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Editorial

Additive Manufacturing of Scaffolds for Bio-implants

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Editorial

One of the critical challenges in artificial implant materials is the design of scaffolds and implants that mimic the physical and mechanical behavior of the human bones. Since the introduction of ceramic-based artificial bio-implants in 1960s, the possibility of the usages of metallic biomaterials, e.g., titanium and its alloys, stainless steel and cobalt-chromium alloys have been growing rapidly in biomedical applications [1,2]. In early stages, some physical properties (e.g. biocompatibility) and chemical reactivity (e.g. non-toxicity) are considered as the key selection criteria for application suitability. However, nowadays some additional physical and mechanical properties that are required to imitate the growth of cells and tissues as in the natural bones are taken as important factors [2-4]. This creates a new challenge of the artificial implant materials made of these metals and their alloy is to adjust the mechanical properties especially stiffness of this bio-implants. In general, the artificial implant materials have high stiffness than that of the natural bones as presented in Figure 1, leading to stress-shielding - a major cause for bone resorption and premature failure of such implants [5]. According to Wegst et al. [5] investigation, the stiffness of widely used metallic implants i.e., stainless steel, Co-Cr, Ti alloys are about 180GPa, 210GPa and 110GPa, respectively while the stiffness of cortical bones is about 10-30GPa. Therefore, to minimize the stress-shielding effect at the bone-implant interface, the stiffness of the artificial implant materials to be adjusted as close to the human cortical bones. To match the material properties of artificial bio-implants, many studies have tried to develop porous scaffold materials which could be both bio-compatible and mech-compatible. However, the strength of scaffolds decreases significantly with the porosity, and may become very low than that of human bone when with the porosity is very high. This creates a new potential problem. Therefore, it has been challenging to develop both bio-compatible and mech-compatible scaffolds for bio-implants. Thus, a promising technique for manufacturing bone substitute scaffolds thus emerges: to match the hierarchical structure of the natural tissues because this manufacturing technique will tolerate to custom design property at various structural length scales so that the scaffolds can fulfil the bio-compatible and mech-compatible requirements.

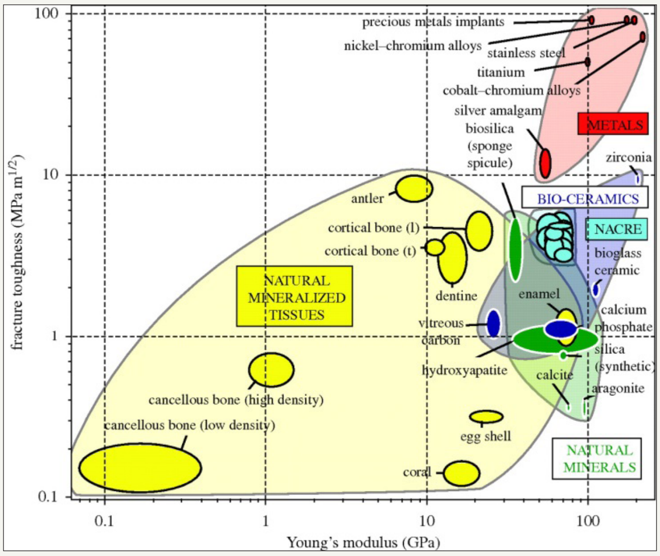

Figure 1: A material property chart showing fracture toughness plotted against Young's modulus biomaterials [5].

Traditional manufacturing techniques for preparation of scaffold materials include liquid state processing (e.g., freeze casting, direct foaming, sol-gel, etc.), solid state processing (e.g., powder metallurgy, multi-pass extrusion and sintering of powders etc.) and vapour deposition [6,7]. Notwithstanding the advancements that have attained in scaffolds manufacturing, the control over scaffolds structure using these traditional methods is highly process dependent. Rapid prototype additive manufacturing technology has been considered as a feasible alternative for fabrication of desired scaffolds structure that mimic the natural bones.

Additive manufacturing (AM) technique creates three-dimensional (3D) components by successively adding thin layer of materials followed by a computer-aided design (CAD) model. After preparing the first layer, a new layer of material is deposited on the top and this process is repeated until manufacture the final product according to Figure 2 [8-10]. Heinl et al. [11] manufactured cellular type Ti foams using prototype AM technique at a vacuum pressure (10^{-4} to 10^{-5}mbar) to avoid contamination due to oxygen or nitrogen. The manufactured interconnected porous structures with different volume percent of porosities (25%, 38%, and 60%) were well controlled the stiffness as close to the natural bones. Furthermore, Harrysson et al. [12] fabricated hip stem using AM technique that well match the physical and mechanical properties as close to natural bones. The low stiffness hip-stem mimics the stiffness of human bone to reduce stress shielding and bone remodeling.

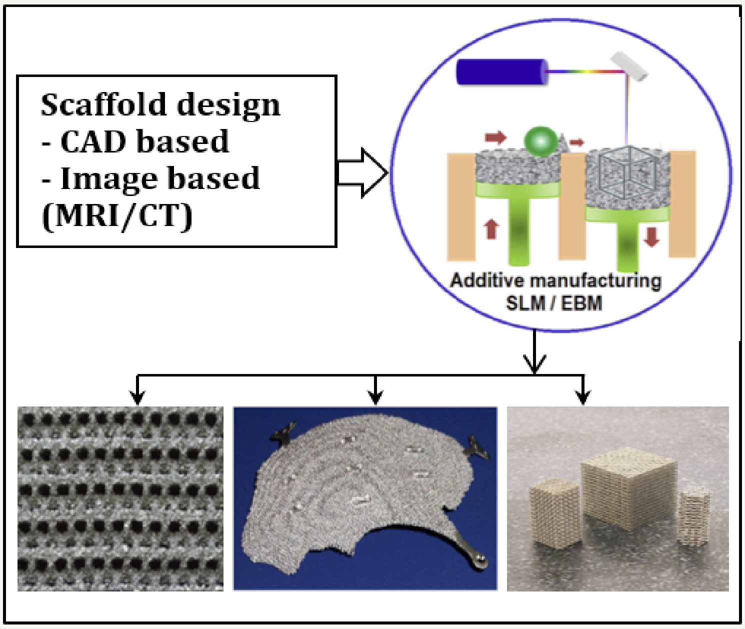

Figure 4: Display of internal filling ratio in parts.

Overall, even though a lot of progressive results have been reported for AM technique of manufacturing scaffold materials, it is still in its early stages. Multidisciplinary research will be essential to minimize the challenges (e.g., excess melt pool temperature, undesirable microstructure, residual stress, surface roughness and local porosity) and completely utilized the AM technique for manufacturing the desired scaffolds in biomedical applications.

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