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Synthesis and effect of $CaTiO_3$ formation in $CaO\cdot Al_2O_3$ by solid-state reaction from $CaCO_3\cdot Al_2O_3$ and Ti

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A B S T R A C T

$CaO\cdot Al_2O_3/CaTiO_3$ material was synthesized by a solid-state reaction. The effects of $CaTiO_3$ formed into the $CaO\cdot Al_2O_3$ during the synthesized process on the microstructure and mechanical properties were studied. $CaCO_3$ was obtained from snail shells, Al_2O_3, and Ti powders were employed as a raw material. A chemical system with a 1:1 M ratio between $CaCO_3$ and Al_2O_3 was formed, with an addition of 10 wt% Ti metallic particles. The microstructural analysis through optical microscopy, scanning electron microscopy, and X-ray diffraction was realized. The apparent density was determined by the Archimedes method, and the mechanical behavior (hardness, fracture toughness, and transversal elastic modulus) were also determined. XRD analysis revealed the formation of calcium aluminate phases such as $CaAl_2O_4$, $CaAl_4O_7$, and $CaAl_{12}O_{19}$; in addition, the $CaTiO_3$ phase was also identified. The in-situ formation of $CaTiO_3$ in the ceramic material, improves the mechanical properties such as the transversal elastic modulus and fracture toughness (48 GPa and 1.32 MPa $m^{1/2}$, respectively) in comparison to the reference material (55 GPa and 0.43 MPa $m^{1/2}$, respectively). Changes in the microstructural morphology, bulk density, and hardness values were also observed with a positive effect in the compound material.

1. Introduction

Calcium aluminate ($CaO\cdot Al_2O_3$) is a mineral with great industrial interest due to its several applications. Namely, $CaO\cdot Al_2O_3$ is used as a binder in refractory castables because this compound presents high refractoriness and also has good performance in corrosive environments [1]. As well, this material has been used for many years as the main constituent of aluminous cement and is also used as an additive in the metallurgical processes [2–5]. On the other hand, calcium aluminate material has also found biomedical uses [6,7], such as bone replacement or bone-graft [8–10] as well as certain dental applications [11–15]. Considering the importance of calcium aluminate material, it has been the focus of several studies regarding the synthesis processes, such as solid-state reaction [16–18], sintering [16,19,20] and sonochemical processes [1], and the sol-gel method [18]. Furthermore, calcium aluminate is synthesized principally from CaO and Al_2O_3 [15–21]. In some cases, CaO is obtained by thermic effect due to the decomposition of $CaCO_3$ [12,15–17,19,20]. $CaCO_3$ can be obtained from natural sources such as snail shells, egg shells, or clam shells [16,22–27]. In a previous investigation, calcium aluminate material was synthesized by a solid-state reaction between Al_2O_3 and $CaCO_3$ obtained from snail shells in an in-situ process. The results showed that the ceramic material is brittle but with favorable refractory properties [16]. However, there are several works showing that the incorporation of metallic or ceramic particles into the ceramic matrix material modified the physical and mechanical properties such as hardness, fracture toughness, elastic modulus, and fatigue strength [5,28–31] as well as the thermal properties [32]. On the other hand, while reviewing other works, there was no information found regarding calcium titanate being used as a reinforcement for calcium aluminate ($CaO\cdot Al_2O_3$ - $CaTiO_3$) synthesized through some in situ method. Instead, there is a lot of information about the synthesis of $CaTiO_3$ from CaO or $CaCO_3$ with TiO_2 as precursor materials [2,33–36] as well as studies of the ternary phase diagram Al_2O_3- CaO-TiO_2 [37,38].

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