Microhardness anisotropy in cubic Zro2
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The hardness test is commonly used to determine the low temperature deformation characteristics of brittle compounds. With this technique, several features can be obtained, mainly the fracture mechanism and toughness, hardness anisotropy and slip systems.

In this work, the microhardness on (100) planes in Y2O3-stabilized cubic ZrO2 single crystals has been studied using both Knoop and Vickers indenters.

The Knoop hardness values (Hk) for different loads and orientations are shown in fig.1. Crack free indentations are obtained for loads up to 2N and permit determination of the ratio of elastic modulus to hardness (E/H), as follows /1/: 

\[ \frac{d'}{D'} = \frac{d}{D} = \frac{aH}{E} \]

where d'/D' is the ratio of the diagonal lengths in the fully loaded state, which is defined by the indenter geometry and equal to 7.1; the ratio d'/D' after unloading is found equal to 8.3, a is a constant equal to 0.45 /1/. Using this equation we find (E/H)\(^{1/2}\) is independent of orientation of the indenter diagonal and equal to 4.7. The Knoop hardness anisotropy (fig.1) is consistent with either \(\{100\}<\{111\> or \{111\}<\{110\> slip systems being activated under the indenter. A similar conclusion was found in another Ytria-stabilized cubic zirconia /2/.

With a Vickers indent and loads of 2N both radial and lateral cracks can occur. The lengths of the radial cracks which are along the indenter diagonals are different for [100] and [110] directions, being shorter for [100]. The lateral cracks, which are absent when the indenter diagonal is along [110], allow the stress relaxation and prevent the radial cracks from propagating as suggested by /3/.

The fracture toughness (Kc) can be obtained from the length of the radial crack, \(c_0\), and the value of (E/H)\(^{1/2}\) determined from the Knoop tests, as follows:

\[ Kc = \frac{c_0^{3/2}}{P/\alpha} \]

where \(\alpha\) is a constant equal to 0.016 /4/. The realationship \(P/c_0^{3/2}\) is shown in fig.2 for the two orientations of the indenter diagonal. We find that \(Kc_1\) for (100) cracks is 1.9 MPa m\(^{1/2}\), while \(Kc_1\) for (110) ones is 1.1 MPa m\(^{1/2}\).

The lower toughness for (100) compared to (100) planes causes greater stress relief from the elastic/plastic incompatibility during unloading, such that the incidence of lateral cracking is nearly reduced to zero along [110]. This lower toughness along (110) can be correlated with the fact that the interplanar spacing normal to the (110) planes is larger than that normal to the (100) planes, but a more microscopic explanation must await future work.

REFERENCES


![Fig.1. Knoop microhardness for three different loads vs. the angle between the indenter diagonal and the direction [100].](image)

![Fig.2. P/c_0^{3/2} vs. load (P) for cracks along (100) and (110). c_0 = radial crack length.](image)