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Research paper

Comparison of the multiphasic model and the transport model for the swelling and deformation of polyelectrolyte hydrogels

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ABSTRACT

Polyelectrolyte hydrogel is a ternary mixture of water, polymer network and mobile ions. The present paper examined two popular models describing the swelling and deformation behaviors of polyelectrolyte hydrogels, i.e. the multiphasic model and the transport model. The water flow, the network deformation and the ionic diffusion are coupled in the multiphasic model, and the gradient of the fluid pressure is taken as the driving force for the network deformation. However, the water flow is neglected in the transport model with the ionic osmotic pressure taking the role of fluid pressure. Two simplified experiments, i.e. the free swelling of a hydrogel sphere in response to the concentration change of the external salt solution and the bending deformation of a hydrogel strip under an external electric field, are simulated by the two models. Simulation shows that the two models lead to the same predictions for the swelling equilibrium of the hydrogel sphere but different predictions for the swelling kinetics of the hydrogel sphere and the deformation of the hydrogel strip under the external electric field. These are due to the fact that the two models are equivalent in thermodynamic equilibrium situations, but in thermodynamic non-equilibrium situations, the transport model is no longer applicable as it neglects the water flow in the hydrogel and takes the ionic osmotic pressure as a mechanical parameter to play the role of swelling pressure. The present work will be helpful for understanding the hydrodynamics of polyelectrolyte hydrogels and the application of the two models.

1. Introduction

Polyelectrolyte or ionic hydrogel is a ternary mixture of penetrating water, mobile ions and three-dimensional polymer network, which is composed of cross-linked polyelectrolytes. Fig. 1 shows the micro-structure of the polyelectrolyte hydrogel schematically. Due to the presence of the fixed charge groups on the polymer network, ionic concentration

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