Project 3.4 Artificial intelligence-assisted 3D digital manufacturing of functionally graded materials: towards the next generation of porous materials.

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Background:

Porous materials – also referred as cellular materials – are a class of materials that contains voids (i.e. pores) within their 2D or 3D structures. The introduction of a macro-porosity – i.e. voids having dimensions larger than 1 micrometer – within a dense material structure dramatically alters its qualities, generally resulting in a positive extension of the range of its physical properties. The manufacturing of porous materials has boomed during the last century thanks to the technological advances and, most importantly, the invention of plastics (most of the porous materials nowadays produced are made of synthetic polymers). Porous materials offer unique structural and functional properties compared to their fully-dense counterpart. As one could easily infer, these properties are intertwined, being influenced not only by the nature of the material (i.e. polymeric, ceramic, metallic etc.), but also by its 3D micro-architecture. With these premises, it should not be surprising that researchers in the last fifty years have spent a great deal of work to develop several technologies to process not only a large variety of materials but also to refine the control over their 3D porous architectures. A first step towards a better control of the architecture and, in turn, of the physical properties of the ensuing materials has been made during 80s with the introduction of compositional or micro-architectural (e.g. porosity or pore size) gradients along at least one material direction. These materials are referred as functionally graded materials (FGMs). Among them, those characterized by a porous structure form another sub-class of materials named porous functionally graded materials (pFGMs).

Thepossibility to have either compositional, micro-architectural or both kind of gradients within a single material has the potential to generate limitless number of new materials with tailored and unprecedented structural and functional properties. However, as one could imagine, fabricating pFGMs is really a daunting task. Our project can be framed in this revolutionary context, aiming at exploring the most advanced manufacturing, designing and informatic tools to fabricate a new generation of porous materials with tailored and unprecedented physico-chemical properties.

Aim:

The goal of the project is the development of new tools for the design and manufacturing of 3D porous functionally graded materials (pFGMs) that exhibit tailored mechanical properties, in particular pre-designed energy absorption profiles. The ability of controlling the energy absorption of graded materials is of critical importance in a vast range of industrial applications that span from aerospace and construction to transportation and bioengineering. However, due to the intrinsic complexity of pFGMs and the lack of a comprehensive model for such material design, researchers working in the field have limited possibilities and often prefer to proceed with empirical trial-and-error approaches. Here, we propose a new approach towards the design and fabrication of pFGM aimed at i) developing efficient in silico (numerical) modelling of such complex materials enabling the design of porous structures with required mechanical properties, and ii) simplifying/extending the manufacturing procedures.

The approach comprises of three steps:

- IN-SILICO MODELLING aimed at identifying — by means of finite element modelling (FEM) coupled with search algorithms based on artificial intelligence (AI) — the 3D architectures and materials optimizing energy absorption.

- DIGITAL MANUFACTURING employing innovative 3D printing technologies of dispersed materials such as emulsions or foams based on the use of reconfigurable microfluidic printing heads allowing to control the droplet/bubble size on-demand; the combination of 3D printing and microfluidics will allow unprecedented control over local material properties (pore size, pore connectivity, material composition etc.);

- ADVANCED MATERIAL CHARACTERIZATION using state-of-the-art technologies including mechanical testing coupled to high-resolution micro computed tomography.

Requirements:

Ideal candidate has a Master degree in materials science, chemistry, physics, or similar fields. Prior research experience in 3D printing or porous material synthesis via foam / emulsion templating will be considered a plus.

Candidate must meets any of the following criteria:

- is a student of a full-time first or second-cycle degree programme or uniform Master's studies at a university in Poland;
- is a participant in a doctoral programme;
- is a doctoral candidate at a doctoral school.

Candidates can simultaneously apply for Warsaw PhD School in Natural and BioMedical Sciences in order to meet the criteria.