Student Speech Contest 2024

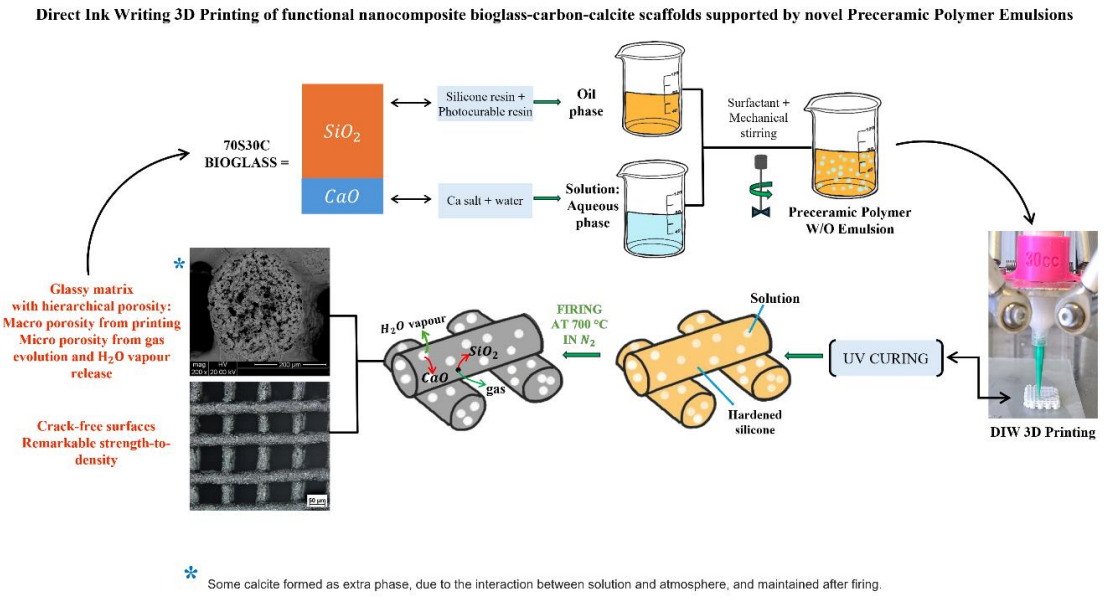
Direct Ink Writing 3D Printing of functional nanocomposite bioglass-carbon-calcite scaffolds supported by novel Preceramic Polymer Emulsions

Name of the student. Valeria Diamanti

Contact mail. valeria.diamanti@studenti.unipd.it

Institution(s) / lab. Università degli studi di Padova, via Marzolo 9, Padova, Italy

Project:



Abstract

Preceramic polymers, i.e., polymers that can undergo a ceramization process upon heat treatment, have been widely recognized for the last 50 years as a valid alternative route for the production of advanced ceramics, including silicate bioceramics. Their main advantage over conventional synthesis methods relies on the possibility to use low-cost plastic-forming techniques, including additive manufacturing (AM) technologies, to shape the material into high

complex geometries which can then be converted into the desired ceramic system, typically at lower temperatures.

All these benefits, applied to bioactive glass compositions, could potentially lead to interesting new perspectives in the field of bone tissue engineering. Recently we successfully employed Vat Photopolymerization AM to yield fully amorphous ceramic scaffolds, resembling 70S30C (70% SiO_2 and 30% CaO) bioglass, starting from preceramic polymer emulsions. The idea of the current study was to adapt the same approach to extrusion-based AM technologies relying on water-in-oil emulsions, in which salts are dispersed in the form of liquid droplets. By applying this novel approach we managed to produce a feedstock with suitable pseudoplastic rheological properties for extrusion and thus, it was successfully employed to fabricate functional nanocomposite bioglass-carbon-calcite scaffolds via Direct Ink Writing.

The idea to include water into the mixture played a crucial role both in terms of rheology and microstructural behaviour, being used as templating agent to achieve an enhanced hierarchical porosity. Nevertheless, the presence of water also significantly amplified the possibility of interaction of the precursors with the firing atmosphere. In fact, final pyrolysis of the scaffolds at 700°C resulted in a SiO_2 glassy matrix with a secondary phase of calcite ($CaCO_3$). In addition, the employment of nitrogen as firing atmosphere for the polymer-to-ceramic conversion, led to an extra carbon phase. This particular composition, however, provided a beneficial combination of the well-known bioactivity mechanism of bioactive glasses with the bone-forming response of calcite and the photothermal properties of pyrolytic carbon. Furthermore, the fabricated scaffolds exhibited a regular morphology and an enhanced pore interconnectivity (~65-80% open porosity) resulting in a good permeability of the structures which is a key factor for a successful interaction with the fluids and the cells of bone tissue. On the other hand, the novel strategy led to crack-free surfaces resulting in structures with a remarkably strength-to-density (bending strength up to ~100MPa) in good agreement with the overall behaviour of natural trabecular bone.