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Mechanical and thermal expansion properties of β-eucryptite prepared by sol–gel methods and hot pressing

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ABSTRACT

The microstructures, mechanical properties and thermal expansion behavior of monolithic lithium aluminosilicate glass–ceramics, prepared by sol–gel method and hot pressing, were investigated by using X-ray diffraction, scanning and transmission electron microscopies, three-point bend tests and dilatometry. β-eucryptite appeared as main phase in the monolithic lithium aluminosilicate glass–ceramics. The glass ceramics exhibited high relative densities and the average flexural strength and fracture toughness values were 154 MPa and 2.46 MPa $m^{1/2}$, respectively. The lithium aluminosilicate glass–ceramics hot pressed 1300 and 1350 °C demonstrated negative coefficient of thermal expansion, which was affected by amount and type of crystalline phases.

1. Introduction

Lithium–aluminosilicate glass–ceramics (Li_2O–Al_2O_3–SiO_2) system can achieve very low bulk thermal expansion [1]. Their thermal stability and resistance to thermal shock have led to many applications in domestic cookware, precision optical devices, turbine engine heat exchangers, and other areas [2].

The β-eucryptite phase has the hexagonal quartz structure in which half of the Si^{4+} ions are replaced by Al^{3+} ions. The charge is balanced by the incorporation of Li^+ ions in the $(Si, Al)O_4$ framework [3]. Its coefficients of thermal expansion (CTE) are highly anisotropic (α_a: 7.26×10^{-6} deg^{-1}; α_c: -16.35×10^{-6} deg^{-1}) [4]. As a result, the polycrystalline glass ceramics have a low volume thermal expansion.

Conventionally, glass–ceramics have been fabricated mainly by the recrystallization of solidified glass melting. Most of researches of lithium aluminosilicate glass–ceramics (Li_2O–Al_2O_3–SiO_2) prepared by this method focused on nucleating agent, such as TiO_2 [5–7], fluorine [8–10] and complex nucleating agent containing ZrO_2, P_2O_5 and TiO_2 [11–13]. The effect of some oxides on the crystallization behavior was also investigated [14–16]. But there arises a problem that it is not easy to obtain homogeneous and fine β-spodumene and β-eucryptite without proper nucleation agent, however, the incorporation of a nucleation aid results in a large thermal expansion coefficient [17]. The other problem is the exorbitant sintering temperature of melting glass. Some oxides such as ZnO, CaO, Na_2O and K_2O, were also added in order to lower the sintering temperature [18–20]. The addition of these oxides can cause the formation of mostly β-eucryptite, β-spodumene and phases consisting of quartz, Zn_2SiO_4, quartz solid solution, diopside, corundum and combination thereof. The formation of these phases will exert undesirable influence on the thermal expansion and mechanical properties. Moreover, more complicated processing parameters must be undertaken in order to eliminate the influence of these phases.

Sol–gel methods have been considered promising for preparing glass and ceramics with the advantages of high purity, lower sintering temperature and a high degree of homogeneity. Naskar and Chatterjee [21] studied the preparation of lithium aluminum silicate powders through sol–gel technique by utilizing agro-based waste material-rice husk ash and other water-based precursor materials. The results showed that a substantial crystallization of β-eucryptite for the composition Li_2O–Al_2O_3–$2SiO_2$ and that of β-spodumene for the composition Li_2O–Al_2O_3–$4SiO_2$ occurred at 1000 °C. Ghosh and Pramanik [22] investigated the preparation of powder precursors in the Li_2O–Al_2O_3–SiO_2 system in the hydroxyhydrogel form by wet interaction technique in aqueous medium. They reported that formation of β-spodumene was almost complete when the samples were heat treated at 1000 °C. Mandal et al. [23,24] synthesized lithia–alumina–silica glass ceramics using the powder precursor in the form of hydroxyhydrogel. They found that β-spodumene phase occurred as main phase when the samples were heat treated above 1000 °C. Wang et al. [25,26] investigated the preparation of the spodumene precursor powder using sol–gel processing and studied the effect of TiO_2 addition on the morphology and mechanism of sintering of β-spodumene precursor powders. The results showed that the TiO_2 addition in the sintering of β-spodumene precursor powders has

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