Letters

The flexural strength of chemically strengthened polycrystalline alumina at elevated temperatures

A number of mechanisms to chemically or physically strengthen brittle ceramics have been developed. One of the established mechanisms to strengthen alumina is the application of surface layer of Al_2O_3–Cr_2O_3 which has a lower thermal expansion coefficient than Al_2O_3 [1]. Such solid solution surface layers are compressive which has been verified experimentally by several workers for Al_2O_3 [2–5]. The present letter compares the strength of polycrystalline alumina treated thermo-chemically with Cr_2O_3 to that of untreated alumina.

The specimens were prepared in the form of bars (0.68 by 0.27 by 4.45 cm) by pressing 1 g powdered alumina* at 4000 psi† and firing under oxidizing condition at 1600° C for 1 h. The additional thermal and chemical treatments given to each group of specimens are shown in Table I.

TABLE I Data of thermal and chemical treatments

Groups	Chemical treatment	Additional thermal treatment	Average density (g cm^{-3})
I	None	None	3.69
IIa	None	1675° C, 3 h	3.67
IIb	Cr_2O_3	1675° C, 3 h	3.88

The modulus of rupture (MOR) of five specimens of each group was determined at constant temperature using an apparatus designed for three-point loading at a constant loading rate of 60 psi sec^{-1}. The variation of MOR with temperature is shown as a semi-log plot in Fig. 1. The modulus of rupture falls off rapidly in the temperature range 900 to 1000° C. This may be due to the onset of grain-boundary sliding [6]. From the statistical point of view the measured strength data, which show a relatively high data scatter, indicated that the Al_2O_3–Cr_2O_3 surface layer was not completely coherent and uniform compressive.

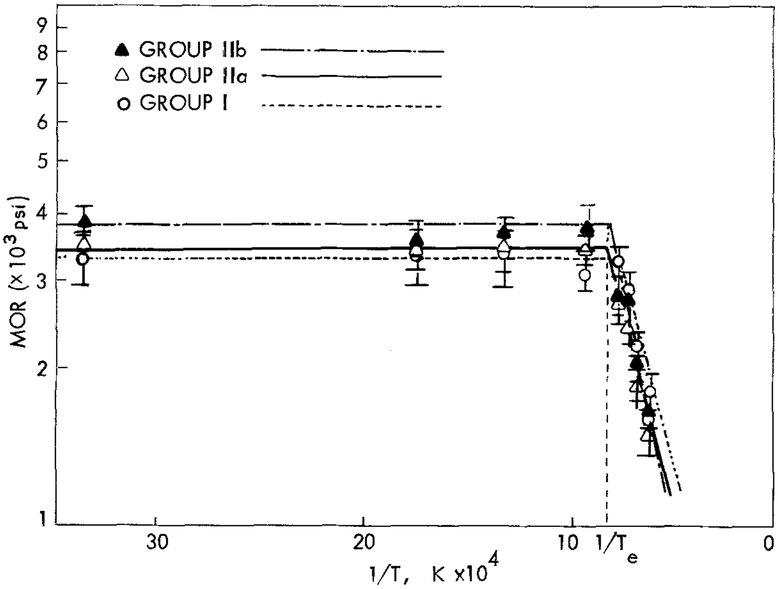

Figure 1 Strengths of each group plotted on semi-log basis and indicated a sharp change of strength with temperature at 950° C (T_e).

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*ALCOA XA-16, Aluminum Company of America, Pittsburgh, PA, USA.
†10^3 psi = 6.89 N mm^{-2}.

The sintered high purity polycrystalline alumina specimens fired in Cr_2O_3 at 1675° C for 3 h showed an increase in average flexural strength at elevated temperatures when compared to control specimens given the same thermal treatment. However, they showed the same proportional reduction in strength with temperature as the untreated materials. The sharp decrease in strength at high temperatures, which may be due to grain-boundary sliding, was almost independent of thermal and chemical treatment.

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References

1. K. M. MERZ, W. R. BROWN and H. P. KIRCHNER, *J. Amer. Ceram. Soc.* **45** (1962).
2. H. P. KIRCHNER and R. M. GRUVER, *ibid* **49** (1966) 330.
3. H. P. KIRCHNER, R. M. GRUVER and R. E. WALKER, *ibid* **51** (1968) 251.
4. *Idem, J. Appl. Phys.* **40** (1969) 3445.
5. J. T. FRASIER, J. T. JONES, K. S. RAGHVAN, T. D. McGEE and H. BELL, *Amer. Ceram. Soc. Bull.* **50** (1971) 541.
6. R. M. SPRIGGS, "Mechanical and Thermal Properties of Ceramics", edited by J. B. Wachtman, Jun., Nat. Bur. Stand. USA, Spec. Publ. No. 303 (1969) p. 189.

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S. M. OH
Department of Metallurgy & Materials Science,
Case Western Reserve University,
Cleveland, Ohio, USA
J. T. JONES
The Pfaltzgraff Co., York, Pennsylvania, USA

A TEM investigation of hydrogen-induced deformation twinning and associated martensitic phases in 304-type stainless steel

Twinning is well known to be one of the basic processes available for plastic deformation in metals [1]. Previous studies [2–5] have shown twinning to be a common deformation mechanism for mechanically strained fcc single-crystal thin films. The purpose of this article is to report the results of a TEM analysis of twins and associated martensitic phases produced by cathodic hydrogen charging of polycrystalline austenitic stainless steel thin foils, in the absence of any externally applied stress. The microstructural characteristics of the hydrogen- and strain-induced deformation twins will be compared.

The specimens used in the strain-induced deformation twin studies [2–5] were produced by vacuum evaporation of pure metals onto $(0\,0\,1)$ cleaved alkali halide substrates to give $(0\,0\,1)$ oriented thin films. Mechanical straining of the specimens, at relatively low strain-rates and along specific crystal directions in the $(0\,0\,1)$ thin-film plane, produced deformation twins on the usual $\{1\,1\,1\}\cdot\langle 1\,\bar{1}\,0\rangle$ fcc twin systems. The deformation twinning was found to occur in very localized regions within the thin foils. With increasing deformation, plastic strain occurred preferentially within the twinned regions, causing the regions to increase in size and local thinning to occur. This process eventually resulted in the formation of cracks within the twinned regions.

Disc specimens of a fully recrystallized 18-8 type stainless steel were prepared using a dish technique [6] to produce a thinned centre region suitable for TEM and supported by a relatively thick outside rim. After a TEM examination to ensure that no deformation structure has been induced during preparation, the specimens were cathodically hydrogen charged. Using a 1 N sulphuric acid solution at room temperature which contained $0.2\,\mathrm{g\,l^{-1}}$ arsenic trioxide to inhibit hydrogen recombination at the specimen surface, cathodic charging times varied from a few seconds to a few minutes with a current density of $0.2\,\mathrm{A\,cm^{-2}}$. Chemical analysis of the material used in this study is given in Table I.

Fig. 1a shows a hydrogen-induced deformation