Summer School on Polymeric Networks for Sustainable Development

July 6th – 12th, 2025

Critical Phenomena in Polymer Gels

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Polymers are among the systems that exhibit the critical phenomena of self-avoiding walk (SAW) universality class [1]. In general, observations of critical phenomena require meticulous fine-tuning to approach the critical point, making it an extensively challenging issue to experimentally extract the critical exponents from the system. In this study [2,3], we experimentally demonstrate that polymer gels, which consist of a cross-linked polymer network containing a large amount of solvent, inherently reside at the critical point without the need for specialized tuning parameters to exhibit universal critical phenomena.

Figure shows the polymer volume fraction (ϕ) dependence on the polymer-solvent mixing contribution to the osmotic pressure Π_{mix} in polymer gels, measured through the macroscopic swelling phenomenon in polymer gels for various network and swelling conditions. We reveal that Π_{mix} universally follows the semidilute scaling law (red solid line) that is governed by the critical exponent ν of SAW universality class:

$$\frac{\Pi_{\mathrm{mix}}}{k_B T} = {\xi_c}^{-3} \phi^{\frac{3\nu}{3\nu-1}}, \tag{1}$$

where ξ_c is the characteristic blob length, and k_B and T are the Boltzmann constant and absolute temperature, respectively. We find that the universal scaling law enables us to experimentally determine the critical exponent $\nu = 0.5889(32)$, which is consistent with reported values of $\nu \approx 0.5876$ obtained by theoretical calculations [4]. Our finding illustrates that polymer gels exemplify the manifestation of the critical exponent within ubiquitous materials, highlighting the physics of critical phenomena tangible at macroscopic scales.

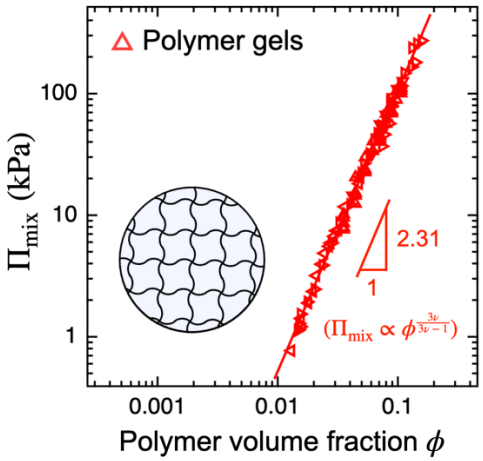

Fig. Semidilute scaling law [Eq. (1)] in polymer gels to demonstrate critical phenomena.

References:
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