ratio, but with decreasing monomer concentration (Zhang et al. 2005). The latter illustrates the importance of the swelling ratio during the formation of the network (q_o) on the final network toughness.

The calculated toughness values obtained for hydrogels are small and accurately reflect the observed brittle nature of these materials. Techniques to toughen gels (for example see Naficy et al. 2011 and Zhao 2014) introduce additional mechanisms to dissipate energy during crack propagation. In 'double network' hydrogels the damage zone size is greatly increased so that many more network strands must be broken in propagating a crack. Other dissipation mechanisms involve viscoelastic effects and interactions with other phases in composite gels.

Conclusions

Hydrogels are unique and extremely useful materials by virtue of their capacity to retain significant amounts of water. Swelling by water has a profound effect on the hydrogel properties and it is important to understand these effects for proper design of hydrogel materials. Great advances have been made in the relation of basic properties of hydrogels, including mechanical properties, swelling and transport properties, by considering the topological structure of the hydrogel network and the relevant thermodynamic relations. As a result, it is possible to predict with reasonable accuracy and within certain bounds, the equilibrium swelling ratios (and the effects of external stress), the modulus, the toughness and the diffusion rates of small molecules within the hydrogels.

References

Baumberger, T., C. Caroli and D. Martina. 2006. Fracture of biopolymer gel as a viscoplastic disentanglement process. Eur. Phys. J. E 21: 81–89.

Bhowmick, A.K. 1988. Threshold fracture of elastomers. J. Macromol. Sci. C, Rev. Macromol. Chem. Phys. 28: 339−370.

Erman, B. and J.P. Flory. 1978. Theory of elasticity of polymer networks. II. The effect of geometric constraints on junctions. J. Chem. Phys. 68: 5363–5369.

Erman, B. and L. Monnerie. 1989. Theory of elasticity of amorphous networks: effect of constraints along chains. Macromolecules 22: 3342−3348.

Erman, B. and L. Monnerie. 1992. Theory of elasticity of amorphous networks: effect of constraints along chains. Macromolecules 25: 4456−4456.

Flory, P.J. 1942. Thermodynamics of high polymer solutions. J. Chem. Phys. 10: 51–61.

Flory, P.J. and J. Rehner. 1943. Statistical mechanics of cross-linked polymer networks I. Rubberlike elasticity. J. Chem. Phys. 11: 512–520.

Flory, P.J. and J. Rehner. 1944. Effect of deformation on the swelling capacity of rubber. J. Chem. Phys. 12: 412–414.

Flory, P.J. 1977. Theory of elasticity of polymer networks. The effect of local constraints on junctions. J. Chem. Phys. 66: 5720–5729.

Flory, P.J. 1979. Molecular theory of rubber elasticity. Polymer 20: 1317–1320.

Flory, P.J. and B. Erman. 1982. Theory of elasticity of polymer networks 3. Macromolecules 15: 800–806.

Fricke, H. 1924. A mathematical treatment of the electric conductivity and capacity of disperse systems I. The electric conductivity of a suspension of homogeneous spheroids. Phys. Rev. 24: 575–587.

Gaylord, R.J. and J.F. Douglas. 1987. Rubber elasticity: a scaling approach. Polym. Bull. 18: 347–354.

Gaylord, R.J. and J.F. Douglas. 1990. The localisation model of rubber elasticity. II. Polym. Bull. 23: 529–533.