3D printing of doped β-tricalcium phosphate bioceramics using robocasting

N. Somers[1], M. Lasgorceix[1], F. Jean[1], N. Preux[2], C. Delmotte[2], L. Boilet[2], F. Petit[2], A. Leriche[1]

[1] UPHF (Université Polytechnique Hauts-de-France) - INSA Hauts-de-France, CERAMATHS - DMP (Département Matériaux et Procédés), Maubeuge, France

[2] Belgian Ceramic Research Centre, Mons, Belgium

GIS TechCera, Mons/Maubeuge

β-tricalcium phosphate (β-TCP, β-$Ca_3(PO_4)_2$) is one of the most attractive biomaterials for bone regeneration and β-TCP macroporous scaffolds are highly promising for bone tissue engineering. Robocasting, an additive manufacturing process based on the extrusion of a concentrated ceramic slurry, is particularly adapted to resolve the main drawbacks associated with conventional shaping of ceramic scaffolds.

In this work, undoped and co-doped β-TCP powders were synthetized by aqueous precipitation and used to print macroporous scaffolds by Robocasting. The doped compositions were produced combining magnesium, strontium, silver and copper cations: Mg-Sr (2.0–2.0 mol%) and Mg-Sr-Ag-Cu (2.0–2.0–0.1–0.1 mol%). Slurries were optimized with undoped and co-doped β-TCP with the use of a dispersant and a carboxymethylcellulose and polyethyleneimine mixture to obtain aqueous slurries filled with 42 vol% of powder. Undoped and co-doped β-TCP macroporous scaffolds were successfully printed and characterized.

Doped β-TCP powders have been proved to exhibit higher thermal stability and densification compared to undoped β-TCP. The β-TCP slurries exhibited a shear-thinning and thixotropic behaviour suitable for the printing process. The whole processing chain including printing, osmotic drying and sintering was optimized. Characterizations of the printed parts after sintering showed a reduction of macropores and microcracks using co-doped β-TCP powders as well as improved compressive strengths and densities compared to undoped β-TCP.

Improved compressive strength and densities were observed for co-doped β-TCP scaffolds with a significant enhancement by comparison with literature data. These results are encouraging for the development of on-demand customized bone substitutes applied to load-bearing areas. It was also demonstrated that the developed process was successively applied to produce more complex shapes opening new possibilities for the fabrication of synthetic bone substitutes or other applications.