Lambda-phage DNAs close to phospholipid walls: a direct visualization of single and double end-grafted polymer conformations

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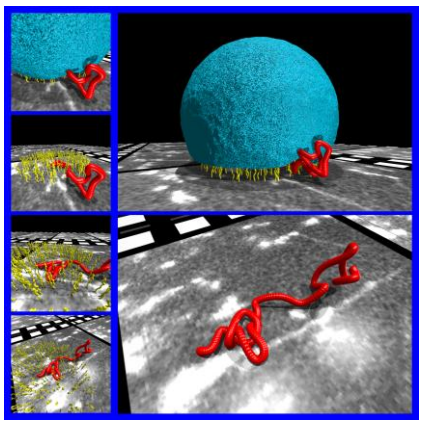
Abstract



Advances in fluorescence microscopy of single-molecule DNA and the preparation of well defined surfaces with end-grafted DNA chains has allowed unprecedented scrutiny of the equilibrium and out of equilibrium behavior of single polymer chains near an impenetrable wall[1]. The physics of polymers in such restricted configurations that include also confined slit- or tube-like geometries of nano-scale dimensions is of importance not only for crude recovery from porous media, for lubrication or for colloidal stabilization but also for the development of biomolecular analysis methods within the context of genomics and for the control of bioadhesion. Here, cell adhesion events proceed by the formation of adhesive patches, the regions where the cell membrane and the adhering substrate are brought into intimate contact by ligand-receptor bonds. Membranes of practical interest bear not only ligands and receptors, but are also densely populated by many other bio-macromolecules. Understanding the interplay between the confining adhesive forces and the repulsive forces of entropic origin is thus crucial to understand adhesion in the biological realm and to design bio-mimetic adhesives[1].

It has been recently shown[2] that when a bio-adhesive phospholipid vesicle is brought into contact with a carpeted surface of end-grafted lambda-phage DNAs, the spreading front of the adhesive patch propagates outwards from a nucleation center, acting as a scraper that strongly stretches the DNA chains. Moreover, the multiple bonds created during vesicle spreading effectively staple the stretched chains in the gap between the membrane and the substrate, creating a tunnel-like channel for the DNA chains. The chain configuration starts thus at its fixed, end-grafted point at the streptavidin substrate, a protein layer of the receptors conjugate to the ligand biotin that end-functionalizes the short polymers to some of the bilayer phospholipids. From its grafted end, the chain meanders through the forest of short polymer bonds that connect the phospholipid membrane above the chain to the protein bed below it, eventually exiting the adhesive gap to adopt a coil-like configuration in the corner between the vertical vesicle wall and the protein surface. Such an experimental geometry provides an unique tool for studying single DNA stretching and confinement in a biomimetic environment[3].

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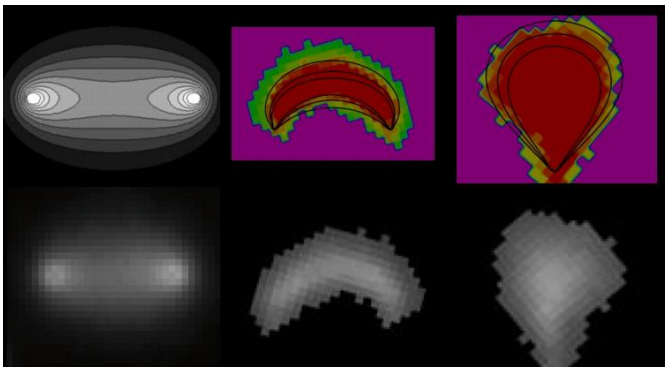
[2] Hisette M.L., Haddad P., Gisler T., Marques C.M., Schröder A.P., Soft Matter, 4, 828 (2008)

[3] Nam, G., Hisette, M.L., Sun, Y. L., Gisler, T., Johner, A., Thalmann, F.; Schröder, A.P., Marques, C.M., Lee, N.K. Phys. Rev. Lett., 105, 088101 (2010)



In this contribution we analyze the conformations of single and double end-grafted DNA chains in the neighborhood of the, almost vertical, phospholipids walls at the border of the adhesive patch. Average images of the fluorescence emitted by these chains allow for a direct visualization of the segment distribution of polymer chain conformations in restricted geometries. The observed distributions can be quantitatively compared to the predictions from polymer theory for monomer concentrations of chains grafted by one or two ends onto a flat surface or at a corner at the intersection of two flat surfaces.