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Sintering behaviour and properties of graphene oxide-doped Y-TZP ceramics

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A B S T R A C T

The effect of varying amounts (up to 1 wt%) of graphene oxide (GO), on the densification behaviour of yttria–stabilised tetragonal zirconia (Y-TZP) was investigated. Green bodies were prepared and sintered in air atmosphere over the temperature range of 1200 °C to 1500 °C. Sintered samples were then evaluated to determine bulk density, Vickers's Hardness, fracture toughness, phase stability and grain size. Furthermore, the samples were subjected to hydrothermal ageing in superheated steam at 180 °C/10 bar for up to 200 h to evaluate the ageing-induced tetragonal to monoclinic phase transformation. The results showed that the addition of GO was beneficial in improving densification and mechanical properties of Y-TZP ceramic, particularly at low sintering temperatures. A high hardness of 14.3 GPa and fracture toughness of 5.6 MPa $m^{1/2}$ were recorded for GO-doped Y-TZP sintered at 1300 °C and 1400 °C, respectively. Despite the improvement in the sintering properties, the addition of GO was not effective in suppressing the ageing-induced monoclinic phase formation for samples sintered above 1300 °C.

1. Introduction

Yttria-tetragonal zirconia polycrystals (Y-TZP) are known for its excellent strength, high fracture toughness and good wear resistance [1–3], thus making it one of the most sought after material for dentistry, orthopaedics and host of engineering applications such as oxygen sensors and electrolytes in fuel cells [4,5]. These excellent mechanical properties of Y-TZP is associated with its ability to undergo transformation toughening as reported initially by Garvie et al. [6]. In this mechanism, the stress produced by a propagating crack will be absorbed by the metastable tetragonal (t) grains thus causing them to transform into monoclinic (m) symmetry [7,8]. This martensitic diffusionless (t) to (m) phase transformation occurs at room temperature and is accompanied by a 3–5% volume expansion resulting in formation of compressive stress around the crack tip, hence preventing further crack propagation [9,10].

One of the major drawbacks of Y-TZP ceramic is its predisposition to hydrothermal ageing, also known as low-temperature degradation (LTD), leading to a spontaneous (t) to (m) phase transformation and a concomitant deterioration of mechanical properties [11,12]. The LTD occurs when the Y-TZP ceramic is exposed in water at temperatures of 65–300 °C or in hot aqueous solution resulting in the undesirable (t) to (m) phase transformation [13–15]. The LTD or ageing was first discovered by Kobayashi et al. [16] who reported that the Y-TZP exhibited a spontaneous monoclinic phase transformation when exposed to humid environment, progressing from the free surface to the interior of the ceramic, accompanied by macro- and micro-cracks and eventually leading to catastrophic failure of the ceramic. Since the discovery of LTD, numerous research were conducted to study the factors governing ageing and to suppress the devastating effect of LTD [17–20]. Although the underlying LTD mechanism is still under debate but it has been widely accepted that the ingression of the hydroxyl ions from the test medium into the zirconia lattice structure resulted in localised stress being generated that in turn destabilises the tetragonal grains [21,22].

To date an economical solution has yet to be found to completely eradicate the LTD, nevertheless there have been reports on

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