

POROSITY GOVERNS NORMAL STRESSES IN POLYMER GELS

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When sheared, most elastic solids such as metals, rubbers and polymer hydrogels dilate in the direction perpendicular to the shear plane. This well-known behaviour known as the Poynting effect is characterized by a positive normal stress [1]. Surprisingly, biopolymer gels made of fibrous proteins such as fibrin and collagen and many tissues exhibit the opposite effect, contracting under shear and displaying a negative normal stress [2, 3]. Here we show that this anomalous behaviour originates from the open network structure of biopolymer gels, which facilitates interstitial fluid flow during shear. Using fibrin networks with a controllable pore size as a model system, we show that the normal stress response to an applied shear is positive at short times, but decreases to negative values with a characteristic time scale set by pore size. Using a two-fluid model, we develop a quantitative theory that unifies the opposite behaviours encountered in synthetic and biopolymer gels. Synthetic polymer gels are impermeable to solvent flow and thus effectively incompressible at typical experimental time scales, whereas biopolymer gels are effectively compressible. Our findings suggest a new route to tailor elastic instabilities such as the die swell effect that often hamper processing of polymer materials and furthermore show that poroelastic effects play a much more important role in the mechanical properties of cells and tissues than previously anticipated.