

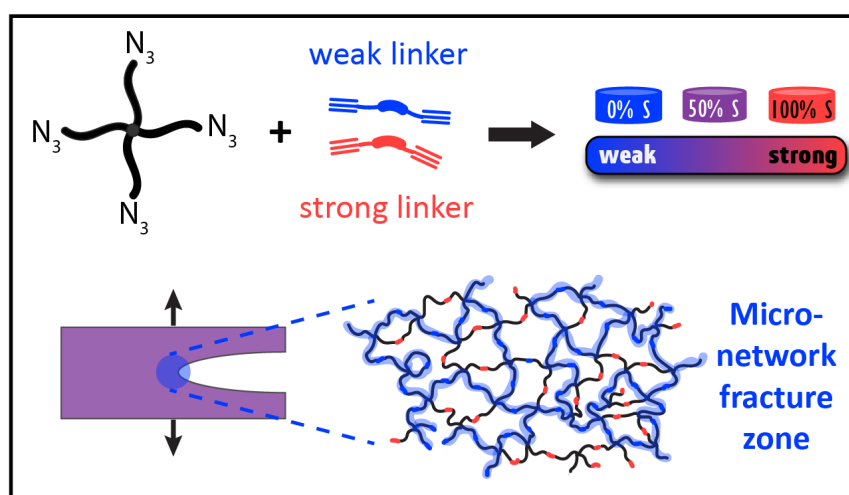
Fracture Across Scales in Polymer Networks

Bradley D. Olsen^{1*} and Devosmita Sen¹

¹ *Massachusetts Institute of Technology, Cambridge, MA, USA*

* email: bdolsen@mit.edu

Polymer networks in the form of gels, elastomers, and thermosets are some of the most common and important polymer materials due to their high extensibility. Substantial recent work has focused on how to also increase their toughness, increasing durability and enabling use in a wider range of applications. These experimental efforts are greatly facilitated by an increased theoretical understanding of fracture. Our lab has developed a coarse-grained simulation engine that is capable of performing simulations of large networks, reproducing key macroscopic properties.[1] Herein, this methodology is applied across different length scales to investigate how individual bond strengths translate into chain breakage and into disordered net topologies within networks that lead to the observed macroscopic failure properties. First, we investigate how the topological position of strong and weak bonds within a polymer network can impact its overall strength, explaining key experimental observations that topology can fundamentally change the role of weak bonds in a polymer.[2,3] Using scaling relationships, we illustrate the key regime in which these experiments operate and why this regime gives such unexpected results. Building on this work that focuses on local connectivity, we expand to larger-scale net structures and explore how the differences in these nets are manifest in varying fracture properties.[4] Examining the spectrum from idealized net to a fully disordered topology provides insight into the quantitative role that topological defects play in controlling network properties.



[1] Arora, Lin, and Olsen. *Macromolecules* **2021**.

[2] Beech et al. *ACS Macro Letters* **2023**.

[3] Herzog-Arbeitman et al. *Nat. Chem.* **2026**.

[4] Sen and Olsen. *Phys. Rev. Materials* **2025**.