CAREER: Beyond alignment: novel mechanisms for controlling block copolymer phase behavior using magnetic fields

Michelle A. Calabrese, University of Minnesota-Twin Cities

This project examines how weak magnetic (***B***) fields cause water-like solutions of block copolymers (BCPs) to turn into soft solids, increasing the material viscosity and stiffness by up to six orders of magnitude. While the low viscosity solutions are composed of spherical micelles, soft solids are composed of ordered phases like cubic crystals (**Fig. 1**). At zero field, these solutions can form soft solids upon the addition of energy (heating) or material (more polymer).

Numerous structure (X-ray scattering) & mechanical property (rheology) measurements revealed that:

- ***B***-fields can greatly reduce the size of the spherical micelle in the initial solution (Fig. 1a)
- ***B***-fields create smaller micelles and increase the material modulus more than results from sample heating (Fig. 1b)
- ***B***-fields produce smaller structures vs. those forming at higher polymer content, often leading to better mechanical properties (Fig. 1b) – *meaning that new, high-performing materials can be made using far less polymer*
- Summary: ***B***-fields form materials of polymer densities & dimensions inaccessible by adding heat or material

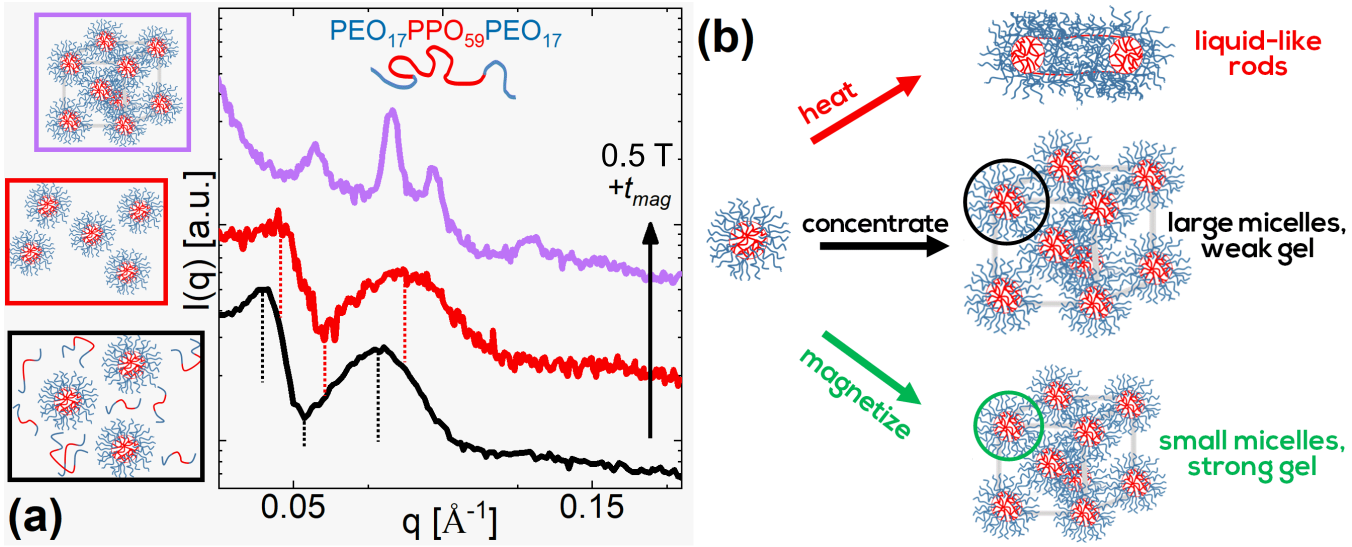

Figure 1. (a) A low viscosity PEO-PPO-PEO block copolymer (BCP) solution (20% wt in water) consisting of spherical micelles and free chains (black X-ray scattering trace & box) forms more, smaller micelles (red trace & box, features shifted to higher q-values) upon exposure to 0.5 T magnetic field. Further magnetization leads to formation of an ordered soft solid of high modulus (purple trace, box). Dotted lines at peak minima and maxima for visual aid only.

(b) This magnetized BCP solution forms small micelles and a strong gel (green, bottom row). When the same sample is instead heated (0 T), rod-like structures form that behave like liquids (red, top row). When the sample is instead concentrated (0 T), an ordered gel with large micelles and a weak modulus forms (black, middle row).

DMR-2143162

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This project uses a *multi-pronged approach* to broaden participation in STEM via recruiting & retaining students from under-represented groups in the PI's lab, in UMN Chemical Engineering & Materials Science (CEMS) & within the broader Minneapolis community.

This year, the PI & graduate students on this project have:

- **recruited 7 summer undergraduates, including:** four women, and students identifying as LGBTQIA+, Latinx, and Black; a Black female student worked on this project
- implemented individualized structured mentoring, biweekly one on one meetings with the PI in addition to subgroup meetings, & career/graduate school sessions
  - *all indicated equal or increased interest in attending graduate school at end vs. start of summer*
  - ***one Latinx & LGBTQIA+ student intends to return to UMN & the PI's lab for a PhD in materials science next year***
- **partnered with UMN Center for Educational Innovation** to implement course-wide surveying on improving STEM climate and inclusive teaching practices in PI's intro chemical engineering course (F2022, re-surveying in F2023; results currently being analyzed)
- developed short memos outlining inclusive teaching practices, disseminated to CEMS faculty by inclusive teaching team

Figure 1: (a) UMN-wide poster session, where Calabrese lab summer undergraduate researcher (on this project) presents her work on the impact of temperature on magnetic field-induced BCP ordering.

(b) PI with five of the seven undergraduate researchers in the lab over the summer. Photo taken at an end-of-summer event to recognize achievements by summer student researchers, hosted annually by the PI.