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A Short Review on Bio-compatible/Bio-degradable Photopolymers for Stereolithography Bio-3D Printing

Yih-Lin Cheng, Freeman Chen, Aamer Nazir* and Jeng-Ywan Jeng

Department of Mechanical Engineering, National Taiwan University of Science and Technology, Taiwan

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***Corresponding author:** Aamer Nazir, Department of Mechanical Engineering, National Taiwan University of Science and Technology, #43, Section 4, Keelung Rd, Taipei 106, Taiwan, Email: aamernazir.an@gmail.com

Abstract

One of the important procedures in Bio-3D printing is to print/fabricate the scaffold for tissue engineering. A scaffold is a porous biomedical implant, which provides a short-term support to seeded cells in order to direct the formation of new tissues. The scaffold must be non-toxic, bio-degradable, biomechanical properties, specific chemical composition and have a precisely defined pore size and geometry. For this reason, it is very important to fabricate scaffolds with high precision. In this review, 3D printing of biomedical scaffolds using photo polymerization process is briefly reviewed. As per requirements of tissue engineering, the choice of best 3d printing method and photopolymer were discussed. Apart from this bio-3D printing application, the bio-compatible photopolymer will be widely used in dental application, like the direct printing of aligner in orthodontics and temporary denture fabrication.

Keywords: Tissue Engineering; Bio-compatible; Photopolymers; Stereolithography

Abbreviations: FDM: Fused Deposition Modelling; SLS: Selective Laser Sintering; 3DP: Three Dimensional Printing; LS: Laser Stereolithography; AM: Additive Manufacturing; DLP: Digital Light Projection; UV: Ultra-Violet;SL: Stereolithography; PCL: Polycaprolactone; PCL-DA: Polycaprolactone-Diacrylate; PGSA: Polyglycerol sebacate Acrylate

Introduction

In biomedical engineering, the tissue engineering is a rapidly growing multidisciplinary research area to reconstruct organs and tissues [1] by using a biodegradable and biocompatible scaffolding structure. As described early, it is very important to fabricate scaffolds with high precision. The scaffold has been fabricated using various 3D printing techniques such as FDM extrusion, SLS, 3DP. In these methods, the smallest printable size is 50-200 µm which is too large to be used for some biomedical implant or certain tissue engineering applications [2].

Stereolithography

LS is presently one of the most rapidly growing AM technique widely used in different areas of science and technology, engineering and biomedicine. LS is a polymerization process in which the spatially controlled solidification of resin is achieved using various types of laser radiations. The key benefit of using LS are high spatial resolution (~0.1 mm), fast manufacturing speed, high precision and a large variety of materials [3]. Commercially available LS 3D printers can print parts with an accuracy of 20µm. A recently developed two-photon polymerization LS setup can build micron-sized structures with sub-micron accuracy [4].

DLP is another emerging SL technique in which an array of millions of independently rotatable mirrors is used to project the light in order to polymerize photosensitive materials layer-by-layer under the action of UV or visible light [5]. LS is one of the best choice to fabricate scaffolds with required size and resolution but expensive. In a recent study, Jeng et al. [6] employed projection based SL technique and precisely printed biocompatible porous matrix structures for tissue engineering.

For 3D bio-printing of implants using Vat photo polymerization technology, the biological material need to benon-toxic, biocompatible and biodegradable photopolymer. Therefore, it is not easy to develop photopolymers for scaffolds and medical related applications. That's why they are rarely available commercially. There are biocompatible/biodegradable polymers available, but mostly are not photo curable and need to be modified to make it photo curable. The photopolymer changes its structural properties when exposed to light, mostly cured by UV light. Photo polymeric materials consists of three main components including monomers (long-chain molecules), Photo initiators (split into radicals after energy input) and additives (UV stabilisators) [7]. A very limited number of photo-curable biocompatible materials are available for scaffold 3d printing. We are capable to describe only a few of them.

Bio-Compatible Photopolymers

PCL is a semi-crystalline polymer of aliphatic polyester group, which is a thermoplastic biodegradable material derived from crude oil by ring opening polymerization. Due to excellent biodegradability, high flexibility and biocompatibility, PCL is widely used in biomedical implants. In 2002, Kweon et al. [8] used PCL-diol with a molecular weight of 2000 for the preparation of PCL-DA through a series of chemical reactions. At Massachusetts Institute of Technology (MIT), another vital material PGSA was prepared in 2007, which is based on a chemical change of PGS with acryl ate moieties. Instead of PGS, PGSA is a rapidly cured material to form polymeric networks at ambient temperature. In a most recent research, Cheng et al. [9] prepared a photo-curable scaffold material by mixing PCL-DA and PGSA and concluded that the new material had improved mechanical properties compared to individuals.

Conclusion

Though several AM techniques are used for bio-3DP applications, Stereolithography setup can print porous biocompatible/biodegradable scaffolds with required size, resolution and surface finish. The bio-compatibility of the photopolymer is one of the most concerns in this VAT process.

PCL and PGSA are photo-curable non-toxic materials with excellent biocompatibility and mechanical properties, however, new materials can be made by combining liquid acrylated polymer precursor with other acrylated molecules for a number of potential biomedical applications. Definitely, there will be more new bio-compatible photopolymer material will be investigated to meet the application of bio 3D Printing and even bio-medical device like dental application.

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