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MICROMECHANICAL STUDY ON THE MORPHOLOGY OF MARTENSITE IN CONSTRAINED ZIRCONIA

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Abstract—Either pure cooling induced martensitic transformation or pure stress assisted martensitic transformation in constrained zirconia in two materials with homogeneous (PSZ) and heterogeneous (ZTA) elastic and thermal properties is investigated by the finite element method. The morphology of the martensite (number of twin bands, relative thickness) determines the strain energy caused by the transformation which contributes to the mechanical transformation barrier. In the case of small particles the interface energy enters the transformation barrier, whereas for large particles it can be neglected. The thermodynamic existence condition predicts that the martensitic microstructure that is most likely to occur for the selected applied loading stress states is in good agreement with the experimental observations. © *1997 Acta Metallurgica Inc.*

Zusammenfassung—Die thermische und spannungsinduzierte Martensitbildung in Zirkonoxid-Keramiken mit elastisch-thermisch homogenen (PSZ) und heterogenen (ZTA) Eigenschaften wird mit Hilfe der Methode der finiten Elemente untersucht. Die Verzerrungsenergie zufolge der Phasenumwandlung hängt von der Morphologie des Martenits (Anzahl der Zwillings-bänder und deren Dickenverhältnis zueinander) ab. Die Umwandlungsbarriere setzt sich aus der Verzerrungsenergie und der Grenzflächenenergie zusammen, wobei der zweite Beitrag für große Körner vernachlässigt werden kann. Die verwendete thermodynamische Existenzbedingung erlaubt, abhängig vom Belastungszustand die energetisch günstigste Martensitstruktur in guter Übereinstimmung mit experimentellen Beobachtungen zu bestimmen.

1. INTRODUCTION

The transition from the tetragonal to the monoclinic (t → m) phase of zirconia is known to be a martensitic transformation [1–4]. The martensitic transformation of tetragonal zirconia (t-ZrO_2) can be triggered by sufficient cooling or by mechanical loading. The latter is called stress induced martensitic transformation. This transformation occurring in ceramics containing t-ZrO_2 greatly enhances the toughness of the material [5, 6]. According to their microstructure, ceramics containing t-ZrO_2 are mainly classified into three groups: tetragonal zirconia polycrystals (TZP), partially stabilized zirconia (PSZ) and zirconia toughened ceramics (ZTC). TZP, such as CeO_2-stabilized tetragonal zirconia polycrystals, usually show a microstructure of homogeneous tetragonal grains [7]. The PSZ ceramics, such as Mg-PSZ, Ca-PSZ and Y-PSZ, consist of relatively large grains of cubic ZrO_2 (c-ZrO_2) containing coherent submicrometre sized tetragonal precipitates [8]. In ZTC, t-ZrO_2 particles are dispersed in a second phase, e.g. Al_2O_3 (ZTA) [9]. Transformed ZrO_2 particles are known to consist of alternative twin bands [10, 11]. The piecewise homogeneous twin layering has been studied recently by Truskinovsky and Zanzotto in a semianalytical way for one-dimensional elasticity (displacement u) [12]. These researchers modelled the straining of the embedding material by a "Winkler" bedding. They could show, by a special minimization technique of the free energy, that one specific number of layers is most likely to occur at a given elongation of the elastic bar.

In the case of a unique transformation strain within the inclusion, the Eshelby solution applies. However, distinct transformation strains cannot be dealt with by Eshelby's method [13]. Therefore, the finite element method is used to explore the influence of the microstructure on the driving force of martensitic transformation in constrained, two-dimensional t-ZrO_2 particles, corresponding to PSZ and ZTC. The thermodynamic approach following an existence condition allows us to calculate the mechanical driving force of martensitic transformation induced either by pure cooling or by a load stress state and to predict microstructural features, such as the number of twin bands and the relative thickness of the bands.

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