Progress in Materials Science 83 (2016) 191–235

Contents lists available at ScienceDirect

Progress in Materials Science

journal homepage: www.elsevier.com/locate/pmatsci

Surface functionalization of biomaterials by radical polymerization

Tian Zhou [a], Yizhou Zhu [a], Xia Li [a], Xiangmei Liu [a,*], Kelvin W.K. Yeung [b], Shuilin Wu [a,*], Xianbao Wang [a], Zhenduo Cui [c], Xianjin Yang [c], Paul K. Chu [d]

[a] *Hubei Collaborative Innovation Center for Advanced Organic Chemical Materials, Ministry-of-Education Key Laboratory for the Green Preparation and Application of Functional Materials, Hubei Key Laboratory of Polymer Materials, School of Materials Science & Engineering, Hubei University, Wuhan 430062, China*
[b] *Division of Spine Surgery, Department of Orthopaedics & Traumatology, Li Ka Shing Faculty of Medicine, The University of Hong Kong, 999077, Hong Kong, China*
[c] *School of Materials Science and Engineering, Tianjin University, Tianjin 300072, China*
[d] *Department of Physics & Materials Science, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China*

ARTICLE INFO

Article history:
Received 28 December 2015
Received in revised form 21 March 2016
Accepted 23 April 2016
Available online 23 April 2016

Keywords:
Surface functionalization
Polymerization
Surface chemistry
Biomaterials
Tissue engineering
Biomimetic

ABSTRACT

One effective strategy in the field of biomaterials is to develop biomimetic interfaces to modulate the cell behavior and promote tissue regeneration and surface modification is the best way to obtain biomaterial surfaces with the desired biological functions and properties. Surface radical polymerization offers many advantages compared to other methods, for instance, low cost and simplicity, ability to control the surface chemistry without changing the properties of the bulk materials by introducing high-density graft chains and precisely controlling the location of the chains grafted to the surface, as well as long-term chemical stability of the chains introduced by this method due to the covalent bonding. Because of the precise control of the macromolecules and easy preparation, controlled/living radical polymerization has been widely used to modify biomaterials. There are three main techniques: atom transfer radical polymerization (ATRP), nitroxide-mediated polymerization (NMP), and reversible radical addition-fragmentation chain transfer (RAFT) polymerization. Some other grafting methods such as plasma-induced polymerization, irradiation-induced polymerization, and photo-induced polymerization also have great potential pertaining to functionalization of biomaterials and tailoring of surface chemistry. This paper summarizes recent advances in the various grafting polymerization methods to enhance the surface properties and biological functions of biomaterials.

Contents

---

* Corresponding authors.
E-mail addresses: liuxiangmei1978@163.com (X. Liu), shuilin.wu@hubu.edu.cn, shuilin.wu@gmail.com (S. Wu).

http://dx.doi.org/10.1016/j.pmatsci.2016.04.005
0079-6425/

1. Introduction

1.1. Necessity for surface modification for biomaterials

Biomaterials are widely used in biomedical devices or biological products in clinical biological diagnosis, treatment/repair, replacement of damaged tissues and organs, and enhancement of functions [1,2]. However, some interactions between the biomaterials and biological tissues may undermine the ability of these materials to carry out their designed biological functions sometimes even producing adverse effects. For instance, the contact between synthetic implants and blood often leads to protein adsorption, platelet adhesion, and concomitant activation of the body's defense system, consequently inducing thrombosis and pulmonary thromboembolism [3–6]. Post-operative implant-related bacterial infection has been reported to result in implant failure in 2%, 5% and 14% of implants for bone fracture fixation, total hip replacement, and knee replacement, respectively [7–9]. Hence, a suitable surface design is crucial to more successful application of biomaterials because surfaces are in direct contact with the biological media [10]. Before biological events take place in response to the biomaterials, cells detect the surface affinity through the recognization of the filopodia of cellular transmembrane proteins. Many studies confirm that both the surface structure and surface chemistry influence the initial cell behavior such as adhesion, migration, proliferation, and differentiation on biomaterials [11–13].

It is important to perform surface functionalization to endow currently available biomaterials with specific and desirable functions. Currently, surface modification can be used to modulate the surface properties of substrates such as adhesion, wettability, biocompatibility, and antifouling [7–9,14]. Radical polymerization as one of surface modification methods is particularly useful because it can easily and controllably introduce high-density graft chains and graft them in a precise manner without affecting the original properties of substrates [15]. Moreover, covalent attachment of graft chains onto the surface can minimize chain delamination improving the long-term chemical stability of the introduced chains and it is possible to graft different polymers onto the same substrate [16].

1.2. General background on grafting polymerization

1.2.1. "Grafting to" and "grafting from" approaches

Polymers can be grafted onto the surface to produce functional polymer brushes to tailor the surface properties and there are two general ways to prepare polymer brushes: physisorption and covalent attachment [17–19]. Polymer physisorption is a reversible process in which the polymer chains with the sticking segments adsorb onto a suitable substrate but such polymer brushes are often unstable. Stamm et al. reported that poly(N-isopropylacrylamide) (NIPAM) brushes were