Microtomy-fabricated two-dimensional nano-slits enable single molecule biosensing

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Abstract

Nanofluidic devices have emerged as a powerful sensor for single-molecule studies. Among these, biological nanopores have demonstrated remarkable capabilities, ranging from detecting epigenetic modifications in DNA to showing promising results for developing protein sequencing technologies. Despite extensive research, their solid-state counterparts, such as solid-state nanopores and nano-slits, have not achieved comparable success. Unlike biological nanopores, where bacterial proteins can spontaneously insert into lipid membranes to create thousands of atomically identical copies, their solid-state counterparts lack a similarly straightforward and scalable fabrication method. This inability to consistently produce multiple devices with the same precision in dimensions as biological systems remains a significant barrier to their academic and industrial adoption and applications in molecular sensing. Towards this direction, we show the potential of ultramicrotomy-based fabrication of atomically smooth two-dimensional (2D) nanocapillaries and their applications in biosensing. This precise and straightforward method enabled the sustainable production of several hundred molybdenum disulfide-based 2D nano-slits with identical cross-sectional dimensions and tunable lengths from layered crystals. Here, we demonstrated DNA sensing with these 2D nano-slits using the resistive ionic current blockade technique. This robust microtomy technique accelerates production from a single device over 2–3 weeks to hundreds of identical nano-slit biosensors in parallel within the same period. In addition to 1/f noise analysis, these MoS2 nano-slits reveal diverse topological local conformations of DNA during translocation.