Measuring DNA Translocation Forces through Nanopores in MoS_2 Monolayer Membranes with Optical Tweezers

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Optical tweezers allow for three-dimensional micromanipulation and force measurements on micrometre-sized dielectric particles in solution. We developed an optical tweezers system which includes video-based force detection to measure the minute forces exerted on single dsDNA molecules during controlled translocation through nanopores (see fig. 1) interference-free with sub-piconewton and sub-millisecond resolution [1,2]. This enables us to study the mechanics and dynamics of translocation processes.

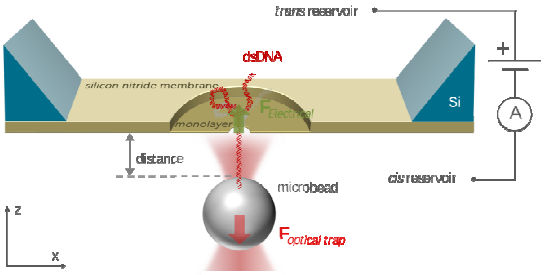

Fig. 1: Schematics of the experimental setup: The focused laser beam coming from below traps a polystyrene microbead with attached dsDNA in the *cis* reservoir. Upon applying a transmembrane voltage (in the range of 100 mV) and approaching the nanopore, the DNA is pulled through the pore and the resulting force can be measured.

We show the successful preparation of free-standing MoS_2-monolayer membranes by viscoelastic stamping [3] where the monolayer thickness was verified by photoluminescence microscopy [4]. Electrochemical pore milling, which allows for a direct control of the resulting nanopore size [5] was used. However, since the monolayers were exfoliated from a high purity synthetic crystal, they have far less defects than CVD monolayers. Those defects serve as a nucleus for electrochemical pore milling, which consequently did not succeed with unmodified monolayers. Therefore, we used helium ion microscopy to introduce a pore nucleus for further widening by electrochemistry.

We also present first successful translocation experiments of lambda phage dsDNA through MoS_2-monolayer nanopores controlled by optical tweezers force mechanics.

References

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