Optimizing nanoscale mechanical properties of agar gels

Fully funded CIFRE PhD opening with Biomérieux in Lyon

Context: Agar is a natural polysaccharide extracted from red algae, which growth is very sensitive to changes in the environment. Commonly used as a thickener for food, agar is also a pivotal ingredient in gel-based culture media in microbiological assay. Among the many consequences of climate change, it is already observed that ocean warming and acidification lead to a significant decrease in agar harvests [1]. In the long run, such a shortage may strongly affect the mechanical quality of agar substrates, or even jeopardize their production. To remedy this problem, the project aims to grow algae under a variety of well-controlled conditions in order to optimize the mechanical properties of agar gels for their applications in microbiology, and eventually implement sustainable solutions for large-scale artificial algae production.

Objectives & scientific approach: In partnership with BioMérieux, we will determine optimal conditions for algae culture in a controlled environment, while measuring the impact of these conditions on the microstructure and mechanical properties of the resulting gels. Algae will be grown by Philippe Potin's group at the Roscoff Marine Station under various conditions of temperature, pH, salinity, etc., before being harvested to extract polysaccharides. After characterizing the chemical structure of these polysaccharides, the PhD candidate will prepare agar gels and determine their mechanical properties by rheometry [2], atomic force microscopy (AFM), and nanoindentation.

For the first time, thanks to these complementary techniques, we will provide a link between the physico-chemical properties of the polysaccharides, the nanoscale mechanics of agar gels, and their macroscopic viscoelasticity. In particular, we will put special emphasis on stress and/or microstructural heterogeneities that may affect the gel macroscopic properties. Indeed, upon gelation, agar gels entrap *residual stresses*, which may be detrimental to agar substrates. Mapping the viscoelastic properties at the microscale through AFM and nanoindentation will shed new light on this phenomenon. Moreover, the statistical analysis of spatially-resolved measurements, and the comparison with rheometry, will help identify what, at the microscopic scale, controls the macroscopic mechanical properties of agar gels.

Miscellaneous: The project will take place in the “Laboratoire de physique de l’ENS de Lyon” in Lyon, France, within the team “Matter & Complexity” and the “PHAST” graduate school (ED52). Applications should be sent to Dr. Thibaut DIVOUX (thibaut.divoux@ens-lyon.fr) and Prof. Sébastien MANNEVILLE (sebastien.manneville@ens-lyon.fr), including at least a CV, a motivation letter or email and transcripts (Bachelor & Master). Starting date: last quarter of 2022, or early 2023.

[1] E. Callaway, *Lab staple agar runs low*, Nature **528**, 171-172 (2015)

[2] B. Mao, T. Divoux & P. Snabre, *Normal force controlled rheology applied to agar gelation*, Journal of Rheology **60**, 473-489 (2016)