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Procedia Chemistry 19 (2016) 410 – 418

Procedia Chemistry

5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP), 4-6 August 2015

Evaluation of UV-crosslinked Poly(ethylene glycol) Diacrylate/Poly(dimethylsiloxane) Dimethacrylate Hydrogel: Properties for Tissue Engineering Application

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Abstract

Hydrogels are widely used as biomaterials in biomedicalfields such as in drug delivery systems, cell-based therapies, wound dressing, implant materials for soft tissue and anti-adhesion materials due to its unique characteristics.The aim of this project is to fabricate UV-crosslinked hydrogel film with the tailored chemical and physical properties that can be utilized as scaffold. Three series of UV-crosslinked poly(ethylene glycol) diacrylate/ poly(dimethylsiloxane) dimethacrylate (PEGDA/PDMS-MA) hydrogels were fabricatedby exposing the precursor solutions under UV chamber that provides a spectral range of UVA at average intensity of $40 W/cm^2$. Equilibrium swelling ratio (ESR) was found higher in the UV-crosslinked hydrogels that exposed to the UV at shorter time, with lower loading of PDMS-MA, and higher molecular weight of PEGDA. The concentration of photoinitiator was found to haveinsignificant effect on ESR%. Whereas, dynamic contact angle (DCA) measurement revealed that the hydrophilicity was higher forPEGDA UV-crosslinked hydrogels with higher ratio. Besides, dynamic mechanical analysis (DMA)showed that the incorporation of PDMS-MA reduced the average value of compressive modulus of the UV-crosslinked hydrogels. Differential scanning calorimetry (DSC) analysis showed that lower glass transition temperature (T_g) of PDMS-MA could be related to the reduction of stiffness in UV-crosslinked hydrogels. It was found that the fabricated UV-crosslinked hydrogels were suited to cartilage tissue engineering application due to similar properties to the cartilage tissue.

Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia

*Keywords:*UV-crosslinked; Poly(ethylene glycol) diacrylate; Poly(dimethylsiloxane) dimethacrylate; Hydrogels; Tissue engineering

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Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia
doi:10.1016/j.proche.2016.03.032

1. Introduction

Tissue engineering (TE) is the use of cell, engineering, materials method and suitable biochemical route paths to replace and improve biological functions. According to Lavik & Langer, a three-dimensional polymeric scaffold is often used to create an environment in which living cells can attach, proliferate, differentiate, and ultimately produce new extracellular matrix[1]. Synthetic polymeric hydrogels have been widely used as tissue engineering scaffolds due to higher water absorption capacity, long service life and wide varieties of raw chemical resources, compared to natural polymers[2].

Hydrogel products constitute a group of polymeric materials, the hydrophilic structure of which renders them capable of holding large amounts of water in three dimensional networks. Extensive employment of these products in a number of industrial and environmental areas of application is considered to be of prime importance. Hydrogels are widely used as platforms in biomedical applications such as drug delivery systems, cell-based therapies, wound dressing and anti-adhesion materials.

The three-dimensional (3-D) network of hydrogel can be fabricated by means of physical or chemical crosslinking method. Chemical crosslinking is often used where stable covalent bonds is formed between polymer chains. The formation of these permanent bonds is mediated by suitable crosslinking agents. Particularly, photo-crosslinking, a type of chemical crosslinking, is conducted in the presence of an UV-radiation, crosslinking agents and chemical photoinitiator. The aim of this project is to fabricate a two-dimensional (2-D) hydrogel samples via UV-radiation with tailored chemical and physical properties that can be used as a scaffold material in a specific tissue engineering application. Hydrogel used in this project is a copolymer system that formed as a result of photo-polymerization of UV-crosslinked poly(ethylene glycol) diacrylate (PEGDA) with poly(dimethylsiloxane) dimethacrylate (PDMS-MA) in the presence of 2,2-dimethyl-2-phenyl-acetophenone (DMPA) as photoinitiator.

PEGDA was selected in this project because the material is highly hydrophilic, biocompatible[3,4], non-toxic and poorly immunogenic[5]. One of the highly desired properties is its inherent resistance to protein adhesion that mostly cannot be found in other hydrophilic materials. This biological property is attributed to the highly hydrated molecules in aqueous solution that allows little time for protein attachments, and the surrounding water molecules hinder other molecules to come closer near the polymer surface[5]. The resistance to protein adhesion allows PEGDA-based hydrogels to act as blank slate for cell adhesion, proliferate and grow[6]. Due to these properties, PEGDA is widely investigated and recognized as one of the most successful scaffolding material for tissue engineering application.

However, one of the main disadvantages of using PEGDA is its low mechanical properties, e.g. soft and fragile[7]. Therefore, PDMS-MA polymer was copolymerized with PEDGA in this project in order to improve the flexibility of the PEGDA. However, the ratio of PDMS-MA: PEGDA is very critical due to the hydrophobicity of PDMS-MA could reduce the biocompatibility of cell-hydrogel scaffold.

In this research work, four various parameters were studied to find the optimum properties of UV-crosslinked hydrogels. Furthermore, the data established or obtained from this project could possibly be used in 3-D printing to fabricate hydrogel scaffolds with specific pores shape and size tailored for a specific tissue engineering application.

Nomenclature

M_c	Original homo- or copolymer molecular weight before crosslink
M_n	Molecular weight of polymer chains between two crosslinks
Q_m	Mass swollen ratio
T_g	Glass transition temperature
W_d	Weight of dried gels
W_s	Weight of swollen gel in equilibrium