The low-stress creep behaviour of fine-grained thin foils of Al was investigated [8] recently, and the data indicated the presence of a threshold stress. If the datum points for two grain sizes are plotted as $\log \dot{\epsilon}$ versus $\log \sigma$ in Fig. 2 (right-hand side), a sigmoidal behaviour, similar to that reported for superplastic alloys, result. On the other hand, when the data are replotted in terms of the effective stress rather than the applied stress (left-hand side of Fig. 2), the creep behaviour at low stresses exhibits a modified form of diffusional creep, i.e., $\dot{\epsilon} \propto \sigma_e/d^2$.

In conclusion, the present analysis, using low-stress creep data of Al, shows that a plot of $\log \dot{\epsilon}$ versus $\log \sigma$ can lead to an incorrect identification of the actual creep process if the creep behaviour exhibits a threshold stress.

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References

1. F. R. N. NABARRO, Report on a Conference on Strength of Solids (The Physical Society, London, 1948) p. 75.
2. C. HERRING, *J. Appl. Phys.* **21** (1950) 437.
3. J. G. HARPER and J. E. DORN, *Acta Met.* **5** (1950) 654.
4. F. A. MOHAMED, K. L. MURTY and J. W. MORRIS Jr., "Rate Processes in Plastic Deformation", edited by J. C. M. Li and A. K. Mukherjee (American Society for Metals, Metals Park, Ohio, 1975) p. 459.
5. F. A. MOHAMED, *Mater. Sci. Eng.* **32** (1978) 37.
6. *Idem, Met. Trans.* **9A** (1978) 1344.
7. E. R. FUNCK, U. UDIN and J. WULFF, *Trans. AIME* **191** (1951) 1206.
8. B. BURTON, *Phil. Mag.* **25** (1972) 645.
9. M. F. ASHBY, *Scripta Met.* **3** (1969) 837.
10. J. E. HARRIS, *Met. Sci. J.* **7** (1972) 1.
11. G. W. GREENWOOD, *Scripta Met.* **4** (1970) 171.
12. J. E. BIRD, A. K. MUKHERJEE and J. E. DORN, "Quantitative Relation Between Properties and Microstructure", edited by D. G. Brandon and A. Rosen (American Society for Metals, Metals Park, Ohio, 1969) pp. 255–342.

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Plastic deformation in CaO-stabilized ZrO_2 (CSZ)

The recent availability [1] of high quality calcia-stabilized zirconia (CSZ) single crystals has prompted study of their deformation behaviour. CSZ is isostructural with CaF_2 and UO_2 and we show in this preliminary communication that it has the same preferred slip system as these compounds.

The crystal studied contained 12 mol% CaO and was optically transparent. Compression specimens with an orientation shown in the inset of Fig. 1 were prepared using standard ceramic techniques. This orientation provided approximately equal Schmid factors of 0.44 for (1 1 1) $[\bar{1}\,1\,0]$ and (0 0 1) $[\bar{1}\,1\,0]$ slip, and a somewhat lower Schmid factor of 0.29 for (1 1 0) $[\bar{1}\,1\,0]$ slip.

Deformation experiments were carried out in air at temperatures of 1350 and 1450° C at $\dot{\epsilon} \sim 1 \times 10^{-4}\ \text{sec}^{-1}$. (At this strain rate, the brittle–ductile transition is between 1200 and 1350° C, as samples failed by brittle fracture when tested at 1200° C.) Samples tested at higher temperatures exhibited considerable ductility (Fig. 1) with a very low work-hardening rate of $\mu/660$, where μ is the shear modulus. As will be shown below, considerable climb is occurring during deformation and the resulting recovery must be responsible for the absence of appreciable work hardening.

Both etch-pit techniques (Fig. 2) and transmitted polarized light examination were used to perform two-surface trace analysis, and (0 0 1) was determined as the preferred slip plane. (One of the side faces of the specimens was cut parallel to (1 1 1); molten KOH at 350° C was found to be an effective dislocation etchant.)

Transmission electron microscopy (TEM) foils were prepared by ion-thinning. A typical dis-

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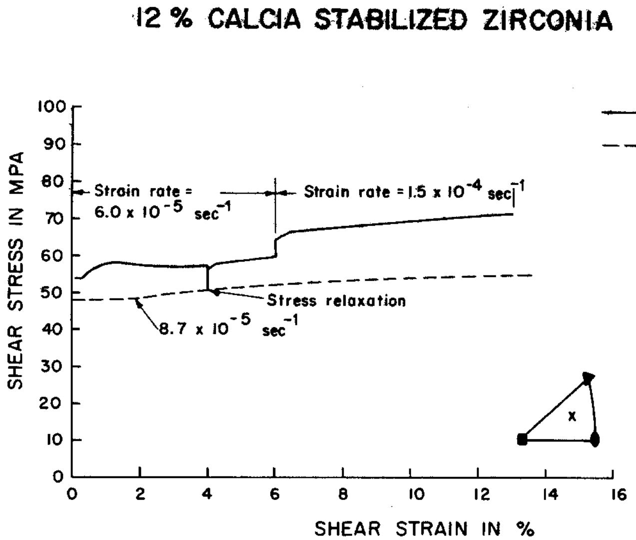

Figure 1 Resolved shear stress–shear strain on the (0 0 1) [$\bar{1}$ 1 0] slip system for specimens deformed along the [$\bar{1}$ 3 $\bar{2}$] direction.

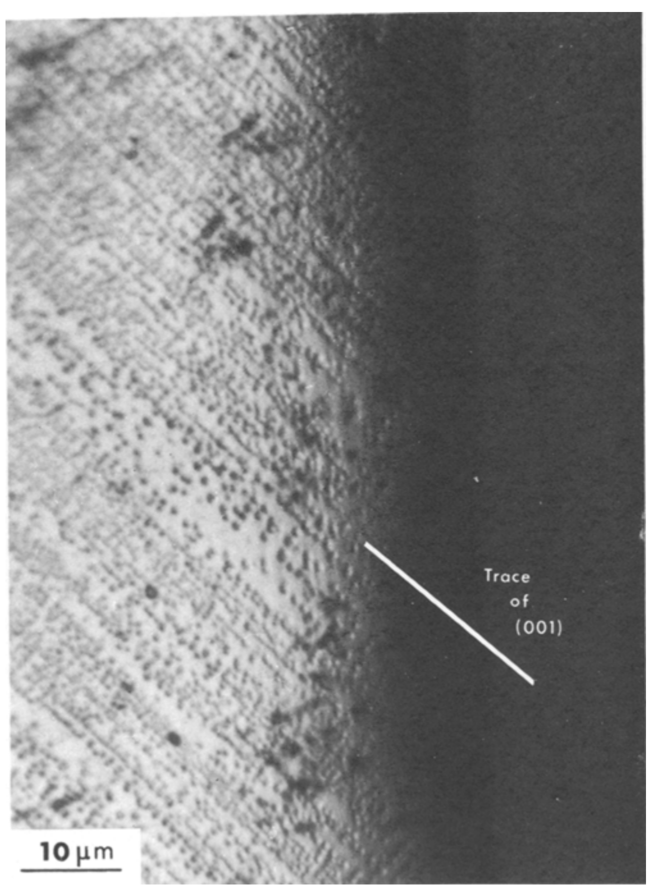

Figure 2 Etch pits (molten KOH, 350° C, 15 min) on sample deformed at 1350° C to 1.5% shear strain. The surface etched is within 5° of (1 1 1) and shows the etch pits aligned along the trace of the (0 0 1) slip plane.

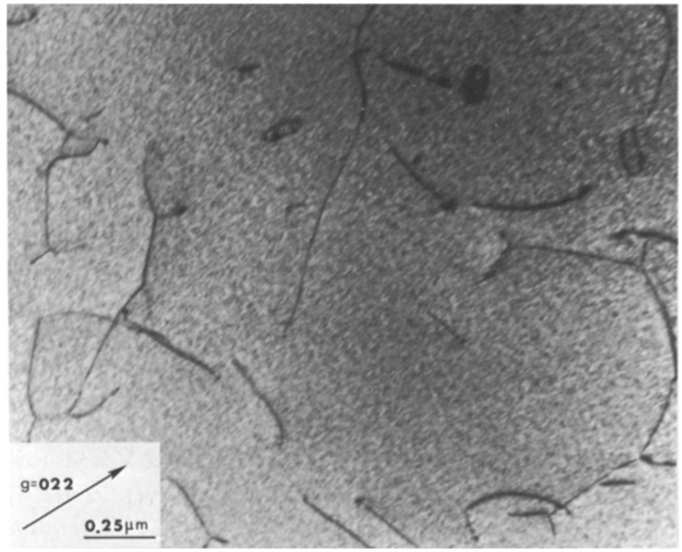

Figure 3 Dislocation substructure in a specimen deformed at 1350° C to 14% shear strain. The foil normal is $[1\ 1\ \bar{1}]$.

location substructure is shown in Fig. 3, a foil from a sample deformed 14% at 1350° C; the extensive node formation suggests that considerable climb occurred during deformation, in addition to the glide responsible for the well-defined slip bands visible in Fig. 2. Specimens deformed at 1350 and 1450° C had similar dislocation substructures, as did samples deformed to 1.5%. The lack of appreciable accummulation of a dense dislocation substructure at high plastic strains most likely resulted from the extensive recovery due to climb, which as already mentioned is marked at these temperatures and resulted in low work-hardening rates. Dislocation loops were also observed as debris from diffusive break-up of glide dislocations.

All six $1/2 \langle 1\ 1\ 0 \rangle$ Burgers vectors were present, as determined by $\mathbf{g} \cdot \mathbf{b}$ analysis, and most dislocations were mixed in character. Weak-beam dark-field electron microscopy was used in order to determine if the dislocations were dissociated, but no evidence of splitting was found (at least to a resolution of ~ 25 Å), indicating that CSZ has a high stacking fault energy.

This preliminary work has indicated that the $\{0\ 0\ 1\} \langle \bar{1}\ 1\ 0 \rangle$ is the primary slip system for CSZ, in agreement with studies of other compounds with the fluorite structure [2]. Furthermore, while slip occurs in well-defined glide bands, extensive climb takes place at temperatures just above the brittle–ductile transition.

Further studies are in progress and will be reported in due course.

References

1. HRAND DJEVAHIRDJIAN, S. A. Valais Suisse, Switzerland.
2. W. D. KINGERY, H. K. BOWEN and D. R. UHLMANN, (eds.) "Introduction to Ceramics", 2nd edn. (Wiley, New York, 1976) pp. 727–8.

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