Why are Double Network Hydrogels so Tough?

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Double-network (DN) gels have drawn much attention as an innovative material having both high water content (ca. 90 wt%) and high mechanical strength and toughness. DN gels are characterized by a special network structure consisting of two types of polymer components with opposite physical natures: the minor component is abundantly cross-linked polyelectrolytes (rigid skeleton) and the major component comprises of poorly cross-linked neutral polymers (ductile substance). The former and the latter components are referred to as the *first* network and the *second* network, respectively, since the synthesis should be done in this order to realize high mechanical strength. For DN gels synthesized under suitable conditions (choice of polymers, feed compositions, atmosphere for reaction, etc.), they possess hardness (elastic modulus of 0.1-1.0 MPa), strength (failure tensile nominal stress 1-10 MPa, strain 1000-2000%; failure compressive nominal stress 20-60MPa, strain 90-95%), and toughness (tearing fracture energy of 100~1000 J/m^2). These excellent mechanical performances are comparable to that of rubbers and soft load-bearing bio-tissues. The mechanical behaviors of DN gels are inconsistent with general mechanisms that enhance the toughness of soft polymeric materials. Thus, DN gels present an interesting and challenging problem in polymer mechanics. Extensive experimental and theoretical studies have shown that the toughening of DN gel is based on a local yielding mechanism, which has some common features with other brittle and ductile nano-composite materials, such as bones and dentins.

References

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