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### **Force measurements on a DNA molecule inserted into a solid-state nanopore**

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Single nanometer-sized pores (nanopores) in an insulating membrane are an exciting new class of nanosensors for rapid electrical detection of and actuation on single biomolecules. I will report (i) our fabrication of solid-state nanopores and translocation measurements of single dsDNA molecules through these pores, and (ii) our recent demonstration of measurements of the force acting on a single DNA molecule that is inserted in the nanopore. Ad (i): Siliconoxide nanopores are fabricated with single nanometer precision and direct visual TEM feedback. Translocation of double-strand DNA is monitored in the conductance of a voltage-biased pore. We find that DNA molecules can pass the pore both in a straight linear fashion and in a folded state. On molecules with a length from 3,000-100,000 base pairs, we observe a power-law scaling of the translocation time versus length, which we attribute to an effect of the hydrodynamic drag on the section of the polymer outside the pore. Measurements of DNA translocation at various salt concentrations reveal a crossover from a high-salt regime where current dips are seen, to a low-salt regime where current enhancements are observed. Ad (ii) For force measurements during the voltage-driven translocation of DNA and RNA, we have added an optical tweezer to our setup. With the tweezer, we hold a bead with a DNA molecule attached. Upon insertion of the DNA into the nanopore, the induced bead deflection yields a measure of the local force that acts on the DNA in the pore. The magnitude of the force involved is of fundamental importance in understanding and exploiting the translocation mechanism, yet so far has remained unknown. We obtain a value of  $0.24 \pm 0.02$  pN/mV for the force on a single DNA molecule, independent of salt concentration. Our data allow the first direct quantitative determination of the effective DNA charge of  $0.53 \pm 0.05$  electrons per base pair, corresponding to a 73% reduction of the bare DNA charge. Our novel single-molecule technique for local force sensing and actuation bears great promise for biophysical studies, e.g. for the study of DNA-protein binding or unfolding of RNA.