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Peparation and Characterization of a Three-Component Composite Based on Polymethylmetacrylate Applied as Bone Cement †

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Abstract: A composite based on three components including PMMA (polymethyl metacrylate), HA (hydroxyl apatite) and LDH (layered double hydroxide) was prepared, characterized and applied as bone cement. Bone cement is a biomaterial performs in clinical applications by fixing joint replacements in hip and knee joints. There are four types of bone cements, two of which applied in dentistry and orthopedics are polymer-based including a) Acrylic cements based on PMMA, b) Cements based on PPF (polypropyl fumarate). LDH with the general formula of $[M(II)_{1-x}M(III)_x(OH)_2]^{x+}.(A^{n-})_{x/n}\cdot mH_2O$ has M(II) and M(III) cations and A^{n-} inter-layer anion. The importance of LDH is for its planar layered structure. HA is a thermodynamically stable calcium phosphate similar to the human hard tissues in morphology and composition. In this work, we have prepared a Zr-CoLDH with a green method and mixed it with PMMA and HA in a given ratio. In order to characterize the composite, XRD, FTIR and SEM analyses are done.

Keywords: PMMA; HA; LDH; bone cement

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1. Introduction

The application of PMMA as a biomaterial was preceded by extensive research in the chemical field. Reportedly, 1843 marked the discovery of 'acide acrylique'. This is derived from 'acreolan', the latin word for vinegary, acid or acrid and it refers to the penetrating smell of the monomer. It was found in 1936 that mixing ground PMMA powder with a liquid monomer results in the formation of a doughy substance. This is due to a partial dissolution of the PMMA in its monomer. Polymer chains from the PMMA become available for free radical polymerization and entanglements of these chains with newly formed chains lead to an intimate connection between the newly formed PMMA with what was already present [1].

Layered double hydroxides (LDH) which are one type of layered materials and are also known as anionic clays, are promising layered materials due to some of their interesting properties, such as ease of synthesis, unique structure, uniform distribution of different metal cations in the brucite layer, surface hydroxyl groups, flexible tunability, intercalated anions with interlayer spaces, swelling properties, oxo-bridged linkage, and high chemical and thermal stability, ability to intercalate different type of anions [2].

The general formula for these LDHs is $(Mg_{1-x}Al_x(OH)_2)^{x+}(A^-)_x\cdot nH_2O$, where "A" represents the interlamellar anion that restore the electroneutrality of the compound. We call these the II–III LDHs. We recently reported that the preparation of Zn-Ti LDH and Co–Ti LDH consisting of di- and tetra-valent cations are possible [3]. The present work examines

the possibility of preparation of other example consisting of bi- and tetra-valent cations LDH by mechanochemical route that has been known as a green method.

2. Experimental Method

2.1. Synthesis of Co-Zr LDH in a Mortar

Co-Zr LDH was prepared by a mechanochemical route with simple and green mechanical grinding method. NaOH pellets were added to a powder mixture of Cobalt (II) nitrate hexahydrate and zirconium chloride and manually ground to a paste. The paste was washed four times with deionized water (20 mL), dried under vacuum, powdered and analyzed [4].

2.2. Synthesis of Three-Component Composite

The samples were prepared with 3% (*w*/*w*) of hydroxyapatite (HA) and 5, 7, 10% (*w*/*w*) LDH. In the first step, HA, PMMA and LDH powder were mixed well with specified weight percent. Then the mixture was introduced to MMA liquid. The mixture was kept in vacuum state to let gases exit from. To prepare composite tablets, the mixture was added to cast and waited for becoming hard.

2.3. Results and Discussion

2.3.1. Co-Zr LDH Characterization

Figure 1 shows XRD pattern which indicates that the Co-Zr LDH was directly synthesized. The sharp peaks in different 2Θ 19.17, 32.57 and 58.16 were referred to (003) and (006) (009) plates, respectively [3].

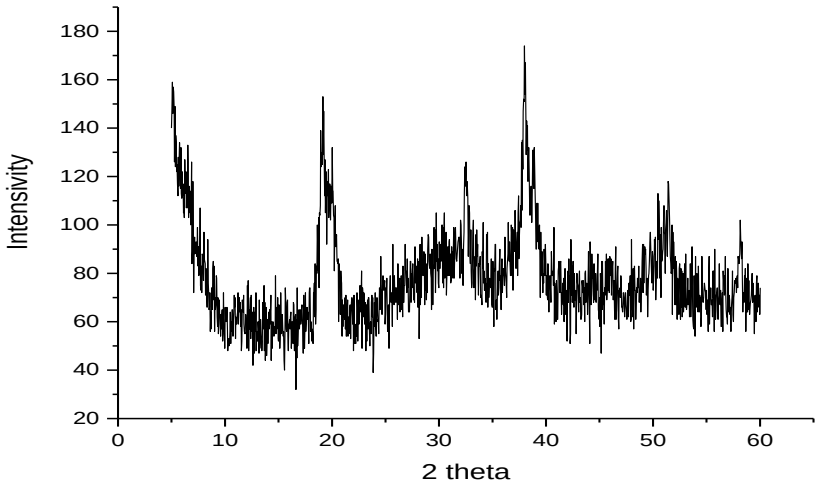

Figure 1. The XRD pattern of Co-Zr LDH.

The FT-IR spectrum of Co-Zr LDH was shown in Figure 2. The widespread and intense band in the 3446 cm^{-1} area is due to the stretch vibrations of O–H groups present in the interlayer and water molecules which are in layers. The 1625 cm^{-1} is related to water bending vibrations. The sharp bands in 1379 cm^{-1} and 827 cm^{-1} are related to stretch and bending vibration of interlayer nitrate anion, respectively. However, the band seen in 1357 cm^{-1} is related to CO_3^{2-} which is caused by existing CO_2 in deionized water [3].the picks were shown in 470 cm^{-1} and 520 cm^{-1} is related to M-O-M witch caused by Zr or Co and Oxygen deionized water.

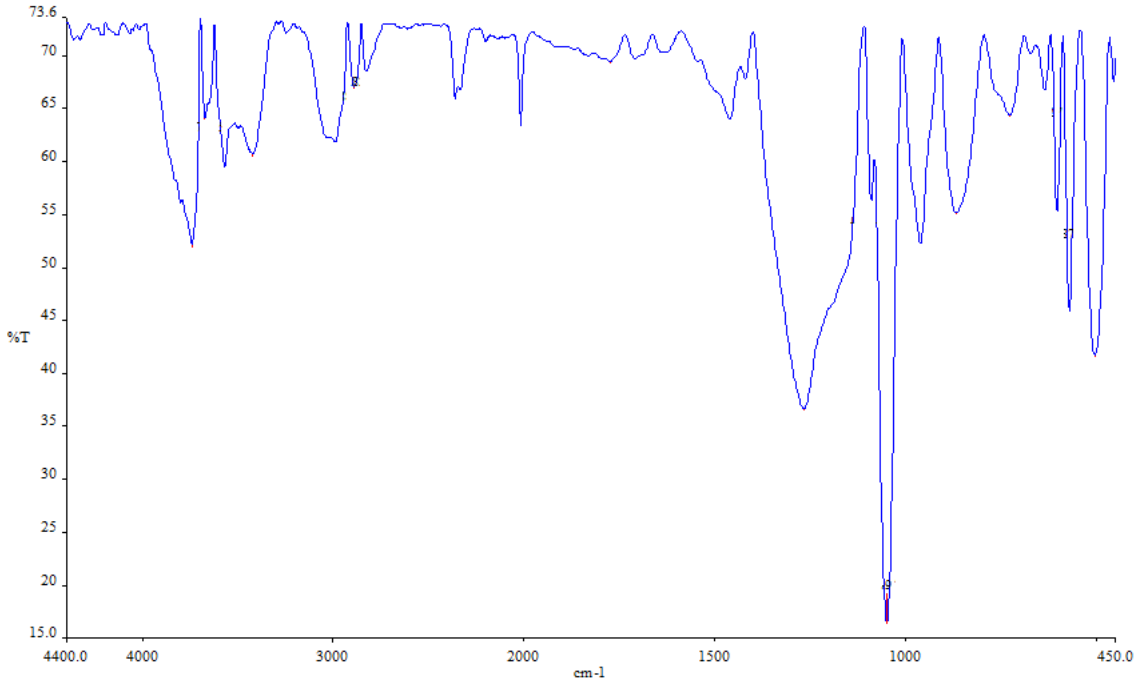

Figure 2. FT-IR spectrum of Co-Zr LDH.

2.3.2. Scanning Electron Microscopy

The method was selected to investigate the morphology and particle size of Co-Zr LDH. Figure 3 shows FE-SEM images which indicates that the Co-Zr LDH plates was directly synthesized.

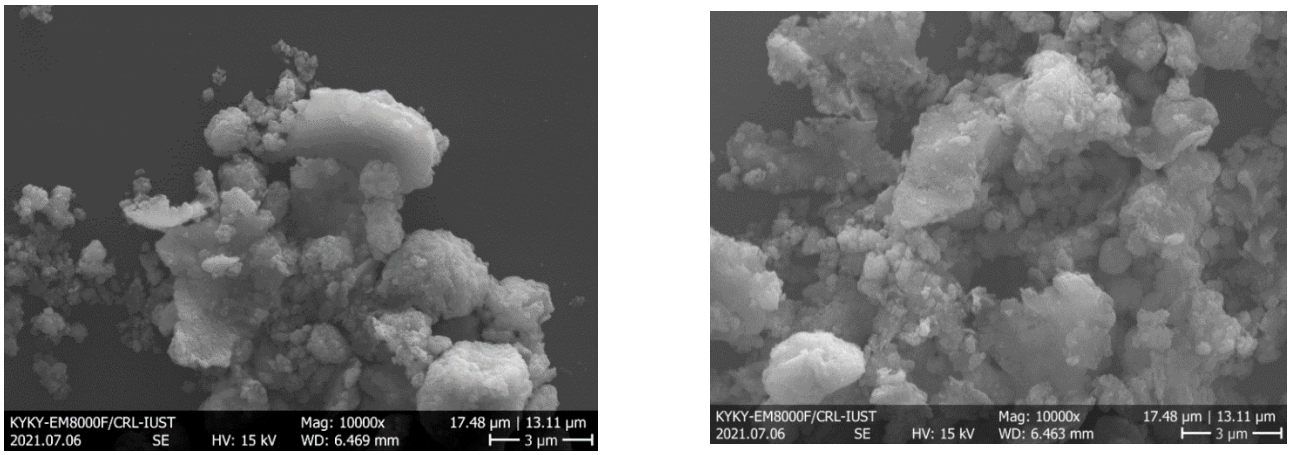

Figure 3. The LDH FE-SEM images.

2.3.3. Three Component Composite Images

Figure 4 shows image of three component composite with 5, 7 and 10% (*w*/*w*) LDH, respectively. The results indicates that pores will increase by increasing the percentage of LDH, shown in Figure 4. It is expected that the phenomena causes to increase the concentration of tension and decrease the strength of the composite [5].

Figure 4. The images of three component composite with 5, 7 and 10% (*w*/*w*) LDH.

3. Conclusions

Co-Zr LDH were proposed to composite with cement bone because of micro sized particle of LDH and Zr mechanical properties. Micro size of LDH will prevent from concentration of tension and decreasing strength of composite. But pores will increase in macro size by increasing of percentage of LDH. This phenomenon causes to increase the concentration of tension and to decrease the strength of composite.

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