Targeted variation of the size evolution of lipid nanoparticles (LNPs) during microfluidic production.

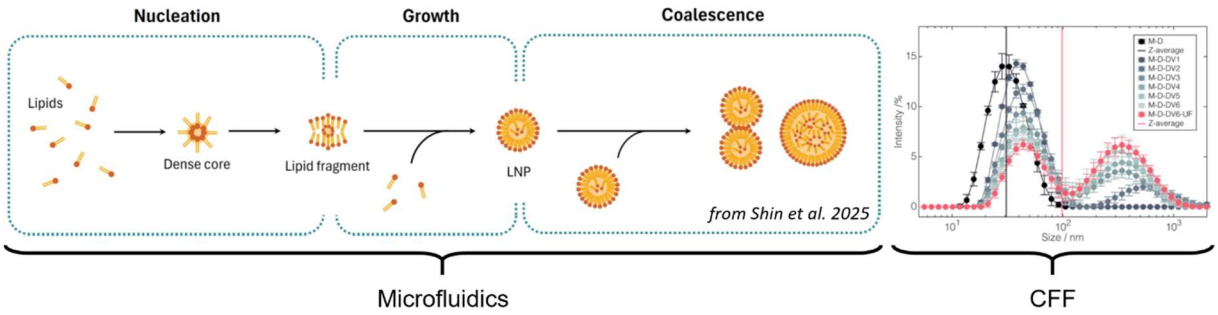
Lipid nanoparticles (LNPs) are at the forefront of modern drug delivery, playing a central role in mRNA vaccines and gene therapies. Their ability to safely and efficiently transport nucleic acids into cells hinges on a key property: particle size. This size is governed by both the composition of the lipids and the process conditions during production, typically involving microfluidic mixing of an organic lipid phase with an aqueous nucleic acid solution. Subsequently, a buffer exchange is performed using dialysis or filtration (CFF) to remove the organic solvent and adjust the pH to neutral.

To investigate size evolution, population balance equations (PBEs) are used, which represent an established modeling tool for describing particle size distributions (PSDs). A recent study successfully applied PBEs to the formation of LNPs, taking into account nucleation, growth, and coalescence. At MVM, a PBE model has also been developed, which is now to be calibrated and validated using experimental data on LNP formation in microfluidic channels.

This thesis aims to experimentally investigate additional mixing processes for LNP production to calibrate and validate the model. Subsequently, the model will be applied for the first time to downstream processing to explain size evolution during buffer exchange.

The work is carried out in close collaboration between the MVM and MAB institutes at KIT. The focus is on experimental work in the laboratory (at MAB), while the resulting experimental data will be implemented into the model (at MVM).

If you're interested in an interdisciplinary project combining pharmaceutical technology, process engineering, and mathematical modelling, send us an email—we’re happy to provide more details!



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- Frank Rhein (MVM): MVM Profile

Further reading:

- Modelling starting point: arXiv:2504.10533
- Experimental background: JCIS 2025