Translocation of DNA through ultrathin nanoslits

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2D nanoslit devices, where two crystals with atomically flat surfaces are separated by only a few nanometers, have attracted considerable attention because their tunable control over the confinement allows for the discovery of unusual transport behavior of gas, water, and ions. In this work(*1*), 2D nanoslit devices are used as a new class of sensors to probe DNA translocation through ultra-smooth geometric confinement and to understand interactions with capillary walls surface. Surprisingly, we observe that the DNA is undergoing virtually frictionless transport in our ultrathin 2D-slits made from graphene walls. This is in contrast with state-of-the-art silicon based nanofluidic devices that have typical roughness of the surfaces in the range of several nanometers or nanopores (especially graphene nanopores) where additionally unknown functional groups on the pore edges make these artificial devices a far cry from natural pores. This surprising lack of interaction between graphene and DNA slit paves the way for truly 'amenable and tunable' nanofluidic devices fabricated from novel 2D-materials to probe nanoscopic biopolymer transport and physics as highlighted in the Nature Material Editorial(*2*), & perspectives from L. Bocquet (*3*).

Our approach uses ionic current sensing, a well-established technique from nanopores, to monitor the passage of DNA. The DNA translocation are marked by clear signals in the current blockade at excellent time resolutions. In combination with coarse-grain molecular dynamics simulations, we are able to identify and observe the evolution of the different polymer configuration and features, such as knots and folds, during the translocation process in both the simulations and experiments. Such features have never been observed under such high confinement due to limitations in fabrication of the device and optical resolution. As our 2D-nanoslits have non-interacting surfaces, we were able to overcome the clogging which is a common problem in nanopore devices where often additional coatings are applied to alleviate such problems. As a result, we have stable devices which can work with reproducible characteristics for long periods, even weeks to months without any degradation. This work on graphene-DNA interactions in nanoslit will be interesting avenues for 2D-material based device geometries used in in the fields of nanotechnology, biosensing, and polymer physics where the height and confinement of the biomolecules/polymer can be controlled with high precision and paving the way for 2D based sensing devices for biopolymers. Furthermore, this result gives an inspiration to slow-down the speed of biopolymers (DNA, RNA, protein) for future studies to achieve single-base resolution.

REFERENCES

1. W. Yang *et al.*, Translocation of DNA through Ultrathin Nanoslits. *Adv Mater* **33**, 2007682 (2021).
2. Nanofluidics is on the rise. *Nature Materials* **19**, 253-253 (2020).
3. L. Bocquet, Nanofluidics coming of age. *Nature Materials* **19**, 254-256 (2020).

FIGURES

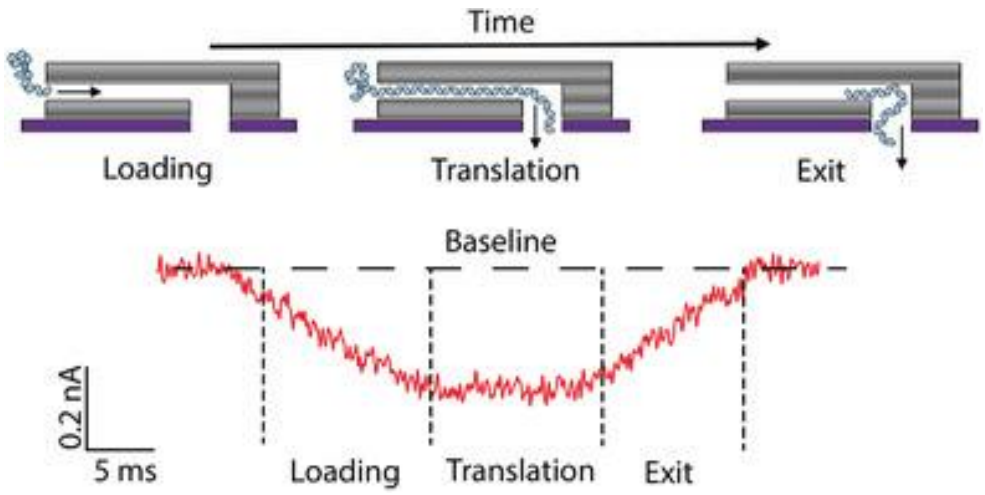

Figure 1: DNA translocation through 2D-nanoslit devices. Sample DNA event showing a distinct arm-chair shape. Three phases can be seen which we interpret as loading, translation and exit. DNA first enters the slit and decreases the open slit current. At some point, the leading end of the DNA reaches the exit of the slit and begins leaving the slit. The current reaches a plateau since there is a constant amount of DNA in the slit. Finally, other end of the DNA enters the slit and starts to translocate through, freeing the slit and returning the current back to the baseline.