MICROMECHANICAL STRESSES IN MONOLITHIC CERAMICS AND CERAMIC COMPOSITE MATERIALS

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by

ZHUANG LI

A dissertation submitted in partial fulfillment
of the requirements for the degree of

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Abstract

MICROMECHANICAL STRESSES IN MONOLITHIC CERAMICS AND CERAMIC COMPOSITE MATERIALS

by Zhuang Li

Chairperson of the Supervisory Committee: Professor Richard C. Bradt
Department of Materials Science and Engineering

Thermoelastic properties of the cubic and hexagonal polytypes of SiC have been determined. The thermal expansion, α, is highly temperature dependent, but only slightly dependent on the crystallographic orientation, while the elastic porperties are highly dependent on crystal orientation, but not very temperature dependent. However, the thermoelastic stress index, αE, is highly dependent both on temperature and the crystallographic orientation.

By developing a modification of the Eshelby method and applying it in matrix form, the micromechanical stresses and strain energy density within polycrystalline ceramics and ceramic matrix composites have been determined. For cubic polycrystalline ceramics the micromechanical stress concentration and the strain energy density are related to the elastic anisotropy of individual large grains within a fine grain size microstructure. Those large grains are

ideal sites for fracture initiation, directly influencing the strength of cubic polycrystalline ceramics.

Micromechanical stresses and strain energy densities of non-cubic polycrystalline ceramics are not only dependent on the elastic anisotropy, but also on the thermal expansion anisotropy. Even without external loading, internal stresses are generated during temperature changes and may result in spontaneous microcracking. Besides the thermoelastic anisotropy, the geometry of the crystals or grains is also important and influences the micromechanical stresses within polycrystalline ceramics.

Micromechanical stresses in SiC reinforced ceramic matrix composites are often in the GPa range and may be expected to influence the strength, fracture toughness and the R-curve behavior. Four microstructural factors affect these composite micromechanical stresses: (i) the thermal expansion mismatch, $\Delta\alpha$, which primarily influences the magnitude and the distribution of the internal stresses, (ii) the elastic modulus difference, ΔE, which strongly affects the distribution of any externally applied loads, (iii) the geometric shape of the reinforcing phase, (L/d), which can either amplify or reduce the thermal and elastic effects on the internal stresses, and (iv) the volume fraction of the reinforcing phase, V_f, which directly affects the magnitudes of the stresses. To design a optimal composite, those four factors must be considered.

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To:

My Parents and My Wife

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