Chapter 53
Introduction to Bio-Inspired Hydrogel and Their Application: Hydrogels

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ABSTRACT

This chapter discusses the synthesis, characterization, and application of covalently and physically cross-linked polymers for biomedical application. This class of molecule is called hydrogels and is defined by a covalently bonded polymer matrix that can hold at least two times its mass in solvent. Hydrogels are general classes of polymeric systems that have further subgroups: semi-interpenetrating networks (SIPN), interpenetrating networks (IPN), block co-polymers, and grafted. The different methods to synthesize these hydrogels are discussed. Specific characterization techniques to evaluate the properties and functionalities of the hydrogels are also described in the chapter. Next, the practical and industrial applications of the hydrogels are detailed. Throughout this chapter we will highlight the different synthesis methods, characterization techniques, and current uses of hydrogels. The chapter will be a particularly useful overview and introduction for graduate students and researchers aiming to work in the field of hydrogels.

1. HYDROGEL

Hydrogels are polymers that can hold water without dissolving. In general, hydrogels show properties of the polymers that make them up (Peppas, Hilt, Khademhosseini, & Langer, 2006). Therefore, a basic understanding of polymers is essential to synthesize hydrogels with desirable material properties. Polymers have a backbone and side chains which contribute to the intrinsic property of the polymer. The backbone is the covalently bonded portion of the chemical structure. The part that is not covalently bonded is called side chain. Figure 1 shows the monomer on top and the corresponding polymer at the bottom. The side chains of the polymer are shown in black while the backbone is shown in blue (Figure

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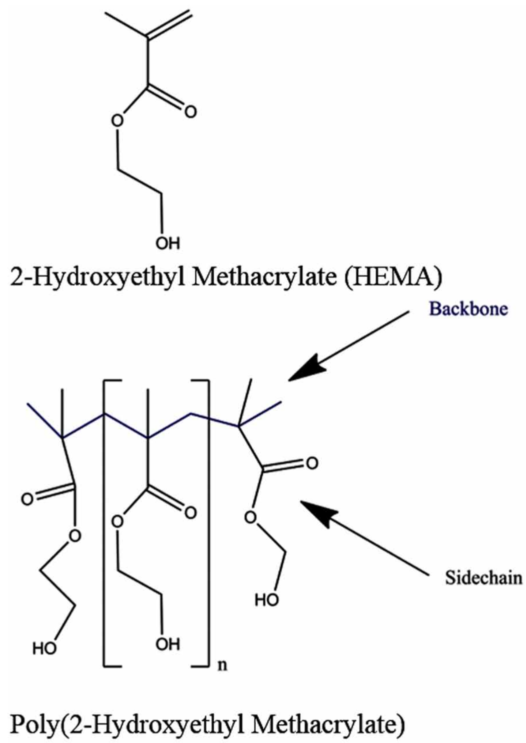
Figure 1. Picture of a HEMA monomer (Top) and polymer (Bottom)



1, bottom). The length of the polymer with average molecular weight $\overline{M}_n$ is denoted by the subscript n. Therefore, the molecular weight increases with length of the polymer (n). Typically, molecular weights of polymers are determined by gel permeation chromatography (GPC), though small molecular weights can be found by using nuclear magnetic resonance (NMR).

The orientation of these side chains are defined by their tacticity and can be measured by either 1D NMR (Wu & Sheer, 1977) or 2D NMR(Schilling, Bovey, Bruch, & Kozlowski, 1985) TOF-SIMS(Vanden Eynde, Weng, & Bertrand, 1997), or Roman/IR (Dybal & Krimm, 1990). Isotactic polymers have the same orientation of all side chains. Syndiotactic polymer means alternate orientations of the side chains whereas Atactic polymers show pure random orientation of the side chain. (Young & Lovell, 2011) These side chain orientations are key influence on the crosslinking of different polymers to form hydrogels.

Hydrogels are 3D networks of polymers that can absorb water by weight and was discovered by Bemmelen in 1894 (van Bemmelen, 1894). Polymer hydrgles were introduced later in the 1960s (Wichterle & Lim, 1960). The water absorption capacity of the hydrogels is facilitated by the hydrophilic functional groups attached to the polymer backbone as well as the degree of crosslinking (da Silva & Ganzarolli de Oliveira, 2007; Fundueanu, Constantin, & Ascenzi, 2009; Zhou et al., 2013). The cross-linking between polymer chains is primarily responsible for the ability of hydrogels to resist dissolution. Therefore, the type of cross-link is an important parameter for the hydrogels. Hydrogels can be cross-linked via physical methods like ionic bonding (Gierszewska-Druzynska & Ostrowska-Czubenko, 2011a), physical entanglements, metal-organic ligand complexation (Datta, 2007; Nonaka, Watanabe, Hanada, & Kurihara, 2001), polymer-polymer complexation (Astrini, Anah, & Haryono, 2012; Esser-Kahn, Iavarone, & Francis,