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Molecular Friction on Porous Membranes – WTC 2021, Lyon

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Understanding and controlling the dynamics of polymer-surface interactions are key to design nanoscale objects and to understand biological processes. Entanglement dynamics of single molecules at solid-liquid interfaces are not fully understood but play an important role in the dynamics of polymer-surface interactions in biological processes and in self-healing materials. We study dynamic friction and adhesion between a single 2.5 µm long DNA molecule and a porous membrane by means of atomic force microscopy (AFM). The results will help to understand entanglement dynamics and energy dissipation mechanisms at the molecular scale.

Keywords (from 3 to 5 max): single-molecule friction, DNA construct, porous membrane, AFM, M13mp18

1. Introduction

In this study, the interaction of a self-assembled micrometer-long DNA polymer with nanometer-scale pores is analysed. The DNA molecule is attached to a tipless AFM cantilever via a micrometer-sized bead. The nanoporous membrane is prepared by polymer self-assembly [1]. Methylisation of the pores created a positive charge which favours the entanglement of the negatively charged DNA molecule.

2. Methods

2.1. Cantilever preparation
A single M13mp18 DNA molecule was functionalised at one side with biotin and on the other side with digoxigenin using DNA hybridisation. One end was attached at a micrometer-sized bead which was coated with streptavidin to form a strong bond between the DNA molecule and the bead. The other side was attached to a flat surface which is coated with anti-digoxigenin. A tipless AFM-cantilever, also coated with biotin is lowered onto the bead so that a bond forms between several biotin and streptavidin molecules. Retracting the cantilever from the surface, the single-molecule is ruptured off from the surface. To verify the attachement of a single DNA molecule to the AFM tip, several force-distance curves are recorded and analysed for typical stretching properties of DNA. Afterwards, the AFM tip with the single DNA molecule is transferred to the Polystyrene-block-poly(4-vinylpyridine)-based membrane.

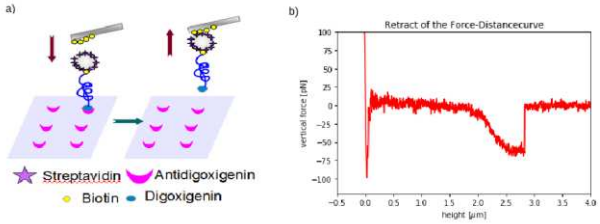

Figure 1: a) Sketch of cantilever preparation, using the adhesive interaction between biotin-functionalised DNA molecule and streptavidin-coated micrometer bead b) Exemplary force-distance curve with typical stretching properties of single DNA molecules and a rupture event at 2.8µm with a rupture force of 65pN.

2.2 AFM friction measurements
Friction measurements were performed by driving the cantilever laterally in parallel to the surface at a height of several hundred nanometers. During scanning, the signal of the lateral and normal force and the change of height are recorded. The data in Figure 2b exhibits modulation in lateral force signal indicating an adhesive interaction of the DNA molecule and the porous membrane.

3. Discussion

The molecular interaction between the single DNA molecule and the porous membrane were studied by means of AFM. The friction force is the force acting opposite to the direction of sliding when scanning across a surface. During sliding, the adhesive interaction between the DNA molecule on the AFM tip and membrane surface cause a torsion bending of the cantilever. Modulation of the lateral and vertical deflection will reveal the adhesive interaction between the polymer and the membrane.

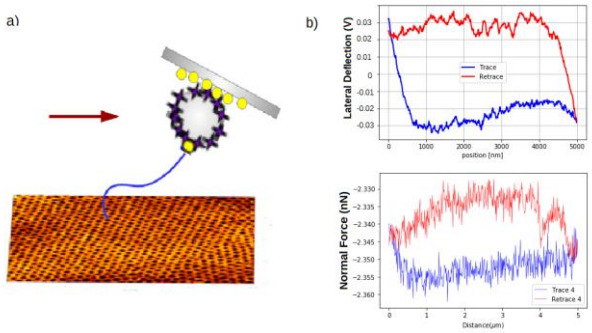

Figure 2: (a) Sketch of friction force measurement with DNA-functionalized cantilever on the porous membrane. (b) Lateral and vertical deflection of a friction loop for a sliding distance of 5 µm 618 nm above the membrane surface.

4. References

[1] M. Gallei, S. Rangou, V. Filiz, K. Buhr, S. Bolmer, C. Abetz, V. Abetz, , Macromolecular Chemistry and Physics, 214 (2013) 1037-1046.