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Bioinspired polysaccharide-based nanocomposite membranes with robust wet mechanical properties for guided bone regeneration

Jian-Hong Xiao[1,2,†], Zhen-Bang Zhang[1,†], JiaHao Li[3,†], Si-Ming Chen[1,*], Huai-Ling Gao[1,3], YinXiu Liao[4], Lu Chen[4], ZiShuo Wang[4], YiFan Lu[2], YuanZhen Hou[3], HengAn Wu[3], DuoHong Zou[2,4,*] and Shu-Hong Yu[1,5,*]

[1]Department of Chemistry, New Cornerstone Science Laboratory, Institute of Biomimetic Materials & Chemistry, Anhui Engineering Laboratory of Biomimetic Materials, Division of Nanomaterials & Chemistry, Hefei National Research Center for Physical Sciences at the Microscale, University of Science and Technology of China, Hefei 230026, China; [2]Department of Dental Implant Center, Stomatologic Hospital and College, Key Laboratory of Oral Diseases Research of Anhui Province, Anhui Medical University, Hefei 230032, China; [3]CAS Key Laboratory of Mechanical Behavior and Design of Materials, Department of Modern Mechanics, CAS Center for Excellence in Complex System Mechanics, University of Science and Technology of China, Hefei 230027, China; [4]Department of Oral Surgery, College of Stomatology, National Clinical Research Center for Oral Diseases, Shanghai Key Laboratory of Stomatology, Shanghai Research Institute of Stomatology, Shanghai Ninth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Shanghai 200001, China and [5]Institute of Innovative Materials (I2M), Department of Chemistry, Department of Materials Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China

*Corresponding authors. E-mails: smchentj@ustc.edu.cn; zouduohongyy@126.com; shyu@ustc.edu.cn

†Equally contributed to this work.

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ABSTRACT

Polysaccharide-based membranes with excellent mechanical properties are highly desired. However, severe mechanical deterioration under wet conditions limits their biomedical applications. Here, inspired by the structural heterogeneity of strong yet hydrated biological materials, we propose a strategy based on heterogeneous crosslink-and-hydration (HCH) of a molecule/nano dual-scale network to fabricate polysaccharide-based nanocomposites with robust wet mechanical properties. The heterogeneity lies in that the crosslink-and-hydration occurs in the molecule-network while the stress-bearing nanofiber-network remains unaffected. As one demonstration, a membrane assembled by bacterial cellulose nanofiber-network and Ca^{2+}-crosslinked and hydrated sodium alginate molecule-network is designed. Studies show that the crosslinked-and-hydrated molecule-network restricts water invasion and boosts stress transfer of the nanofiber-network by serving as interfibrous bridge. Overall, the molecule-network makes the membrane hydrated and flexible; the nanofiber-network as stress-bearing component provides strength and toughness. The HCH dual-scale network featuring a cooperative effect stimulates the design of advanced biomaterials applied under wet conditions such as guided bone regeneration membranes.

Keywords: bioinspiration, heterogeneous crosslink-and-hydration, dual-scale network, nanocomposite membrane, wet mechanical properties, guided bone regeneration

INTRODUCTION

With increasing demand for the repair of tissue defects in the clinic, various biomaterials have been developed to provide specific biological functions [1–6]. Among them, membrane materials are particularly important for *in vivo* treatment, e.g. hydrogel membranes for the repair of damaged tendons [7,8], antiadhesion membranes for the prevention of postoperative tissue adhesion [7,9,10], as well as barrier membranes for guided bone regeneration (GBR) [11–13]. Currently, clinically used biomedical membranes are mainly derived from animal acellular tissues (such as small intestinal submucosa and porcine dermis) [14–16] and collagen products like Bio-Gide membrane (the current gold standard in the clinic for GBR) [17]. However, animal-derived membranes may cause risks of immune rejection *in vivo* due to incomplete decellularization [16,18]. In recent years, many polysaccharides (such as cellulose, sodium alginate (SA), chitosan (CS), and chitin) have attracted increasing attention in the fabrication of new-style biomedical membranes due to their excellent biocompatibility, non-toxicity, bioactivity, and biodegradability [19–22]. For instance, SA and CS, two common natural polysaccharides derived from algae and crustacean shells, respectively, have been extensively utilized for tissue engineering and wound dressings, yet their mechanical properties are less satisfactory [21,23–30].

To expand the applications of these polysaccharide-based membranes, nanofillers