# Actin Networks: Continuum Formulation and Computational Analysis

**Gerhard A. Holzapfel**

Institute of Biomechanics, Graz University of Technology
Kronesgasse 5-I, 8010 Graz, Austria
E-mail: holzapfel@tugraz.at URL: www.biomech.tugraz.at

**ABSTRACT**

The mechanical response of cells is governed by an actin network with high rigidity. In the present talk we introduce an actin network model based on nonlinear continuum mechanics. The overall properties of the actin network are described by a free-energy function $\Psi$ per unit reference volume according to [1]

$$\Psi(\mathbf{C},\mathbf{M}) = n\int_{\Omega}\rho(\mathbf{M})w(\lambda)\mathrm{d}\Omega + (1-\varphi)\Psi_{\mathrm{mat}}(\mathbf{C}), \tag{1}$$

where $\Psi_{\mathrm{mat}}$ is the free energy of the isotropic matrix, $1-\varphi$ is the volume fraction of the isotropic matrix, $\mathbf{C}$ is the right Cauchy–Green tensor, $\mathbf{M}$ is the orientation of a typical filament in the reference configuration according to

$$\mathbf{M} = \sin\Theta\cos\Phi\mathbf{e}_1 + \sin\Theta\sin\Phi\mathbf{e}_2 + \cos\Theta\mathbf{e}_3, \tag{2}$$

with the two spherical polar angles $\Theta$ and $\Phi$ ($\Theta \in [0,\pi]$ and $\Phi \in [-\pi,\pi]$) and the unit rectangular Cartesian basis vectors $\mathbf{e}_1$, $\mathbf{e}_2$, $\mathbf{e}_3$. Additionally, in (1), $n$ denotes the numbers of filaments per unit reference volume, $\rho$ is the relative angular density of filaments, $w$ is the energy of a single filament dependent on the stretch $\lambda\,(>0)$ in the direction $\mathbf{M}$ and $\Omega$ is the unit sphere.

The related stress and elasticity tensors with an extension to include cross-linking and viscoelastic effects were implemented into the finite element analysis program FEAP. One representative numerical example, namely the micropipette aspiration experiment, is analyzed to illustrate the efficacy of this modeling approach. In particular a droplet is modeled as a cross-linked actin envelope with a very soft inside. The pressure difference between the environment and the micropipette is achieved by applying a suction pressure (i.e. a tensile follower load) on those nodes of the axisymmetric setup which lie inside the micropipette. Between the rigid micropipette and the surface of the droplet, a frictionless contact condition is employed.

# References

[1] G.A. Holzapfel, M.J. Unterberger and R.W. Ogden, An affine continuum mechanical model for cross-linked F-actin networks with compliant linker proteins. *J. Mech. Behav. Biomed. Mater.* 38:78–90, 2014.

[2] G.A. Holzapfel and R.W. Ogden, Elasticity of biopolymer filaments. *Acta Biomater.* 9:7320–25, 2013.