tumors is being studied at the present time and will be reported at a later date.

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History of Crystal Growth Revealed by Fractography [1]

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During the war there was developed at Battelle Memorial Institute (*8*) and later at the Rustless Iron and Steel Corporation (*6, 7*) a microscope technique for viewing directly the individual granular facets of fractured materials, particularly metals. Under sponsorship of the Office of Naval Research, this technique has been extended to elemental metals (*4*), alloys (*5, 7*), and certain intracrystalline phenomena such as Neumann bands (*2*), as well as dissociation phenomena within inclusions (*3*). The technique is now referred to as "fractography"—the study of fracture facets at high magnification.

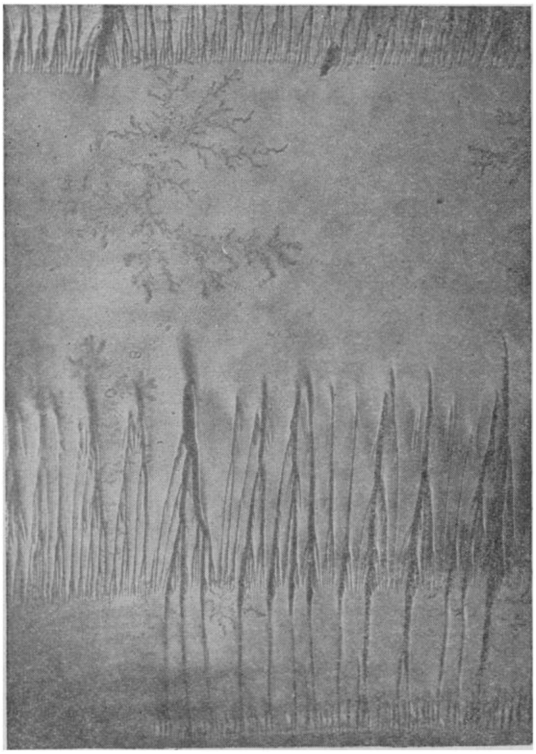

FIG. 1. Ammonium dihydrogen phosphate (140×).

FIG. 2. Molybdenum metal (175×).

Among the numerous informational patterns already observed on fracture facets, those markedly revealing crystal history have not yet been emphasized. Unlike the fracture facets of glass, the patterns of metallic fracture seem always to relate to intrinsic crystal structure, not to superimposed stress pattern—that is, the "hackle structure" typical of glass fractures is generally absent in metal fractures. Fractographs of metals therefore reveal much of the history of original crystal growth.

In Figs. 1–4 are exhibited fractographs, each containing most marked registration of growth characteristics.

A nonmetallic crystal, ammonium dihydrogen phosphate, discloses on its fractured face both extrinsic and intrinsic patterns (Fig. 1). The javelin-shaped markings relate to the pattern of stress at the time of fracture, whereas the dendrite patches obviously refer directly to original imperfection in crystal growth.

A fractograph of molybdenum metal (Fig. 2) reveals an involved pattern which expresses virtually in its entirety the imperfection in structure of the crystal. This metal was melted by an electric arc and cast in vacuum by a process invented at the Climax Molybdenum Corporation's Research Laboratory (*1*). The tortuous path of fracture reveals the great conditions of strain and

[1] From research conducted in the laboratory of the senior author under contract with the Office of Naval Research.

resulting imperfection accompanying solidification. In this fractograph one essentially witnesses the process of accretion during solidification; and the contortions of the pattern therefore have significance in studies of crystal growth. Conditions of fracture may comminute this pattern, but rarely change it.

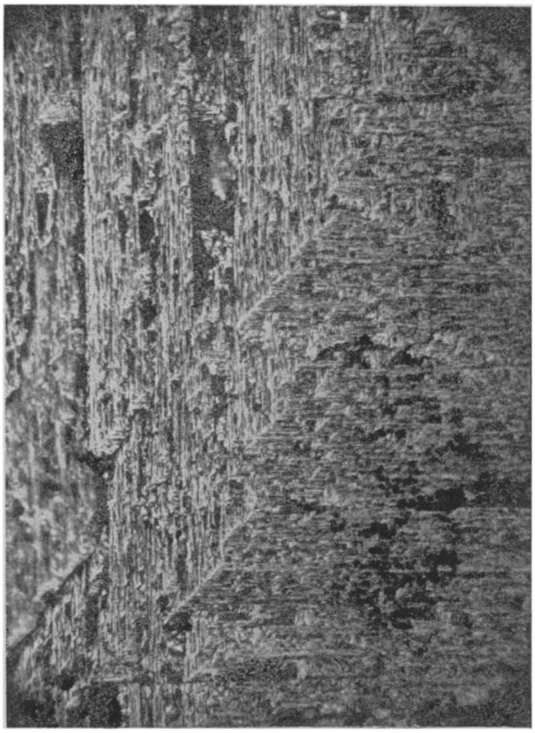

FIG. 3. Chromium ferrite (750 ×).

In Fig. 3, a fractograph of chromium ferrite (28% Cr; 0.10% C; remainder, Fe) discloses a vastly complex substructure. Note the magnification of 750 diameters. The entire field lies well within a single grain, as proved by the fact that the crystallographic directions project unaltered throughout the pattern. Note the 90° and 45° symmetry. Since the structure is body-centered cubic, the cleavage facet under observation is (001). Certainly the substructure revealed here is of great significance in studying crystal growth; and one is not surprised to find this pattern of rectangular and extensive cleavage weakness in a material commercially notorious for its low notch-impact resistance (Type 446 stainless steel).

Fig. 4 shows at a magnification of 2,000 ×, the characteristic pattern by which the zeta phase in iron-silicon alloys can always be instantly identified (7). A characteristically terraced pattern, as shown, it is uninfluenced by extrinsic factors during fracture. The pattern is therefore an intrinsic one, revealing true weakness within the structure of the individual crystal. Obviously, cleavage could not follow such an elaborate pattern through a homogeneous matrix in the absence of pre-existent weakness, and regardless of the nature of the stress causing fracture.

While these patterns of imperfect crystal growth are curious in themselves, perhaps their most curious aspect is their constancy by which metals can be readily distinguished from one another and even from slightly modified alloy compositions. One can say with some earnestness that the crystals seem "perfectly imperfect"; for each consistently identifies itself with a pattern which is highly characteristic and seemingly unalterable in its principal features.

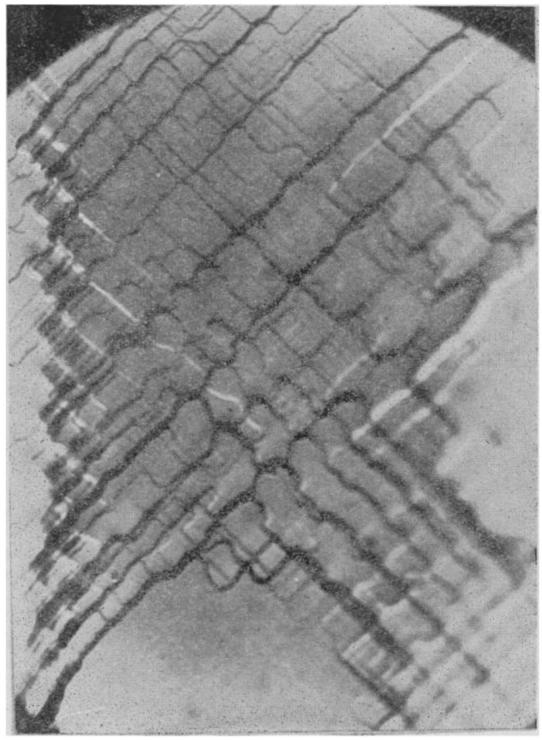

FIG. 4. Zeta silicon ferrite (2,000 ×).

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