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Apatite-wollastonite glass-ceramics containing B_2O_3 and Na_2O: Potential bioactive material for tissue protection during radiation therapy procedures

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ABSTRACT

In this study, an attempt to expand available data and functionality of apatite-wollastonite glass ceramics (AW GCs) in medical therapy and bone engineering by estimating and analysing the physical, structural, fast neutron and gamma interaction properties of B_2O and Na_2O doped AW GCs is presented. The pristine (AW) and (20 wt% B_2O_3 and 30 wt% Na_2O) doped AW GC (AW-B20-N30) samples were prepared using the cold isostatic press method. The samples were subject of structural and physical characterisation through experimental procedures, while their radiation interaction parameters were obtained following standard theoretical models. Samples' densities were calculated as 2.917 and 2.613 g/cm^3, while the Vickers hardness was 553 and 518 HV for AW and AW-B20-N3, respectively. The structure of the samples revealed that Na_2O formed the brianite phase inserted in the apatite structure. The mass and linear attenuation coefficients fluctuated within the ranges, 0.0232-13.6853 cm^2/g and 0.0676-39.92 cm^{-1} for AW and 0.021-8.313 cm^2/g and 0.055-21.7223 cm^{-1} for AW-B20-N30, respectively. The half- and tent-value layers increased from about 0.02 to 10.25 cm and 0.06 to 34.05 cm for AW; for AW-B20-N30, the increase is from 0.032 to 12.61 cm and 0.11 to 41.88 cm, respectively. AW was more effective for shielding photons and fast neutrons, and had lower gamma buildup factors compared to AW-B20-N30. The study showed doping AW with B_2O and Na_2O could be optimised to get equivalent bone material in radiation studies. The AW GCs also showed better shielding effectiveness compared to some traditional shields and could therefore be applied for shielding tissues outside the target volume in radiation therapy.

1. Introduction

Bioactive materials (also known as biomaterials) have become invaluable in several biochemical and medical procedures. They are now major players in proffering solutions to many medical related problems. Notable among the areas where biomaterials (BMs) applications have been successful include controlled drug or protein delivery, tissue care, repair, and regeneration [1-4]. In addition, advances in BMs production and characterisation offers alternative diagnostic and therapeutic trajectories to the traditional procedures and pharmaceutical formulations used in the identification and management of deadly diseases such as cancer, cardiac diseases, asthma, diabetes, and bone injuries [1-7]. Today, there exist many useful BMs in the form of polymer, glass, hydrogels, and ceramics. Despite the huge number of BMs that presently exist, many are still limited in their applications. Therefore, the proliferation of BMs production with exotic attributes and wider applications continues. The choice of BMs application depends on purpose, bioactivity, chemical formulations and structural properties. Switching the chemical formulations of existing BMs is an easy way of expanding their features and applications.

Apatite-wollastonite (AW) glass ceramics (GCs) are BMs that combine good biocompatibility, bioactivity, tuneable porosity, and mechanical features that make them attractive for bone injury treatment, regeneration and engineering. The AW glass ceramics is a composite of the apatite and wollastonite crystal phases within a glass system. The apatite phase occurs naturally as phosphate mineral, its structure is similar to the synthetic hydroxyapatite (($Ca_{10}(PO_4)_6(OH)_2$)), while the wollastonite is the $CaSiO_3$ mineral. A combination of the high thermal stability, bioactivity, and mechanical strength of the wollastonite phase with the biocompatibility of the apatite structure in a glass system produced a BM that has been extensively used in biomedicine [8]. As an important BM, different aspects of the AW GCs have been

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