PhD position: Mechanical instabilities of complex fluids undergoing drying in confined microfluidic geometries

Microfluidic pervaporation techniques proved successful for making functional materials such as optical metamaterials [1, 2], conductive tracks, organic MEMS [3], out of water-based dispersions or solutions. These tools combine microscaled top-down architectures and bottom-up self-assemblies to make it possible the precise printing of advanced materials starting from dilute complex fluids, an issue of prime importance within the LabEx Amadeus. (http://amadeus.labex.u-bordeaux.fr/).

While the pervaporation process leading to dense materials is well understood [4, 5], several issues remain unsolved: they concern the mechanical instabilities that often occur during the solidification. In most of the investigated cases (dispersions, polymers, inks,...), the evaporation of the solvent indeed significantly deforms the pervaporation matrix, leading to the delamination of the material from the substrate and very often, fracture and crack eventually form. Such an outcome is quite deleterious to the good quality of the final material, both for its characterization and its application.

We wish to understand (and to master) the combined roles of i) the microfluidic matrix and ii) the dispersed fluid undergoing evaporation on the properties of the final printed micro-structures. Importantly, the high confinement of the pervaporation technique is likely to play a crucial role as compared to the traditional case of the drying of thin films, but the two techniques share important similarities which we will exploit next in the film-making processes in order to produce large-scale materials.

The aim of the PhD work is to investigate the interplay between the mechanical properties of the dispersion and that of the matrix into which it evaporates on the morphology and properties of the final dried material (dimensions, composition, fractures, delamination, etc.), in order to provide experimental guides that may lead to a better shaping of organized soft materials.

This work by far exceeds the microfluidic pervaporation, as indeed such instabilities may occur in all the techniques involving a drying stage (inkjet printing, drop casting, spin-coating, thin film coating …). Yet, the microfluidic geometry is a model one, and as such quite useful. We thus plan to investigate the microfluidic drying kinetics of a series of complex fluids (from polymer solutions to colloidal dispersions) with well-defined properties in terms of rheology and physical-chemistry.

In particular, the materials synthetized in the framework of AMADEus are excellent candidates essentially because they can be tailor tuned. We identified two main families that can be supplied by partners from the LabEx consortium: nanoparticle dispersions and polymer solutions. In particular (but not only), plasmonic nanoparticles are extremely interesting because their optical signature permits us to measure their concentration while they can be coated with a variety materials such as polymers or silica, turning them from soft to hard. Copolymers are also interesting especially if they possess a hydrophobic group which can get adsorbed onto the microfluidic matrix. It is thus possible, in principle, to tune the coupling between the solution undergoing drying and the matrix into which it dries.

The outcomes of the PhD are expected to be manifold: a guide to dry in a controlled manner complex fluids in confined geometry, the opportunity to assemble nanoobjects manufactured in AMADEus, and precious information concerning the larger scale process of thin film formation.

Profile of applicant

We are looking for an experimentalist in physics with a good knowledge of mechanics and rheology of hard and soft matter systems and with a strong interest physical-chemistry. Experience in microfluidics is not a prerequisite.

Key words

microfluidics, soft matter, drying, mechanics & rheology, material science

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Research labs involved & collaborations

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- Eric Cloutet, LCPO, Bordeaux

How to apply ?

http://amadeus.labex.u-bordeaux.fr/Jobs/

[1] Angly et al., ACS Nano 2013; Gomez-Grana et al., Chem. Mater 2015, [2] Baron et al., Opt. Mat. Exp. 2013; [3] Yao et al., Macromolecules 2015; [4] Merlin et al. Soft Matter 2012; [5] Leng et al. Phys. Rev. Lett. 2006