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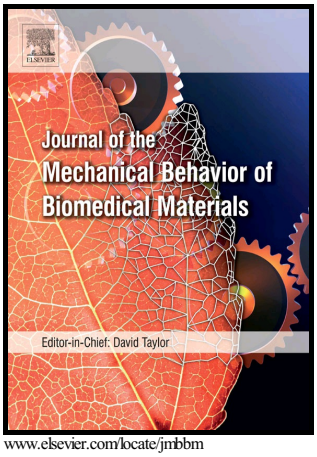

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Modulus of elasticity of randomly and aligned polymeric scaffolds with fiber size dependency

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Abstract. The stiffness of a nano-fibrous scaffold is generally enhanced due to the size-dependency of the thin nanofibers contained in the scaffold. We proposed a model that incorporates size-dependency of single nanofibers to predict the scaffold effective modulus, in which the fibers' random or orientation distribution are considered. In the model the fiber segments between rigid fiber-fiber bonds can be stretching, shearing and bending. Using deformation energy equilibrium between sum of individual fibers and the plate of nano-fibrous scaffold, the scaffold effective modulus was derived explicitly. The model was verified via finite element analysis (FEA) and published experimental results. The parametric studies revealed that the fiber diameter is the dominant parameter to stiffen the scaffold beyond the fiber density and fiber aspect ratio when the fiber diameter is reduced below the onset value of size-dependencies. As a result, the scaffold stiffness can maintain its higher value and lower decrease rate because of the size-dependency with a decreasing diameter of the nanofiber as a result of biodegradation. This inspires the idea of selecting nanofibers near the onset value of size-dependency to obtain a controlled tuning of the scaffold stiffness in the design of novel nano-fibrous scaffolds.

Keywords: *design of scaffolds, nano-fibrous scaffolds, electrospinning, elastic modulus, size-dependent effects*

1. Introduction

Polymeric scaffolds fabricated via electrospinning have fibers of diameters between 100−5000 nm, and depending how the fibers are collected, they are either randomly distributed or aligned in a desired direction in the scaffold (Yoshimoto et al., 2003; Zhong et al., 2006). A new technology of *Biocell* printing for making a scaffold was published recently, which can control the fiber alignment and porosity with micro-fibers (Domingos et al., 2013; Patrício et al., 2013). To support a three-dimensional (3-D) tissue formation, a scaffold must be able to withstand and transfer local stresses uniformly over the implanted area. Further, it should be able to sustain forces arising from say, a large static pull of seeded live cells, loading spikes from the pulsating peripheral blood, dynamic load variations during a scaffold biodegradation as it is progressively replaced by the extracellular matrix, etc. To promote high porosity and adequate pore size for improved cell seeding, diffusion and differentiation in the scaffold structure, nanofibers (dia. < 300 nm) are increasingly preferred as the construction material over macrofibers (dia. > 1000 nm). Kazantseva et al. (2016) recently showed that nanofiber scaffolds may be able to guide stem and cancer cells to act in controlled way *in vitro*. These challenging demands of next generation scaffolds fabricated from nanofibers pose additional difficulties in the structural modeling. Nanofibers have been extensively reported (Shin et al., 2006; Sun et al., 2008; Zussman et al., 2006) via sophisticated single-strand nanofiber experiments to exhibit a dramatic stiffness enhancement as the fiber diameter is reduced. The onset of this