propagation is the critical stage in ductile cleavage. Because microcracks are not observed in the brittle specimens away from the fracture surfaces it appears quite possible that the first crack to be nucleated will propagate.

If, at T_T, stresses for crack nucleation, σ_N, and propagation, σ_P, are equal and equal to the yield stress, then:

$$\sigma_C=\sigma_N=\sigma_O+k_N(Y\gamma)^{\frac{1}{2}}l_C^{-\frac{1}{2}}=\sigma_P=k_P(Y\gamma_B)^{\frac{1}{2}}l_C^{-\frac{1}{2}} \tag{5}$$

where σ_O, k_N, k_P are constants, Y is Young's modulus (4.04×10^{12} dyne cm^{-2}), γ and γ_B are the surface energies for crack nucleation (true surface energy) and crack propagation across a grain boundary respectively, and l_C the crack length, which is probably related to the grain diameter. Let us assume that l_C equals the grain diameter, l, and that k_P is $(2/\pi)^{\frac{1}{2}}$, which is given by the simplest (Griffith–Orowan–Irwin) model of surface crack propagation. γ_B then evaluates to $\sim6\times10^4$ erg cm^{-2}, which compares reasonably with surface energy values estimated by HULL *et al.*[9], *e.g.* $\sim3\times10^4$ erg cm^{-2} at 350°K for propagation of cracks in tungsten single crystals, in which blunting of the cracks is thought to occur above ~150°K.

Below 150°K their values of γ were near the theoretical estimates, *e.g.* on GILMAN's model[10]: 4.7×10^3 and 3.3×10^3 erg cm^{-2} for $\{100\}$ and $\{110\}$ cleavage, respectively[11]. Assuming the smaller value to be correct and taking[12] k_N to be ~2.4 it is also possible from eqn. (5) to estimate the lattice friction stress, σ_O. It is seen to be ~22 kg mm^{-2}, which is in excellent agreement with the value estimated by HULL *et al.*[9] at a strain rate of 5×10^{-4} sec^{-1} using a different analysis.

The work described forms part of an investigation supported by the Science Research Council. It was initiated with Prof. A. A. JOHNSON by one of us (ASW) during the tenure of a visiting professorship at the Polytechnic Institute of Brooklyn. The award was made as part of the Polytechnic's Science Development Programme founded by the National Science Foundation. The authors acknowledge the provision of laboratory facilities at Bradford by Prof. D. L. SMARE and ACC the award of a University of Bradford scholarship. The investigation was made possible through the skill of Mr. L. BOYAJIAN and Mr. E. JEFFREY who ground the tensile specimens.

School of Materials Science,
University of Bradford,
Bradford (Gt. Britain)

A. C. CHILTON
A. S. WRONSKI

1 F. B. BULLEN AND H. L. WAIN, in A. C. STICKLAND (ed.), *Physical Basis of Yield and Fracture*, Inst. of Phys. and Phys. Soc., 1966, p. 60.
2 H. G. MELLOR AND A. S. WRONSKI, *Ocean Eng.*, in press.
3 A. S. WRONSKI AND H. G. MELLOR, *J. Inst. Metals*, *97* (1969) 63.
4 A. S. WRONSKI, A. C. CHILTON AND E. M. CAPRON, *Acta Met.*, *17* (1969) in press.
5 A. WRONSKI AND A. FOURDEUX, *J. Less-Common Metals*, *8* (1965) 149.
6 H. G. MELLOR AND A. S. WRONSKI, unpublished results, 1968.
7 G. DAS AND S. V. RADCLIFFE, *Trans. Japan. Inst. Metals*, *9* (Suppl) (1968) 334.
8 A. WRONSKI AND A. FOURDEUX, *Phil. Mag.*, *10* (1964) 969.
9 D. HULL, P. BEARDMORE AND A. P. VALENTINE *Tech Rept. A.F.M.L.-TR-66-369*, Vol. II, 1967.
10 J. J. GILMAN, in G. T. HAHN (ed.), *Fracture*, Wiley, London, 1959, p. 193.
11 A. WRONSKI AND A. FOURDEUX, *J. Less-Common Metals*, *6* (1964) 413.
12 E. SMITH, *Acta Met.*, *14* (1966) 985.

Received November 13th, 1968

Journal of the Les
Elsevier Sequoia

Growth of or
technique

A grain
bicrystals of ca
allow a compari
ries. Oriented ni
method[2] and th
an attempt was
quality bicrysta
Prior to
boundary orient
due to the large
inherent with th
desired bicrystal
cular importanc
crucible which
For the
on the specimen
Since the growth
it was decided to
was originally d
the larger diame
the development
as the "pillbox".
found in the lite
blies used on sm
relative physical
diameter nickel
To deter
modeled after on
runs were then p
is shown in Fig.
rium wire which
illustrated focus
meter in length
potential.
Several
nickel rods of
sectioned to th
chemical polish
HCl[6]. The best
tom to the top

---

* This work is ba
for the degree of