CHEMICAL ENGINEERING
UNIVERSITY of WASHINGTON

SEMINAR

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Illuminating polymer resins for sustainable 3D printing

Monday July 17th
Lecture 4:00-5:00 p.m. | Physics/Astronomy Auditorium (PAA) A110
Reception 5:00-6:00 p.m. | Benson Hall Lobby

Bio

Dr. Michael C. Burroughs is an Arnold O. Beckman Postdoctoral Fellow in the Department of Chemical Engineering at Stanford University. Under the mentorship of Prof. Danielle Mai, his current research explores the dynamics of complex polymer architectures from molecular to macroscopic length scales for applications pertaining to human health and the environment. Prior to Stanford, Mike obtained his Ph.D. in Chemical Engineering from the University of California, Santa Barbara where he was co-advised between Profs. Matthew Helgeson and L. Gary Leal. While at UCSB, he pioneered advanced rheological techniques to enable simultaneous velocity and concentration measurements of entangled polymer liquids in shear flows. Before his Ph.D., he received his B.S. in Chemical Engineering from North Carolina State University. At NCSU, Mike was designated as a University Scholar and received the Chemical and Biomolecular Engineering Department's Senior Award for Scholarly Achievement. Mike is committed to the advancement of diversity, equity and inclusion initiatives in STEM as evidenced by over a decade of continued engagement in mentoring, outreach, and service activities. Recently, he was named a 2023 ACS Polymeric Materials Science and Engineering Future Faculty Scholar.

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Abstract

Most plastic materials end up in landfills due to an inability to efficiently recycle polymers back into useful chemicals.[1–3] Despite rising concerns about the "plastics problem," the demand for plastics continues to grow at an unsustainable rate that will directly lead to more plastic waste accumulation. Moreover, these demands are accelerating as plastic manufacturing by 3D printing becomes more widely adopted. The broad adoption of 3D printing has been enabled by new light-based technologies[4] that facilitate rapid print speeds, opportunities for bottom-up resin design, and direct printing in liquid (**Fig. 1a**). Unfortunately, current 3D printing resins are based on conventional polymer chemistries that are designed to be permanent, preventing recycling of printed plastic parts. To circumvent continued unsustainable practices in plastics manufacturing, it is crucial to engineer recyclability into polymer resins.

In this talk, I will discuss progress towards engineering recyclability into polymer resins that are suitable for light-based 3D printing. Resins comprise star-shaped polymers with terminal anthracene groups (PEG-anthracene, **Fig. 1b**) that enable reversible, light-triggered printing and erasure.[5] This light-responsiveness stems from the ability of anthracenes to form dimers when irradiated with 365 nm ultraviolet (UV) light and subsequently dissociate with 265 nm (deep UV) light. Upon UV exposure, PEG anthracene resins exhibited rapid printing as indicated by a dramatic increase in material stiffness (**Fig. 1c**). Subsequent irradiation with deep UV light resulted in erasure back to a liquid resin. Systematic studies of different star PEG-anthracene compositions revealed high material stiffness and fast print rates for star PEG-anthracene with many arms, but these materials exhibited incomplete reversibility compared to star PEG-anthracene with fewer arms. **Overall, these findings present a molecular framework to guide the rational design of recyclable polymer resins for sustainable 3D printing.** Further understanding of the interplay between material composition, molecular architecture, and processing of polymer resins will advance their broad use in sustainable 3D printing of functional materials.

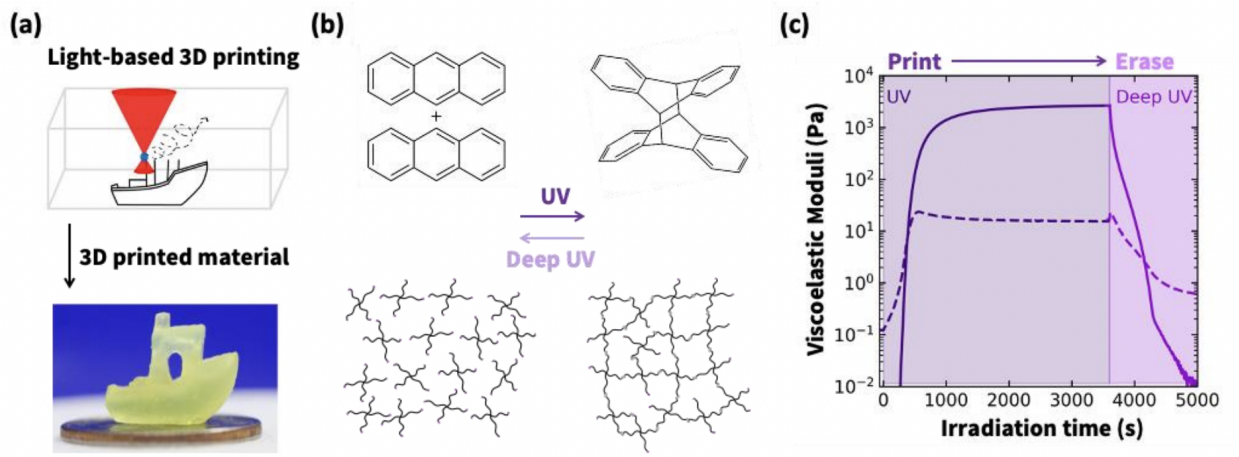

Fig. 1. Molecular design and material characterization of recyclable polymer resins for light-based 3D printing applications. **(a)** Light-based 3D printing enables complex shapes to be printed directly in a liquid resin.[4] **(b)** Polymer resins composed of multi-arm star polymers with photo-responsive anthracene end groups facilitate reversible network formation (365 nm, UV) and dissociation (265 nm, deep UV). **(c)** Dynamic rheology quantifies polymer resin evolution between predominantly elastic, solid-like (solid line) and viscous liquid-like (dashed line) behaviors during printing (t < 3600 s) and erasure.

1. **Burroughs, M.** *et al.*, *Phys. Rev. Fluids* (2020)
2. **Burroughs, M.** *et al.*, *PRL* (2021)
3. **Burroughs, M.** *et al.*, *Journal of Rheology* (2023)
4. Sanders, S., Schloemer, T., *et al.*, *Nature* (2022)
5. **Burroughs, M.**, *et al.*, *ACS Polymers Au* (2023)