8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

ELECTROACTIVE POLYMERS - BASICS, MODELING AND APPLICATIONS

Thomas Wallmersperger

Institut für Statik und Dynamik der Luft- und Raumfahrtkonstruktionen
Universität Stuttgart, Pfaffenwaldring 27, D-70569 Stuttgart, Germany
e-mail: wallmers@isd.uni-stuttgart.de

Key Words: *Ionic Polymer Gels, Ionic Polymer Metal Composites (IPMCs), Modeling, Numerical Simulation, Statistical Theory, Coupled Multi-Field Formulation, Discrete Element Formulation*

ABSTRACT

Electroactive polymers (EAP) are very attractive actuation materials with remarkable electronic and mechanical properties with a great similarity to biological contractile tissues [1]. They consist of polymers in various compositions and in variable forms. They are lightweight, fracture-tolerant and can be manufactured in variable shapes [2].

In the present work we are investigating chemically and electrically stimulated polymer gels in a solution bath as well as ionic polymer-metal composites (IPMCs).
Ionic polymer gels consist of a solid phase containing a polymer network with bound charges and a liquid phase with mobile ions. By changing the ambient conditions, a diffusion/migration flux of hydrated ions - from the gel to the solution phase or vice versa - leading to a swelling or deswelling of the gel, occurs.

We present modeling on different scales: On the macroscopic scale, a model based on the statistical theory by Flory and Rehner [3, 4] is given, while on the micro-mesoscopic scale, a coupled chemo-electro-mechanical formulation [5, 6] which is capable to give the concentrations and the electric potential in the gel as well as in the solution is presented. The chemo-electric field is decsribed by a convection-diffusion equation while the unsteady swelling behavior of the gels is formulated by an equation of motion. In this work, a full coupling between all the fields (chemical, electrical and mechanical) involved is applied.
In order to represent the local mechanical properties of the polymer chains, a (microscopic) discrete element formulation is also employed.

To demonstrate the quality of the given formulations, numerical simulations for different EAPs have been performed, based on unconditionally stable space-time finite elements. For the ionic polymer metal transducers, the migration of the ions in the composite material for an applied alternating electric field will be presented, while for the polymer gels, the ion movement as well as the swelling and bending of the fibers will be given.

REFERENCES

[1] P. Chiarelli, P. J. Basser, D. D. Rossi, S. Goldstein, *The dynamics of a hydrogel strip*, Biorheology, pp. 383–398.

[2] Y. Bar-Cohen, *Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential, and Challenges*, vol. PM 98, SPIE Press, Bellingham, WA, USA (2001) pp. 4–44.

[3] J. Flory, J. Rehner, *Statistical mechanics of cross-linked polymer networks i. rubberlike elasticity*, J. Chem. Phys.

[4] J. Flory, J. Rehner, *Statistical mechanics of cross-linked polymer networks ii. swelling*, J. Chem. Phys.

[5] T. Wallmersperger, B. Kröplin, R. W. Gülch, *Electroactive Polymer (EAP) Actuators as Artificial Muscles - Reality, Potential, and Challenges; Second Edition*, vol. PM 136, SPIE Press, Bellingham, WA, USA (2004) pp. 335–362.

[6] T. Wallmersperger, B. Kröplin, R. Gülch, *Coupled chemo-electro-mechanical formulation for ionic polymer gels - numerical and experimental investigations*, Mechanics of Materials, 36(5-6), (2004), 411–420.