Bismuth-doped mesoporous bioactive glass nanoparticles with broad mesoporous distribution: physicochemical properties, bioactivity, and radiopacity

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Abstract

Dendritic mesoporous bioactive glasses (DMBGs) are promising biomaterials due to their radial pore structure, broad mesoporous distribution, and high surface area, which support efficient loading and release of biomolecules. In this study, bismuth-doped DMBGs (Bi-DMBGs) were synthesised and characterised, with bismuth incorporated to provide radiopacity for clinical imaging and to impart reported antibacterial [1], photothermal [2], and angiogenic effects [3]. Mesoporous silica nanoparticles were prepared by a dual-surfactant sol-gel method, followed by sequential impregnation with calcium nitrate and a Bi-acetylacetone complex in acidic medium, and calcination to yield compositions containing 0.5, 1, and 2 mol% Bi_2O_3. Fourier-transform infrared spectroscopy (FTIR) confirmed the silica network and near-complete surfactant removal, while inductively coupled plasma-optical emission spectrometry (ICP-OES) validated compositions close to the intended targets. X-ray diffraction (XRD) revealed an amorphous matrix without crystalline bismuth phases, indicating Bi dispersion in the glass network. Scanning electron microscopy (SEM) revealed dendritic morphology and energy-dispersive X-ray spectroscopy (EDS) showed homogeneous elemental distribution. Nitrogen sorption using the Brunauer–Emmett–Teller (BET) model indicated broad mesoporosity with high surface area and pore volume, which decreased with Bi content but remained within reported MBG ranges [4]. In vitro assays in simulated body fluid (SBF) showed sustained Si, Ca, and P release, Bi detection in doped samples, and apatite formation in all samples within 7 days, although higher Bi content slightly delayed crystallisation. Radiopacity increased proportionally with Bi concentration. These findings demonstrate that Bi-DMBGs combine dendritic morphology, ion release, bioactivity, and radiopacity, making them promising candidates for bone regeneration applications.

Key Words: Mesoporous bioactive glass, dendritic nanoparticles, bismuth doping, bioactivity, radiopacity.

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