SOFT ADHESION AND DECOHESION DYNAMICS OF FLUID MEMBRANES MEDIATED BY MOBILE BINDERS

Pradeep K. Bal[1], Dimitri Kaurin[1] and Marino Arroyo[1,2]

[1] Universitat Politècnica de Catalunya-Barcelona Tech, 08034 Barcelona, Spain.
[2] Institute for Bioengineering of Catalonia (IBEC), The Barcelona Institute of Science and Technology, 08028 Barcelona, Spain.

Key Words: *Adhesion Dynamics, Fluid Interface, Capillary Model, Chemo-mechanics.*

Cellular materials need a tuneable cohesion, to transit from resistance to fracture, and need to be able to heal if damaged. Adhesion and decohesion are vital in biology, to keep cells attached in a tissue to resist deformation and allow cells to disintegrate when remodeling is required. Due to the fluid nature of the surface of animal cells, the molecular bonds that hold the cells together are laterally mobile, which limits the use of classical theories of adhesion in this context. Very few theoretical models of cell adhesion have considered bond mobility, and adhesion dynamics under force is also barely studied empirically. We develop a theoretical and computational model for a systematic study to understand the mechano-chemistry of adhesion between fluid membranes bridged by mobile adhesion molecules forming transient bonds. The developed model can be used to map various distinct and biologically relevant scenarios of biological adhesion and forced decohesion. This model considers the reaction kinetics of bond formation that strongly depends on the distance to potential partners and dissociation which depends on the force experienced by the bonds (slip bond behavior) and the lateral diffusion of adhesion molecules and the mechanics of the adhesion patch and of the adhering vesicles. We consider the adhesion and decohesion dynamics between two fluid membranes decorated with mobile adhesion molecules. The membranes are subjected to a fixed tension and a loading device such as a micropipette applies a separation force.

We study how the interaction of mechanics and chemistry at adhesion patches leads to a wide range of behaviors that cells can use to stabilize cell-cell junctions during the physiological stretch or to selectively separate during morphogenesis. Different regimes with distinct adhesion dynamics are identified and we observed that adhesion dynamics is a remarkably complex process in which reactions and diffusion are closely intertwined, and which depends on the molecular properties of bonds. We identify a diffusion-dominated regime, appropriate for long-lived bonds, where patches shrink and become more concentrated in bonds through the diffusion of bonds under force. In the mixed regime, reaction and diffusion compete, under an applied force, the adhesion patch shrinks possibly until complete separation. For short-lived bonds with low diffusivity, we have identified a new unconventional tear-out regime, characterized by traveling solutions. We methodically inspect the dynamics of adhesion and decohesion, which rely on a combination of bond breaking and bond motion. Our study identifies mechanisms by which cells can tune adhesion by controlling the actively generated surface tension, or by modifying the physical properties of the adhesion molecules. Beyond cells, our investigation also provides a conceptual framework for artificial biomimetic systems with a comparable degree of adhesive tunability.

REFERENCES

[1] L. Casares, et al., Hydraulic fracture during epithelial stretching. *Nat. Mater*, Vol. **14**, pp. 343–351, 2015.

[2] D. Kaurin, M. Arroyo, Surface tension controls the hydraulic fracture of adhesive interfaces bridged by molecular bonds. *Phys. Rev. Lett*, Vol. **123,** 228102, 2019.