World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:15, No:04, 2021

Sol-Gel Derived Yttria-Stabilized Zirconia Nanoparticles for Dental Applications: Synthesis and Characterization

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Abstract : In restorative dentistry, yttria-stabilized zirconia (YSZ) nanoparticles can be applied as fillers to improve the mechanical properties of various resin-based materials. Using sol-gel based synthesis as simple and cost-effective method, nano-sized YSZ particles with high purity can be produced. The aim of this study was to synthesize YSZ nanoparticles by the Pechini sol-gel method at different temperatures and to investigate their composition, structure, and morphology. YSZ nanopowders were synthesized by the sol-gel method using zirconium oxychloride octahydrate ($ZrOCl_2.8H_2O$) and yttrium nitrate hexahydrate ($Y(NO_3)_3.6H_2O$) as precursors with the addition of acid chelating agents to control hydrolysis and gelation reactions. The obtained powders underwent TG_DTA analysis and were sintered at three different temperatures: 800, 1000, and 1200°C for 2 hours. Their composition and morphology were investigated by Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction Analysis (XRD), Scanning Electron Microscopy with associated with Energy Dispersive X-ray analyzer (SEM-EDX), Transmission Electron Microscopy (TEM) methods, and Dynamic Light Scattering (DLS). FTIR and XRD analysis showed the presence of pure tetragonal phase in the composition of nanopowders. By increasing the calcination temperature, the crystallinity of materials increased, reaching 47.2 nm for the YSZ1200 specimens. SEM analysis at high magnifications and DLS analysis showed submicron-sized particles with good dispersion and low agglomeration, which increased in size as the sintering temperature was elevated. From the TEM images of the YSZ1000 specimen, it can be seen that zirconia nanoparticles are uniform in size and shape and attain an average particle size of about 50 nm. The electron diffraction patterns clearly revealed ring patterns of polycrystalline tetragonal zirconia phase. Pure YSZ nanopowders have been successfully synthesized by the sol-gel method at different temperatures. Their size is small, and uniform, allowing their incorporation of dental luting resin cements to improve their mechanical properties and possibly enhance the bond strength of demanding dental ceramics such as zirconia to the tooth structure. This research is co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme 'Human Resources Development, Education and Lifelong Learning 2014- 2020' in the context of the project 'Development of zirconia adhesion cements with stabilized zirconia nanoparticles: physicochemical properties and bond strength under aging conditions' (MIS 5047876).

Keywords : dental cements, nanoparticles, sol-gel, yttria-stabilized zirconia, YSZ
Conference Title : ICNMM 2021 : International Conference on Nanomaterials, Microstructure and Macrostructure
Conference Location : Athens, Greece
Conference Dates : April 08-09, 2021

Open Science Index, Materials and Metallurgical Engineering Vol:15, No:04, 2021 publications.waset.org/abstracts/128609.pdf