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Photo-mechanics of Polymer Structural Alteration Due to Light Irradiation

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Abstract

The development of light activated polymers, which undergo network structural alternation and consequent mechanical deformation responding to light, promises to offer exciting, innovative, and unique material capabilities. Currently, several light-activated polymers have been developed with very different underlying photo-mechanical mechanisms. Such materials include: photo-radical mediated cleavage and reformation of the polymer backbone in cross-linked elastomers that results in local stress relaxation; photo-switching cross-links in shape memory polymers. This paper developed a thermodynamically consistent constitutive framework to model photo-mechanical behaviors of these polymers. This framework was applied to a cross-linked elastomeric system that is able to undergo cleavage/reformation of the polymer backbone and photo-switching cross-links. In these systems, the presence of radical species is modeled to locally relieve stress through network rearrangement. Modeling this photo-radical-mechanical behavior constitutes a multi-physics problem with three primary constituents: the optical penetration and attenuation throughout the material; the photo-chemistry and associated radical concentration field; and the radical concentration-coupled mechanical behavior of the material. These three processes have been implemented in a finite element code. Experimental data are used to calibrate the photo-mechanical model. Model prediction simulations of novel actuators are compared with experimental results. Finally, a few examples of applications are demonstrated.