Summer School on Polymeric Networks for Sustainable Development

July 6th – 12th, 2025

Development and Analysis of a Theoretical Model for Mechanical Properties of Self-Growing Gel

Tatsunari Masumi[1], Tsutomu Indei*[2]

[1] Laboratory of Soft & Wet Matter, Grad. Sch. of Life Sci., Hokkaido Univ., Sapporo, Japan
[2] Laboratory of Soft & Wet Matter, Fac. of Adv. Life Sci., Hokkaido Univ., Sapporo, Japan
*indei@sci.hokudai.ac.jp

Common artificial materials deteriorate and break when subjected to mechanical load. In contrast, self-growing hydrogels based on double network (DN) gel[1] improve their mechanical properties by loading[2] because, when DN gels are deformed, brittle network is broken and generates radicals, resulting in polymerization of new network (Fig. 1). Theoretical study is needed to investigate elementary processes that cause unique mechanical properties of such self-growing hydrogels throughout entire deformation process. We developed a theoretical model based on kinetic approaches to predict the mechanical properties of self-growing hydrogels. It was verified that, in a closed system where monomers are not supplied into gels during deformation, monomer depletion in the solvent prevents the growth of the new network, but in an open system where monomers are continuously supplied into gels during deformation, network grows efficiently due to radicals generated from broken strands. It was predicted that, if the tensile rate is sufficiently lower than the reaction rate, growth ends during the loading process of the first cycle in closed system. In the opposite case where the tensile rate is sufficiently higher than the reaction rate, little growth occurs because reactions do not proceed during the first cycle. These results show that continuous monomer supply and the balance between the reaction rate and the tensile rate control self-growing dynamics of hydrogels. It was also verified that strands generated in gels with small elongation ratio make significant contributions to the stress of largely deformed gels. It was predicted that radicals generated from newly formed networks are essential to make the network continuously grow when the maximum elongation ratio in loading is constant throughout the entire multicycle process.

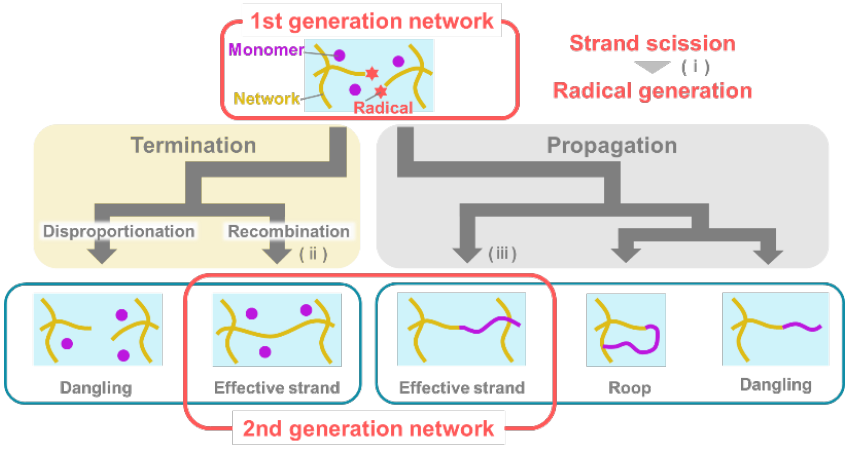

Fig. 1 Schematic illustrations to explain how elastically effective strands are generated by loading.

References:

[1] *Gong, J, P, et al., Adv. Mater.,* ***15****, 1155-1158 (2003).*

[2] *Matsuda, T, et al., Science, 363, 504-508 (2019).*