studies of crystal defects. The electron micrographs of lattice defects obtained from these films were of a quality comparable to that of bulk specimens.

These tin films are presently being used for electron microscope studies of dislocations, small angle grain boundaries, and deformation twins. It has been found that above room temperature the motion of single dislocations under the influence of electron beam bombardment is rapid and wandering. The major slip systems operating are (121) [$\bar{1}$01] and (101) [$\bar{1}$01]. Dislocations of the latter slip system move at considerably faster speeds than those of the former. The wandering characteristics of both dislocations suggests that they have screw character. Cross-slip from (121) [$\bar{1}$01] to (101) [$\bar{1}$01] and *vice versa* has also been observed.

A typical example of slip and cross-slip taking place in these films is shown in the accompanying

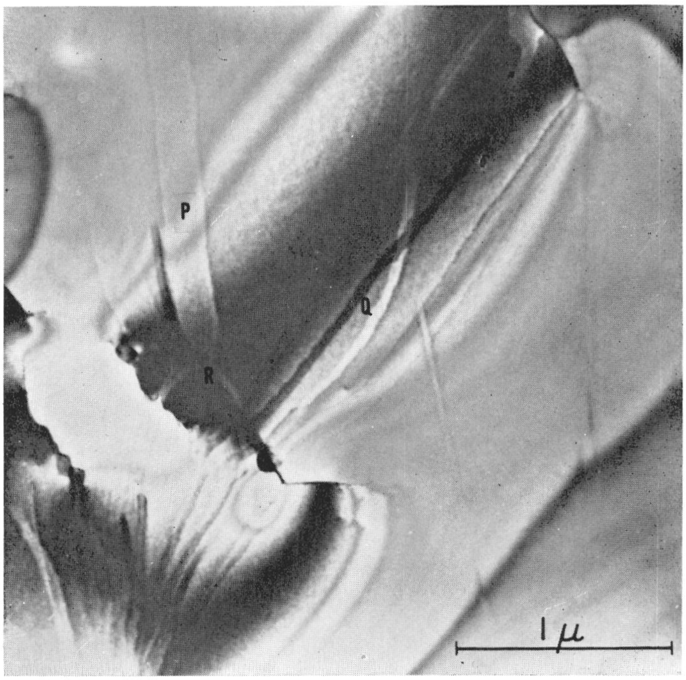

Fig. 1

* Presented by H. G. F. Wilsdorf.

figure. The strain in the film results from the electron beam bombardment and the simultaneous formation of a contamination layer on the film. The wide traces, such as the one at P are due to {101} slip. {121} slip occurs at Q. An example of {101}-{121} cross-slip occurs at R.

Dislocations may also move in a cooperative manner. Small angle grain boundaries, again under the influence of electron beam bombardment, have been observed to move through the lattice and decompose into single dislocations. Deformation twins may be formed by impact outside the microscope or as a result of electron beam bombardment in the microscope. Under the influenue of the electron beam these twins may grow in length and width or decay in a similar manner. The rate of lengthening is considerably faster than widening. Similar observations on twins have been made by Fourie *et al.* with thinned bulk samples[3]. One of the more interesting problems that has arisen is the origin of the dislocations in the twin boundaries. The twinning plane is the (301) plane. It is not a normal slip plane. It has been shown that at least some of the dislocations in the twinning plane were {121} dislocations which moved on their own slip plane until they intersected a (301) twinning plane. This plane then acted as a barrier for further motion, thereby effectively trapping the dislocations in the (301) plane[4].

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The Origin of Substructures Formed during the Growth of Crystals from the Melt

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The origin of optically visible imperfections in metallic crystals grown from the melt is discussed; these imperfections are classified as the dendritic, cellular and lineage structures. Dendritic structures and cellular structures are attributed to the instability of linear heat flow and solute diffusion, respectively, in the liquid; the origin of lineage structures, still somewhat obscure, is discussed in terms of vacancy mechanisms and other possible ways in which dislocations may be generated.

Introduction

Metallic crystals that have been grown by the solidification of molten "pure" materials, usually contain imperfections that are readily observed optically. The imperfections to be discussed occur in crystals which, because all parts derive from the same nucleus, are properly described as single crystals. The existence of a sub-structure indicates that different parts of the crystal differ from each other, either in orientation or in composition. The purpose of this paper is to discuss why these heterogeneities occur under conditions in which the imposed physical variables (temperature gradient, rate of change of temperature) are uniform.

There are three distinct types of optically visible substructure, namely, dendritic, cellular and lineage structures. Dendritic solidification in a pure melt is caused by the instability of a smooth solid-liquid interface in contact with an undercooled melt, if the growth rate is controlled mainly by heat flow but also varies with crystallographic direction. Dendritic freezing occurs only in those substances, and under those conditions, in which dislocations are not required to form a perpetual growth step; this mode of solidi-