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Physical, mechanical properties and antimicrobial analysis of a novel $CaO{\cdot}Al_2O_3$ compound reinforced with Al or Ag particles

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ABSTRACT

Ceramic-metal ($CaO{\cdot}Al_2O_3$–Al and $CaO{\cdot}Al_2O_3$–Ag) compounds were prepared by mechanical milling and consolidated through an *in-situ* sintering process. The aim of this work is to study the effects of the Al and Ag particles to ceramic-base compound, primarily in the microstructure, and its mechanical and antimicrobial properties. Chemical systems with a 1:1 M ratio between $CaCO_3$ and Al_2O_3 powder were formed, with the addition of 10 wt% Al or 10 wt% Ag, respectively. The compound material that consolidated were microstructurally characterized through X-ray diffraction, scanning electron microscopy, optic microscopy, and X-ray computed tomography. In addition, the hardness, the fracture toughness, the transversal elastic modulus, and the antimicrobial property were evaluated. The results of X-ray diffraction identified the formation of the calcium aluminate phases, such as $CaO{\cdot}6Al_2O_3$ (hibonite:CA6), $CaO{\cdot}2Al_2O_3$ (grossite:CA2), and $CaO{\cdot}Al_2O_3$ (krotite:CA); as well as Al and Ag were identified in its respective system. In addition, the mechanical properties show changes compared to the reference material that was synthesized under the same conditions and, finally, these materials also have an antimicrobial effect, against the *Staphylococcus* bacterium that is common in the oral cavity, when studied in synthetic saliva.

1. Introduction

The ceramics nowadays have many industrial applications; for example, in the aeronautic industry, naval industry, military industry, sports industry, automotive industry, medical industry, and others. In especially the calcium aluminate $CaO{\cdot}Al_2O_3$ is a ceramic material with a considerable importance due to its several applications, such as a refractory material (Miranda Hernández et al., 2018), concrete-based calcium aluminate cement (Scrivener et al., 1999), catalyst (Zabeti et al., 2009), and metallurgical processes (Jiangling et al., 2015; Jifang et al., 2012, 2016). Also, this material has been studied for biomedical applications (Regina de Oliveira et al., 2015), such as in odontology (Leal Silva et al., 2014; Engqvist et al., 2004; Parreira et al., 2016; Loof et al., 2003; Oliveira et al., 2010; Andrade et al., 2014), bone replacement (Uchida et al., 1984) and bone-graft applications (Kalita et al., 2002; Hulbert et al., 1970). As well, calcium aluminate has been the focus of several studies about of the synthesis processes, such as the sol-gel method (Aitasalo et al., 2002), solid state reaction (Miranda Hernández et al., 2018; Aitasalo et al., 2002; Yongpan et al., 2016), sintering (Miranda Hernández et al., 2018; Iftekhar et al., 2008; Rivas et al., 2005), mechanochemical synthesis (Wieczorek-Ciurowa et al., 2010), and the sonochemical process (Lourençoa et al., 2013). Calcium aluminate is synthesized principally from the CaO and Al_2O_3 (Andrade et al., 2014; Yongpan et al., 2016; Iftekhar et al., 2008; Rivas et al., 2005; Wieczorek-Ciurowa et al., 2010; Lourençoa et al., 2013; Zawrah and Khalil, 2007), but in some cases, the CaO is obtained through the thermic effect from $CaCO_3$ (Miranda Hernández et al., 2018; Andrade et al., 2014; Iftekhar et al., 2008; Rivas et al., 2005; Galan et al., 2013). Also, $CaCO_3$ can be obtained from natural sources such as snail shells, egg shells or clam shells (Miranda Hernández et al., 2018; Singh and

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