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Effect of two-step sintering on the hydrothermal ageing resistance of tetragonal zirconia polycrystals

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ABSTRACT

The effects of two-step sintering (TSS) on the mechanical properties and hydrothermal ageing resistance of yttria-stabilized tetragonal zirconia polycrystals (Y-TZP) were investigated. In TSS, the first step involved heating the samples up to 1400 °C at a heating rate of 10 °C/min and holding the samples at this temperature for 1 min. The second step involved sintering by cooling the samples down to 1200 °C and holding the samples at this temperature for various holding times (t) ranging from 0 to 30 h before cooling to room temperature. Moreover, TSS promoted densification with increasing holding time without sacrificing the mechanical properties of the sintered body and causing abnormal grain growth. The average grain size was found not to be affected by the long holding times, and the final microstructure composed of a uniformly distributed tetragonal grain having sizes ranging from 0.24 to 0.26 μm. The beneficial effect of TSS in suppressing the hydrothermal ageing of Y-TZP has been revealed in the present work. In particular, samples sintered at t=20 and 30 h exhibited excellent resistance to low-temperature degradation when exposed to superheated steam at 180 °C, attributed mainly to the enhance densification of the sintered bodies.

1. Introduction

Zirconia has been used in a wide variety of structural, functional, and medical restoration applications due to its high strength, toughness, and bioinertness. Additionally, zirconia is one of the promising materials for nuclear waste storage given its radiation stability and ultra-high melting temperature [1] and is a viable material for solid oxide fuel cell electrodes because of its oxygen vacancies in the lattice structure [1,2]. Recent research on zirconia has significantly improved its prospect as an industrial catalysts or catalyst support [3]. Furthermore, zirconia is an outstanding material used in optics application due to its high refractive index and low phonon energy [4,5]. Zirconia has also been employed in the medical field as biomedical implants [6]. This ceramic has been chosen as the packaging material for small implantable neutral muscular sensors and stimulators because of its combination of excellent mechanical properties and bioinertness [6].

Nevertheless, despite the excellent properties of zirconia which rendered this ceramic to be employed in many applications, a major drawback of this ceramic is the undesirable spontaneous tetragonal (t) to monoclinic (m) phase transformation when exposed to water or hydroxyls at low temperatures (65–300 °C), a phenomenon known as low-temperature degradation (LTD) or hydrothermal ageing [7,8]. The LTD transformation starts at the free surface of the ceramic and propagates inward accompanied by microcracking, grain pullout, and surface roughening [9–12]. These series of activities would eventually lead to property degradation and ultimately fracture of the ceramic. Hydrothermal ageing even occurs at human body temperature in the presence of fluid secretion in femoral heads made of Y-TZP [10].

A number of known factors contribute toward the hydrothermal ageing of zirconia ceramic including stabilizer content and distribution [7,8], environmental condition [11], and grain size and distribution [6]. Higher densities, fine grain size and regular-shaped grain distribution, higher yttria content and homogeneous yttria distribution, and

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