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Hydrogel nanocomposites as remote-controlled biomaterials

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Abstract

Nanocomposite hydrogels are a new class of intelligent materials which have recently attracted interest as biomaterials. In this study, magnetic nanocomposites of temperature-sensitive hydrogels have been developed and demonstrated to be responsive to alternating magnetic fields. Nanocomposites were synthesized by incorporation of superparamagnetic Fe_3O_4 particles in negative temperature-sensitive poly(*N*-isopropylacrylamide) hydrogels. The systems were characterized for temperature-responsive swelling, remote heating on application of an alternating magnetic field and remote-controlled drug delivery applications. The rise in temperature in external alternating magnetic field depends on the Fe_3O_4 particle loading of the system. Preliminary studies on remote-controlled drug release showed reduced release in the presence of an alternating magnetic field.

Keywords: Hydrogel; Nanocomposite; Remote control; Drug delivery; Magnetic

1. Introduction

Hydrogels are cross-linked hydrophilic polymers that can absorb water or biological fluids and swell several times of their dry volume. Due to the high level of water in their composition and their elastic structure, hydrogels are considered as excellent biocompatible materials [1]. There are numerous applications of hydrogels in the medical and pharmaceutical sectors, such as contact lenses, membranes for biosensors, sutures, drug delivery devices, and matrices for the repair and regeneration of tissues and organs [2–4].

Hydrogels can show swelling behavior depending on changes in the external environment. Some of the factors that can affect the swelling of responsive hydrogels include pH, ionic strength and temperature [5]. Hydrogels can also be made to respond to diverse external stimuli, such as light, electric current, ultrasound, and the presence of a magnetic field or a particular molecule. The unique property of responsiveness has resulted in their applications in sensors [6,7], self-regulated and externally actuated intelligent drug delivery systems [8–11] and microfluidic devices [12,13].

Hydrogel nanocomposites have recently attracted considerable attention due to their accelerated response and capability of action at a distance. The properties of the nanocomposites can be easily tailored by manipulating the properties of the hydrogel and the composite material. Hydrogel nanocomposites with magnetic particles have been demonstrated as potential candidates for pulsatile drug delivery and soft actuator applications. Zrinyi and co-workers reported that magnetic composites of poly (vinyl alcohol) undergo quick, controllable changes in response to an applied magnetic field and thus can be used in soft actuator-type applications [14,15]. Further studies on magnetic composites of *N*-isopropylacrylamide (NIPAAm) have shown that magnetic particles do not affect the temperature sensitivity of the hydrogel network, including the lower critical transition temperature (LCST) [16].

One of the first approaches to achieve an externally controlled drug delivery system using biomaterials was by Langer and co-workers [17–20]. They embedded macroscale magnetic beads (~1 mm diameter) in ethylene vinyl acetate along with various macromolecular drugs like insulin. Both in vivo and in vitro studies have shown that application of

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