Surface tension versus elasticity gradient

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Scientific context In most solids, small forces lead to small deformations. A soft solid, on the contrary, can experience large deformations under minute forces: a phenomenon as minor as depositing a millimetric droplet leads to divergent deformations of its surface [1–4] (Fig. 1A). Such materials, which can take the form of gels, pastes, or elastomers, are ubiquitous in our lives: They amount to most of our body tissues, and can be used as lubricants, glues, and water-repellent coatings. In past years, it has been shown that surface stresses are essential in wetting, adhesion, and fracture, and can be harvested in composites [1–11]. **Yet, the physical origins of surface stresses are poorly understood.** This statement is especially true in gels, in which cohabitation of a crosslinked polymer network and a liquid solvent complexifies the link between molecular structure and mechanical properties (Fig. 1B).

To tackle this fundamental question, the dominant approach is to investigate surface elastic properties [12–16]. For instance, surface topography measurements of a stretched patterned silicone gel revealed an elastic surface, with surface stresses that increase with surface deformations [12]. This result hints towards a role of the crosslinked polymeric network in the surface constitutive behavior of silicone gels. **Recent preliminary results, however, suggest that soft materials may exhibit a gradient in elastic properties.** This unexpected feature could overturn experimental interpretation on the topography of soft solids [12].

Missions In this project, we will conduct Finite Elements Simulations of soft materials with a surface topography, surface stresses, and a gradient of surface elasticity (Fig. 1C). We will use the software COMSOL, and put emphasis on understanding the effect of elasticity gradient on surface mechanics. The results will be directly compared with existing experimental results [12].

Outlooks You will be using state of the art numerical analysis tools, and the expected results are likely to be published in a peer-reviewed international journal. The opportunity to continue as a Ph.D. student can be considered.

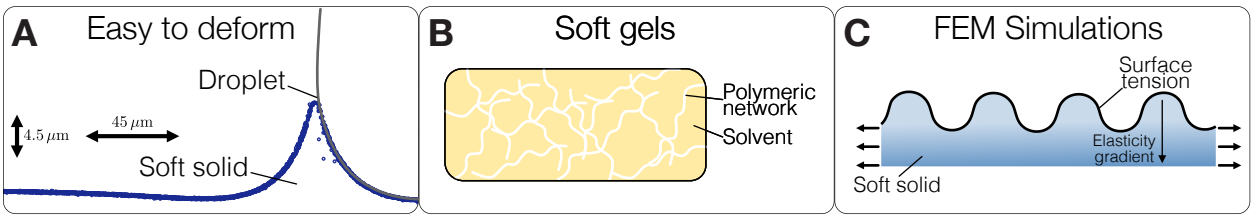

Figure 1: Project overview (A) Soft solids experience large deformations from perturbations as small as a sessile drop. (B) Gels have a complex molecular structure. (C) We will conduct Finite Elements simulations on soft solid with a surface topography, surface stresses and an elasticity gradient.

Bibliography

[1] R. W. Style et al. *Annual Review of Condensed Matter Physics* (2017).

[2] B. Andreotti and J. H. Snoeijer. *Annual review of fluid mechanics* (2020).

[3] R. W. Style et al. *Phys. Rev. Lett.* (2013).

[4] C.-Y. Hui and A. Jagota. *Proc. R. Soc. A* (2014).

[5] K. Smith-Mannschott et al. *Phys. Rev. Lett.* (2021).

[6] R. D. Schulman et al. *Nature communications* (2018).

[7] C.-Y. Hui et al. *Proc. Roy. Soc. A* (2020).

[8] R. W. Style et al. *Nature communications* (2013).

[9] K. E. Jensen et al. *Proc. Natl. Acad. Sci.* (2015).

[10] M. Grzelka, J. B. Bostwick and K. E. Daniels. *Soft matter* (2017).

[11] R. W. Style et al. *Nat. Phys.* (2015).

[12] N. Bain et al. *Phys. Rev. Lett.* (20 2021).

[13] S. Heyden et al. *Proc. Roy. Soc. A* (2021).

[14] S. Heyden, P. M. Vlahovska and E. R. Dufresne. *Journal of the Mechanics and Physics of Solids* (2022).

[15] A. Carbonaro et al. *Soft Matter* (36 2020).

[16] Q. Xu, R. W. Style and E. R. Dufresne. *Soft Matter* (2018).