LETTERS TO THE EDITORS

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Metal Whiskers

'Whiskers' are small crystals which grow from the surface of several metals. It is believed that their structure is to an unusual degree free from imperfections[1]. Whisker growth from the free edges of tin plate is affected by stress in the tin, both growth-rate and whisker population being increased[2]. Hasiguti[3] has suggested that whisker growth is a means of reducing stress when general extrusion is inhibited. In the present work evidence has been obtained that extrusion must be obstructed if whiskers are to form. Thus on compressing a 3-mm. slab of an alloy containing small particles of tin dispersed in aluminium, profuse growth of whiskers occurred over the whole exposed tin surface (Fig. 1).

Growth of a whisker ceases abruptly at a length independent of pressure[2]. It has now been observed that after a crop of whiskers has been wiped from the tin plate a further set will grow. After twelve cycles of growth and removal a few sources remained active, and some sources produced a total whisker length of about 1 cm. although individual whiskers were rarely as long as 1 mm. There was sometimes an 'incubation period' of a few days before growth recommenced on a source.

When the sources in a surface had been exhausted, grinding away 20μ from this surface made fresh growth possible.

Near the melting point of tin, growth is more rapid and whiskers are longer (up to 5 mm.).

Electron micrographs of carbon replicas of tin whiskers showed star-shaped cross-sections to occur in those of smaller diameters (Fig. 2). Thicker whiskers appear as bundles of thinner ones: using the optical microscope, striations along the length of some of these were seen and occasionally they branched toward their tip.

It appears difficult to account for such properties as the abrupt termination of growth, a constant growth-rate and the reactivation of sources by a dislocation mechanism involving climb only. It is now proposed that whiskers are generated mainly

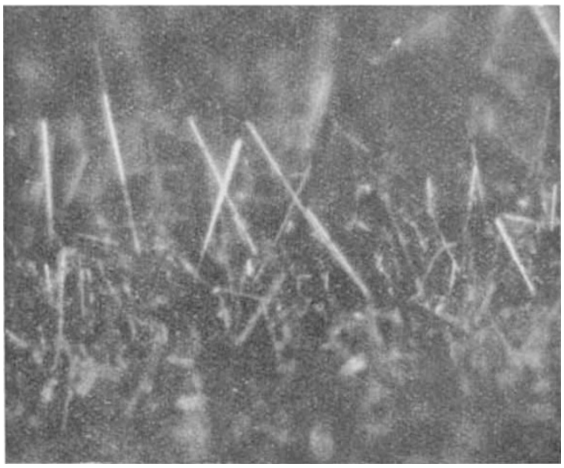

Fig. 1. Tin whiskers growing from tin finely dispersed in aluminium (approximately equal weights of each metal). Oblique view. (× 60)

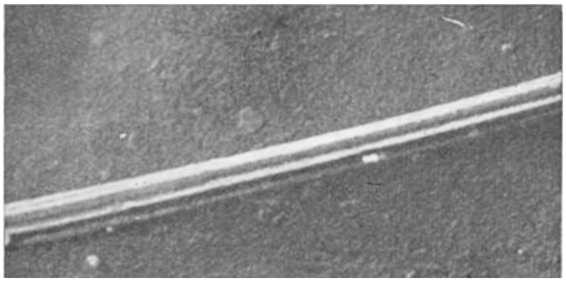

Fig. 2. Electron micrograph of tin whisker. (× 20,000)

by a glide mechanism; but that the frequency with which the whisker generating dislocations operates depends on diffusion: this will still give the linear relationship between growth-rate and pressure[3]. This model will be discussed in detail elsewhere.

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[1] Herring, C., and Galt, J. K., *Phys. Rev.*, **85**, 1060 (1952).
[2] Fisher, R. M., Darken, C. S., and Carroll, K. G., *Acta Met.*, **2**, 370 (1954).
[3] Hasiguti, R. R., *Acta Met.*, **3**, 200 (1955).

Microwave Detection of Metallic Ions and Organic Radicals in Plant Materials

In numerous plant substances we have detected strong electron-magnetic resonances from manganese ions (see Fig. 1, for example). The manganese resonance can be immediately recognized by its six-line hyperfine structure resulting from the manganese nuclear interaction (spin 5/2). In all plant materials in which it was found, the multiple spacing was exactly that for manganese ions in aqueous solution (component separations of 95 gauss). Since the manganese multiplet spacing in crystals has been found to depend upon crystalline fields, we conclude that the manganese ions which we have found in plants may be dissolved in their water content.

Note the single sharp line with $g = 2 \cdot 00$ superimposed on the manganese hyperfine structure for pine cone and pine needle in Fig. 1. In pine needles picked up from the ground, this single resonance appeared much stronger relative to the manganese resonance. Possibly its greater strength relative to the manganese structure came about because the fallen needles had lost some of their water content. We have observed similar resonances in fallen oak leaves, naturally dried ivy stems, and other apparently dead plant materials.

The sharp single resonance observed in these experiments, which is apparently like that observed by Commoner, Townsend and Pake[1] in many lyophilized substances, may in some instances arise from bound or semi-bound oxygen. We have identified a similar resonance[2] of bound oxygen in irradiated 'Teflon'; but for plants which generate oxygen, a controlled experiment to test this hypothesis is more difficult.

A third type of resonance we have observed in several plant materials is illustrated by Fig. 2. This