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Nonlinear viscoelasticity and generalized failure criterion for polymer gels[1]

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Polymer gels display a multiscale microstructure that is responsible for their solid-like properties. Upon external deformation, these soft viscoelastic solids exhibit a generic nonlinear mechanical response characterized by pronounced stress- or strain-stiffening prior to irreversible damage and failure, most often through macroscopic fractures. Here we show on an acid-induced protein gel that the nonlinear viscoelastic properties of the gel can be described in terms of a "damping function" which predicts the gel mechanical response quantitatively up to the onset of macroscopic failure. Using a nonlinear integral constitutive equation built upon the experimentally-measured damping function in conjunction with power-law linear viscoelastic response, we derive the form of the stress growth in the gel following the start up of steady shear. We further couple the shear stress response with Bailey's durability criteria for brittle solids in order to predict the critical values of the stress σ_c and strain γ_c for failure of the gel, and how they scale with the applied shear rate. Our work provides a consistent framework to describe the failure of polymer gels in a range of different deformation histories explored under external applied shear rate or shear stress.

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