

Student Speech Contest 2025

Hybrid Direct Ink Writing of silicone-based Emulsions for Advanced Biosilicate® scaffolds

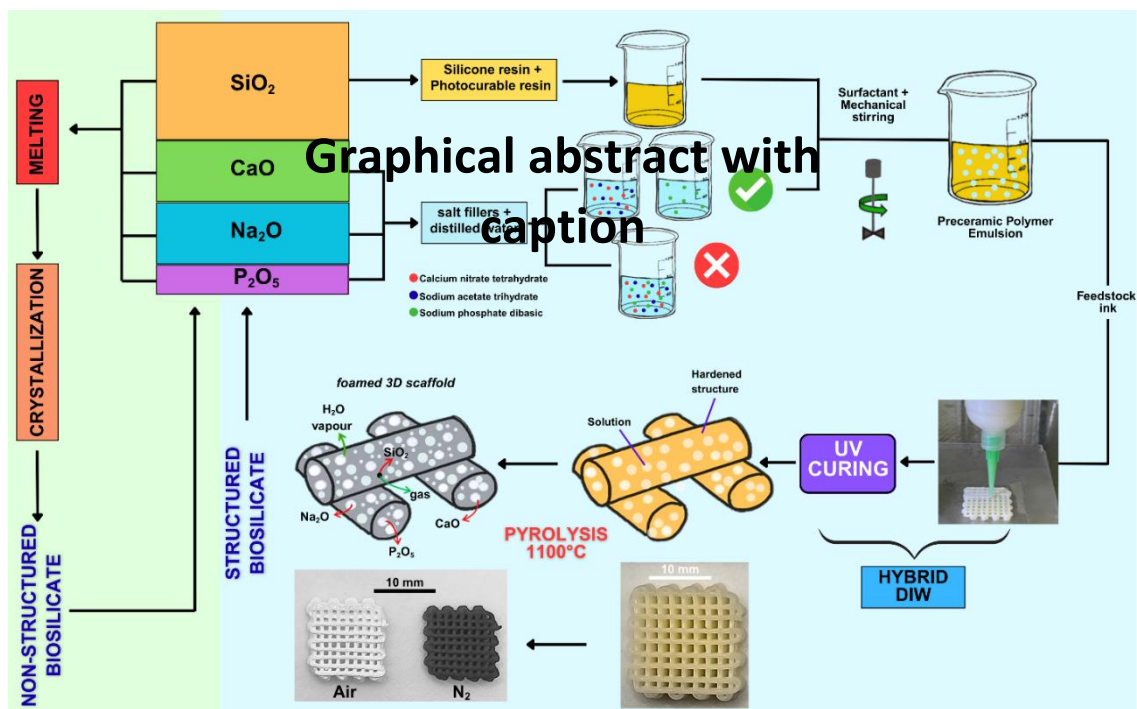


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Abstract.



Biosilicate glass-ceramic (23.75 Na₂O, 23.75 CaO, 48.5 SiO₂, and 4 P₂O₅, by wt%), is one of the most interesting alternatives to 45S5 bioglass, in bone tissue engineering. It is generally known for a more favourable trade-off between bioactivity, mechanical properties and ability to be shaped into highly porous scaffolds. Viscous flow sintering of 45S5, applied to consolidate shaped porous bodies, generally leads to crystallization and reduction of bioactivity. Biosilicate powders, already mostly crystallized, may undergo sintering with no change in the phase assemblage. However, multi-step treatments are always necessary (i.e. glass melting, crystallization, sintering). Preceramic polymer emulsions have recently shown great potential in the production of ceramics featuring a glassy matrix owing to their ability to achieve a high degree of homogenization of fillers. The present study aims to extend the silicone emulsion approach to glass-ceramic materials, specifically targeting the Biosilicate® composition. Silicone blends are successfully developed and combined with Direct Ink Writing additive manufacturing and thermal treatment in air to fabricate highly porous biosilicate-like scaffolds (up to 94% total porosity) with outstanding strength-to-density ratios. Water, used as the dispersing medium, also acts as an additional pore-forming agent, leading to unprecedented levels of hierarchical porosity where the macroporosity, defined by the printing design, is coupled with the porosity arising from thermal treatment. Firing under nitrogen atmosphere is also explored focusing on its effects on the crystalline phase assemblage, morphology, and physical properties of the scaffolds. The achieved foam-like architecture of the struts is later demonstrated to be suitable for post-processing infiltration techniques. The uniform distribution and thorough infiltration of the polymeric resins into the porous network formed during heat treatment may contribute to the development of organic/inorganic composites with enhanced mechanical performance. Finally, the extreme versatility and adaptability of the synthesis strategy is highlighted: minor adjustments in formulation and processing conditions may indeed make the silicone emulsions compatible with additional 3D printing technologies, such as stereolithography and hybrid direct ink writing with in situ photopolymerization.