A novel perspective of the scale-law of elastic moduli and polymer fraction in soft materials (hydrogel)

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Abstract

In polymer science, many different types of scale-law and scale invariant behavior have been found. For example, the root-mean-square of the head-tail distance of a polymer chain, R, and its segments number, N, follow a strange scale-law relation, $R\sim N^{0.59}$ in three dimensions. Another example is that the elastic moduli of a solvent-absorbable polymer and its polymer fraction also have a scale-law with exponent factor of 2.3, 3 or even 0.56 in different conditions. de Gennes has developed a systematic methodology in the 1970s to handle these class of problems, but it sometimes requires cunning approximations and assumptions rather than rigorous mathematical derivations. As a result, it can't be unified effectively with today's mechanics of soft matter. Hence, we try to break through this obstacle by using complex network theory rapidly developed in recent years. We designed an interesting polymer network growth algorithm and energy transmit algorithm by MATLAB to reveal the essence of elastic moduli. We believe this material property, elastic moduli, in fact, stands for an ability to transfer energy among a certain material. For example, different materials have their own speed of sound, which represents the speed of energy (sound is one form of energy) transferring or spreading among materials. Finally, we find that our method can much more easily explain the power-law between elastic moduli and polymer fraction. We hope our work can inspire others to consider polymers in a very novel and different perspective and establish a bridge between complex network theory and polymer science in the future.

Keywords: Polymers, Elastic moduli, Scale law, Energy transfer speed