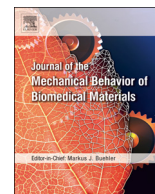




Contents lists available at ScienceDirect

Journal of the Mechanical Behavior of Biomedical Materials

journal homepage: www.elsevier.com/locate/jmbbm

Physical, mechanical properties and antimicrobial analysis of a novel CaO·Al₂O₃ compound reinforced with Al or Ag particles

Sandra G. Gómez de Saravia^a, Silvia E. Rastelli^a, Mayahuel Ortega-Avilés^b,
Carlos O. González-Morán^c, Enrique Rocha-Rangel^d, José G. Miranda-Hernández^{c,*}

^a Centro de Investigación y Desarrollo en Tecnologías de Pinturas (CIDEPIINT), (CICPBA-CONICET-UNLP), Facultad de Ciencias Naturales y Museo, UNLP, La Plata, Buenos Aires, Argentina

^b Instituto Politécnico Nacional, CNMN, Ciudad de México, Mexico

^c Universidad Autónoma del Estado de México, Centro Universitario UAEM Valle de México, Laboratorio de Investigación y Desarrollo de Materiales Industriales, Atizapan de Zaragoza, Estado de México, Mexico

^d Universidad Politécnica de Victoria, Departamento de Manufactura de Materiales Avanzados, Ciudad Victoria, Tamaulipas, México de postgrado, Ciudad Victoria, Tamaulipas, Mexico

ARTICLE INFO

Keywords:

Calcium aluminate-metal
Metallic particles
Snail shell powder
Solid state reactions
Mechanical properties
Antimicrobial analysis

ABSTRACT

Ceramic-metal (CaO·Al₂O₃-Al and CaO·Al₂O₃-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 CaCO₃ and Al₂O₃ 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·6Al₂O₃ (hibonite:CA6), CaO·2Al₂O₃ (grossite:CA2), and CaO·Al₂O₃ (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·Al₂O₃ 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 (Lourenço et al., 2013). Calcium aluminate is synthesized principally from the CaO and Al₂O₃ (Andrade et al., 2014; Yongpan et al., 2016; Iftekhar et al., 2008; Rivas et al., 2005; Wieczorek-Ciurowa et al., 2010; Lourenço et al., 2013; Zawah and Khalil, 2007), but in some cases, the CaO is obtained through the thermic effect from CaCO₃ (Miranda Hernández et al., 2018; Andrade et al., 2014; Iftekhar et al., 2008; Rivas et al., 2005; Galan et al., 2013). Also, CaCO₃ can be obtained from natural sources such as snail shells, egg shells or clam shells (Miranda Hernández et al., 2018; Singh and

* Corresponding author. Blvd. Universitario S/N predio San Javier, Pedregal de Atizapán, C.P. 52948, Atizapán de Zaragoza, Estado de México, Mexico.
E-mail address: jgmirandah@uaemex.mx (J.G. Miranda-Hernández).