Multi-material droplet generation and solidification via microfluidics

Semester Project

(Section: Material Science – Microengineering)

Droplet microfluidics is a technology used to encapsulate fluids, cells, and other materials into microscale droplets.[1] In this project, droplet microfluidics is employed to generate microdroplets of diverse materials, which can then be solidified into microbeads and assembled to construct three-dimensional (3D) objects. This approach enables the conceptualization of a novel 3D printing process based on the voxel-by-voxel assembly of materials with contrasting properties. Recent advancements have been made in developing printheads capable of producing parts with multi-material compositions on a voxel-by-voxel basis.[2,3] However, current techniques remain limited in combining materials with dissimilar properties. In order to develop a novel microfluidic-based additive manufacturing (AM) technique that can deposit materials with distinct properties, there is a research gap to study the multi-material compatibility in droplet microfluidics.

To obtain functional microbeads with nanoparticle fillings, appropriate ink formulations of surface-treated nanoparticles, monomers, and photoinitiators should be prepared at the first step. Rheology of the inks are characterized with a rheometer. With these inks, droplet production and solidification can be studied using the established droplet microfluidic platform. For example, droplet size and generation frequency can be influenced by droplet contents, such as nanoparticle concentrations. The in-flow polymerized microbeads are characterized using SEM. In the end, microfluidic compartments are designed to assemble droplets or beads into 2D structures. The 2D assembly strategies will set fundamentals for 3D microbead assembly in the future.

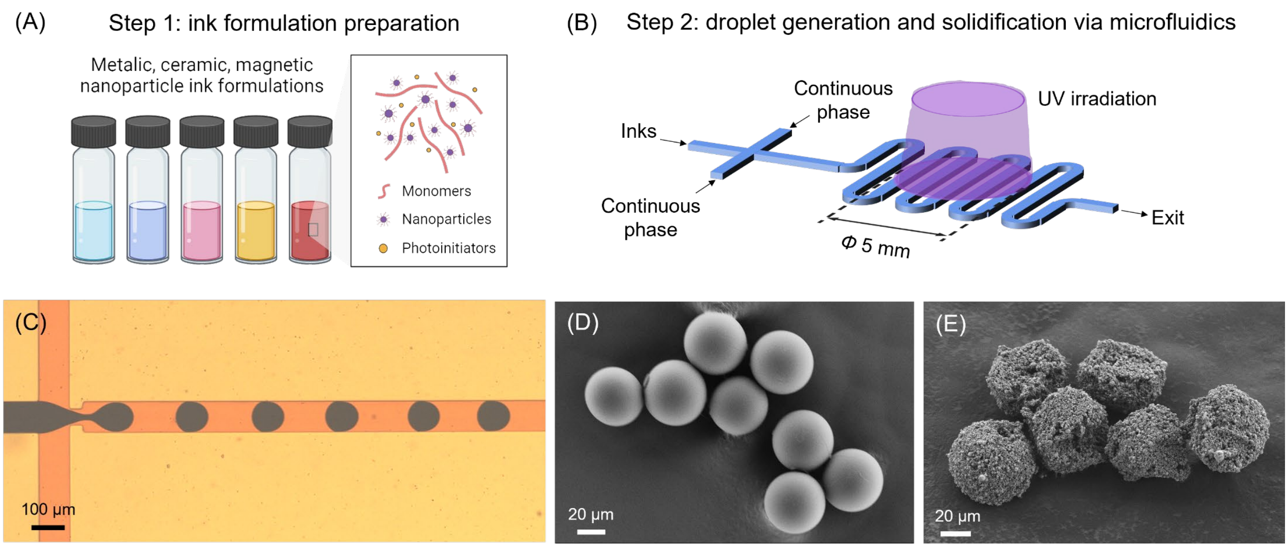

Figure: (A) Preparation of ink formulations. (B) Droplet generation and solidification using a droplet microfluidic platform. (C) Droplets containing silver nanoparticles were formed at a flow-focusing junction in an aqueous continuous flow. An SEM image of UV polymerized microbeads made of (D) PEGDA250 and (E) PEGDA250 with 27 wt% silver nanoparticles.

Possible tasks:

a) Polymerizable ink preparation and rheology (viscosity or viscoelasticity) characterization.
b) Droplet generation and solidification with different droplet contents such as nanoparticle concentration.
c) Droplets or beads 2D assembly using microfluidic compartment designs.

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[1] Zhang, *et al. Trends in Biotechnology* (2023).
[2] Skylar-Scott, *et al. Nature* 575.7782 (2019): 330-335.
[3] Buchner, *et al. Nature* 623.7987 (2023): 522-530.

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