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Development and characterization of xyloglucan-poly(vinyl alcohol) hydrogel membrane for Wireless Smart wound dressings

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ABSTRACT

Hydrogel-based smart wound dressings that combine the traditional favourable properties of hydrogels as skin care materials with sensing functions of relevant biological parameters for the remote monitoring of wound healing are under development. In particular, lightweight, ultra-high frequency radiofrequency identification (UHF RFID) sensor are adjoined to xyloglucan-poly(vinyl alcohol) hydrogel films to battery-less monitor moisture level of the bandage in contact with the skin, as well as wireless transmit the measured data to an off-body reader. This study investigates the swelling behavior of the hydrogels in contact with simulated biological fluids, and the modification of their morphology, mechanical properties, and dielectric properties in a wide range of frequencies (10^0–10^6 Hz and 10^8–10^{11} Hz).

The films absorb simulated body fluids up to approximately four times their initial weight, without losing their integrity but undergoing significant microstructural changes. We observed relevant linear increases of electric conductivity and permittivity with the swelling degree, with an abrupt change of slope that is related to the network rearrangements occurring upon swelling.

1. Introduction

Chronic wounds and ulcers are particularly distressful for patients and challenging for health care providers and national health provisions [1].

Patients generally suffer for relentless pain, discomfort caused by malodour, need of frequent inspections and medication [2,3]. Moreover, chronic wounds are highly susceptible to infection. Choosing a proper dressing is a challenging aspect of wound care, because there is no single dressing that suits all wounds; indeed, the biochemical healing pattern is dependent on cells type, healing phase and can be complicated by comorbidity.

Protection from infection and traumas is the most fundamental and traditional role of wound dressings in the medical practice [3,4]. In more recent times, further features have been added, such as the ability to provide oxygenation, hydration, absorption of wound fluids and exudates, to release growth factors, to prevent and treat infectious states through the incorporation of anti-microbial agents [5,6].

Hydrogels are optimal candidates as wound dressing materials [7–9]. They are hydrophilic networks with the ability to retain a significant amount of water [10]. Therefore, they can absorb and retain exudates and necrotic tissue, together with the biological components, for example proteinases, that are deleterious for wound healing, while concurrently providing appropriate levels of hydration [11,12]. Indeed, an optimal level of hydration is required for the best wound management; excessive moisture results in maceration, while too little hydration results in wound drying and impaired tissue regrowth [13].

Hydrogel wound dressings are generally non-adhesive to the skin and high conformable, therefore particularly apt to be used in patients with thin or fragile skins [14]. Hydrogels can be self-standing films, coatings of textiles and non-woven mats, or adjoined with other synthetic materials.

The incorporation of diagnostic tools in wound dressings to measure biologically relevant parameters can be of great support for chronic

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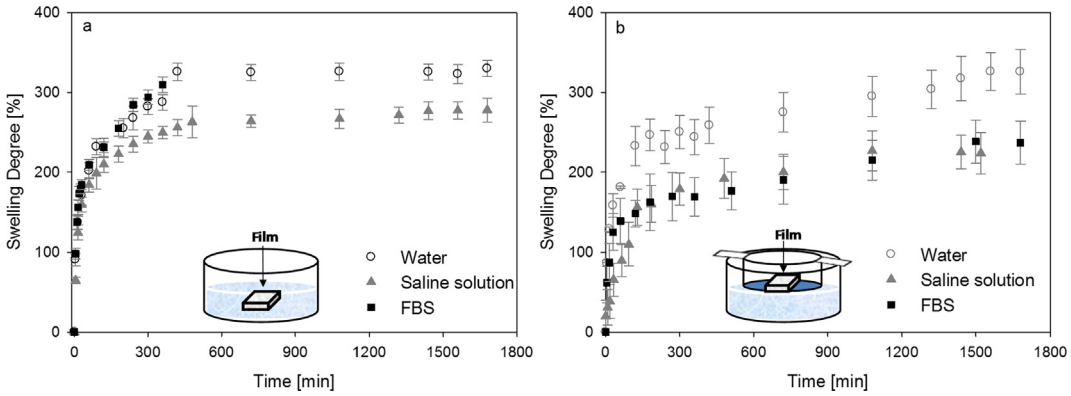

Fig. 1. Swelling behaviour of XG-PVA immersed in (a) or in contact with (b) MilliQ water, 0.9% wt NaCl isotonic solution, and fetal bovine serum (FBS).

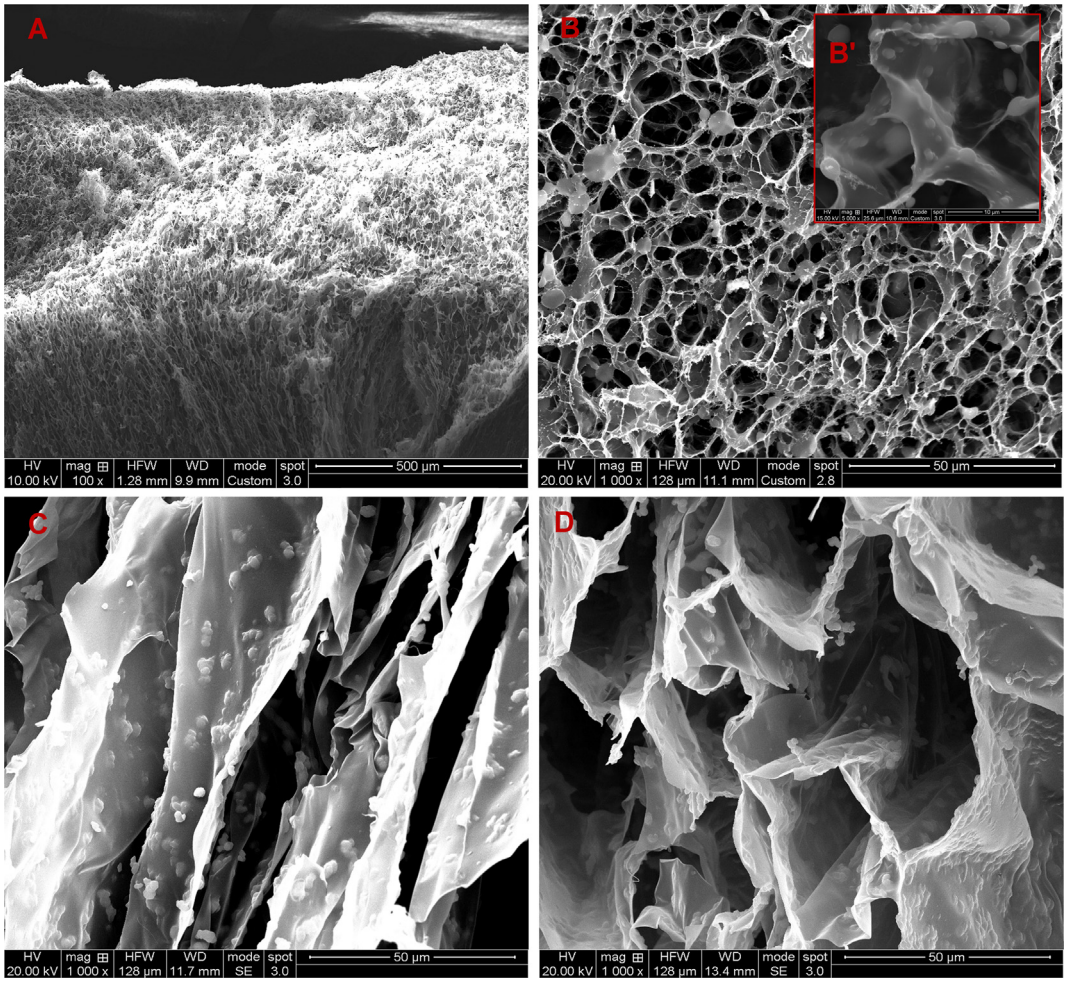

Fig. 2. SEM micrographs of the as-prepared film (A-B, B′) and films incubated for 24 h in water (C, D).

wound care [15,16]. Continuous or semi-continuous interrogations and readouts can reduce the frequency of medical interventions by signalling conditions that require attention, and enable data collection to resolve predictive trends and elaborate more efficacious therapies [16,17].

While technologies that detect specific markers of the wound healing process still need to await a clearer understanding of the chronic wound biochemistry, hydration and temperature are two parameters already identified to be critical for healing [18].

Early detection of bacterial infection is a valuable information to avoid complications. Likewise, indication of absence of infection is also important to avoid unnecessary inspections and dressing changes, and overuse of antibiotics with the connected risk of development of antibiotic-resistant strains [4]. One early indication of bacterial infection is heat production. Therefore, an accurate measurement of temperature can be used to create an alert for a potential infectious state [19].

Ideally, the sensors used for the application should be almost invisible and fully integrated in the dressing [15]. We have already proposed the concept of coupling hydrogel films with inexpensive, lightweight, UHF RFID sensor tags to produce hydrogel wound dressings that can battery-less monitor temperature and moisture level of the bandage in contact with the skin [20], as well as wireless transmit