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The Characteristics of the Smart Polymeras Temperature or pH-responsive Hydrogel

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Abstract

Hydrogels have unique swelling behaviour and three-dimensional structure and can be applied in biomedical and tissue engineering fields. Hydrogels also can be prepared by several methods. They are called as smart hydrogels as they able to undergo transitional changes in response to environmental stimuli. One of the stimuli is temperature. The temperature can create changes to the smart polymer as they have a very sensitive balance between the hydrophobic and the hydrophilic groups in their structure. Some hydrogels exhibit a separation from solution and solidification above a certain temperature. This threshold is known as the lower critical solution temperature (LCST). The other stimulus is pH which also can give effect to hydrogel in order to be further applied as drug delivery agents. The main feature of this kind of smart polymer is an ability to receive or release protons which responding to the pH changes. These polymers are polyelectrolyte where containing acid groups or basic groups. Temperature and pH responsive hydrogel is essential and currently investigated in many various applications specifically in drug delivery system due to their unique responsive characteristics.

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1. Smart hydrogel

Recently, hydrogels have been a topic of many researches due to their unique swelling behaviour and three-dimensional (3D) structure and have resembles the physiological environment properties which make them applicable in biomedical and tissue engineering fields. Hydrogels are composed of hydrophilic homopolymer or copolymer crosslinked networks and can swell in the presence of water or physiological fluids[1]. Hydrogels also can be prepared by allowing the polymer solution to gel in situ after photopolymerization, chemical crosslinking, and ionic crosslinking or in response to an environmental stimulus like temperature, pH or ionic strength of the surrounding medium[2].

The stimulus-responsive hydrogels are also known as smart polymers which means they have shown an active response to small signs and changes in the surrounding environment by showing the significant changes in their microstructure as well as in the physiological and chemical properties[3,4]. There are several important features of these smart polymers. Firstly, their macroscopical changes are reversible which means they can change back to their original state with the absent of stimuli[5].Besides that, the others features of smart polymers are listed as below[6]:

- biocompatible
- non-thrombogenic
- flexible
- easy shaping
- easy manufacturing

Generally, hydrogels are regarded as biocompatible materials due to their soft nature and retaining large amount of water which make them similar to natural extracellular matrices[7]. Furthermore, they also have porous structure and along with the water content, they are suitable to accommodate high loads of water soluble compounds[8]. This will make the smart hydrogels can be apply for wide range of biomedical and pharmaceutical applications such as drug delivery, tissue engineering, contact lens and many more.

An injectable hydrogels also have been developed in order to overcome macroscopic hydrogels which need to be administered by surgical intervention. The injectable hydrogels can be administered in a minimum invasion and less in cost as compared to the surgery which also bring inconvenient to the patient. The injectable hydrogels also can be in the clear form of polymer solutions before the administration and then turn into viscoelastic system or gel after responding to the environmental stimuli[9].

2. Temperature stimulus

The temperature can create changes to the smart polymer as they have a very sensitive balance between the hydrophobic and the hydrophilic groups in their structure[10]. The phenomenon of transition from a solution to a gel is usually referred as sol-gel transition as shown in Fig.1. Some hydrogels exhibit a separation from solution and solidification above a certain temperature. This threshold is known as the lower critical solution temperature (LCST). It is also defined as the critical temperature in which the polymeric solution shows a phase separation from one phase or isotropic phase to two phase or anisotropic phase[12]. The polymer is in soluble state below the LCST. When above the LCST, they become increasingly hydrophobic and insoluble, leading to gel formation[13]. In other words, the interaction strengths of hydrogen linkages between the water molecules and the polymer become unfavourable and lead to dehydration and polymer swelling[14]. On the other hand, hydrogels that are formed upon cooling of a polymer solution have an upper critical solution temperature (UCST)[13]. The examples of thermoresponsive polymers are poly(N-isopropylacrylamide) (PNIPAAm) and triple blocks of copolymers polyoxyethylene-polyoxypropylene-polyoxyethylene (PEO-PPO-PEO) also known as Pluronic.