MATERIALS SCIENCE AND TECHNOLOGY

CRT/DISAT - 3D printing of ceramic and glass materials for biomedical and energy applications

Funded By	Dipartimento DISAT FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]
Supervisor	BAINO FRANCESCO - francesco.baino@polito.it
Contact	BAINO FRANCESCO - francesco.baino@polito.it ANELLI SIMONE - simone.anelli@polito.it SMEACETTO FEDERICO - federico.smeacetto@polito.it
Context of the research activity	The research activity to be carried out will concern the design, fabrication and characterization of ceramics, glasses and glass-ceramics for potential use in the biomedical and energy fields, with focus on porous scaffolds for bone tissue engineering and H2 conversion systems, respectively. Materials will be fabricated using additive manufacturing technologies, specifically vat photopolymerization (in this regard, new state-of-the-art facilities have recently been acquired in our research group at DISAT).
	Additive manufacturing technologies, also known as 3D printing, collectively refer to a set of layer-wise deposition methods that typically rely on CAD-CAM approaches for obtaining high-quality, reliable and reproducible products even with a complex shape/geometry and potential for industrial scalability. While additive manufacturing of polymers is relatively easy and popular due to the low temperatures required to obtain processable polymer-only inks, using similar technologies to fabricate ceramic or glass products is indeed more challenging but, on the other hand, allows for high-quality results that would not be achievable through conventional methods. Furthermore, the implementation of 3D printing enables addressing some crucial concerns related to the environment and sustainability, including the minimization of resource depletion and waste production/disposal. In this regard, lithography-based methods allow obtaining the best spatial resolution among the currently available 3D-printing techniques. The latest evolution of stereolithographic methods is based on digital light processing, which relies on a dynamic mask to polymerise a complete layer of photocurable resin, gluing ceramic or glass particles with each irradiation cycle. Vat photopolymerization has become highly appealing in high-tech fields, such as biomaterials and energy materials, and the general goal of this PhD thesis will be to develop 3D-printed materials and structures for potential use in these strategic sectors. With regard to the first topic, bioactive glass-based porous scaffolds will be

Objectives	developed for bone tissue engineering applications. Special care will be devoted to the optimization of the 3D architecture of the scaffolds by implementing and fabricating, for example, triply-periodic minimal surface (TPMS) geometries. The scaffolds will be characterized in terms of morphology, overall porous structure, mechanical properties and bioactive potential in vitro (e.g. apatite-forming ability in bio-fluids). Advanced physical characterizations (e.g. permeability), biomechanical modelling and biological testing (studies with living cells or even in animals) may also be envisioned in collaboration with partner Universities, Research Centres or companies, in Italy or abroad, depending on the evolution of the research activity. With regard to the second topic, this research focuses on the development of proton-conducting ceramic components for green hydrogen conversion via Protonic Ceramic Electrochemical Cells (PCECs) operating at intermediate temperatures of 400–600¿°C. Advanced fabrication techniques, including 3D printing by Digital Light Processing (DLP), robocasting, and spray coating, are employed to produce BaZrO3- and BaCeO3-based perovskites, such as BZCY and BZCYYb. Additive manufacturing enables innovative geometries that improve proton conductivity, mechanical stability, and seamless integration with other cell components, offering significant potential for enhanced performance and durability. The manufactured devices will undergo comprehensive electrochemical characterization, including impedance spectroscopy (EIS), i–V curves, and long-term testing to evaluate efficiency and reliability. Furthermore, specific stages of the manufacturing process and device characterization will be supported through international collaborations, fostering knowledge exchange across research facilities in Italy and abroad.

Skills and competencies for the development of the activity	Knowledge about ceramics and glass science, bulk and porous materials fabrication, additive manufacturing technologies applied to ceramics and/or glasses Knowledge about printable glass and ceramics-based ink characterization (e.g. rheological measurements). Knowledge about materials characterization (e.g. thermal analyses, morphology, mechanical behaviour…). Knowledge about modelling/imaging and CAD software. General skills: ability of (i) planning and implementing the research activity beyond the state of the art, (ii) organizing the experimental activity, (iii) critically interpreting the results, (iv) working in a research team.