Integrating nanopore sensors within microfluidic networks using controlled breakdown of a dielectric

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Introduction

Nanopore sensing relies on the application of a voltage across a nano-scale aperture fabricated in a thin, insulating membrane and monitoring the ionic current modulations produced by the passage of target biomolecules (proteins, DNA).

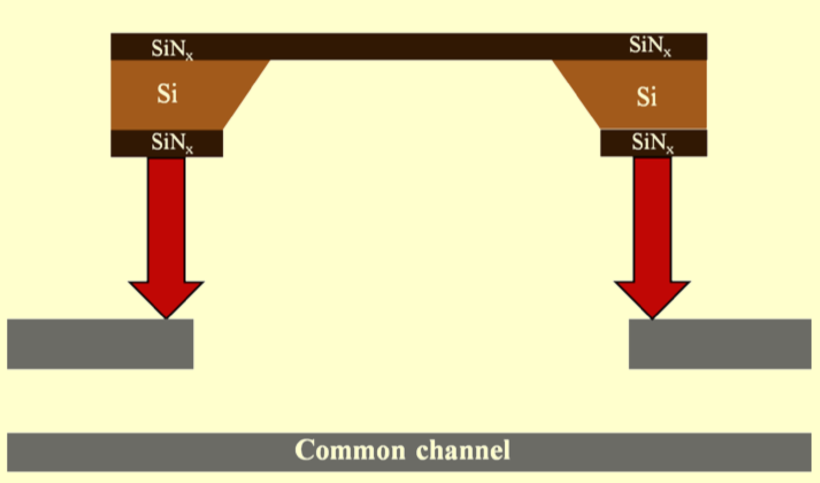
While traditional solid-state nanopore fabrication using electron microscopy is time-consuming and expensive, a new technique called controlled breakdown (CBD) has been discovered which generates nanopores using only strong electric fields in an aqueous environment. Subsequent treatment of a nanopore with similar high electric fields allows for the precise control of its size and noise properties.

We recently demonstrated that CBD can be used to fabricate an array of solid-state nanopores within a single membrane, each individually addressable both fluidically and electrically, directly in a microfluidic environment. By confining the electric field using micro-*vias*, nanopore formation is localized to specific regions of a membrane, electrical noise is reduced, and a symmetric electric field is generated around the nanopore for increased molecular detection efficiency.

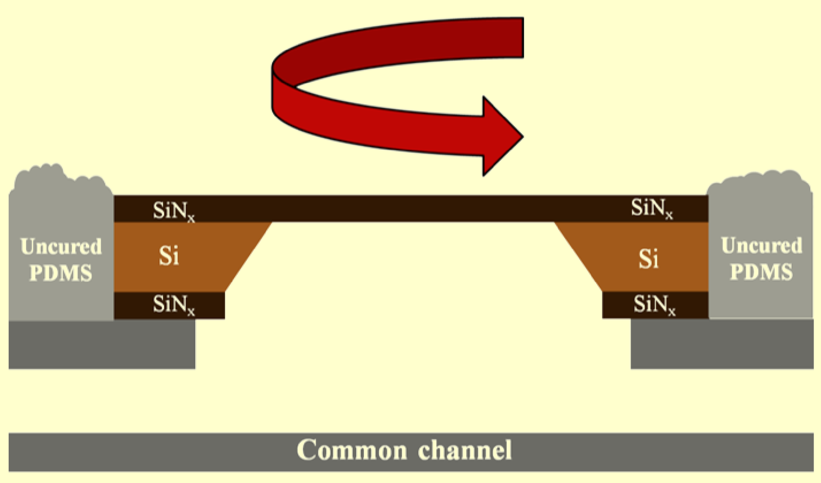
Device Fabrication

Steps

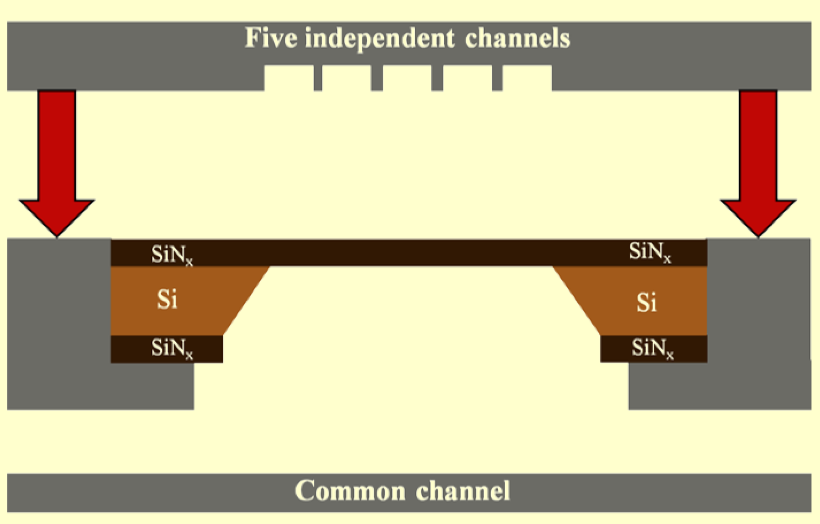
1) The silicon chip is bonded to the common channel



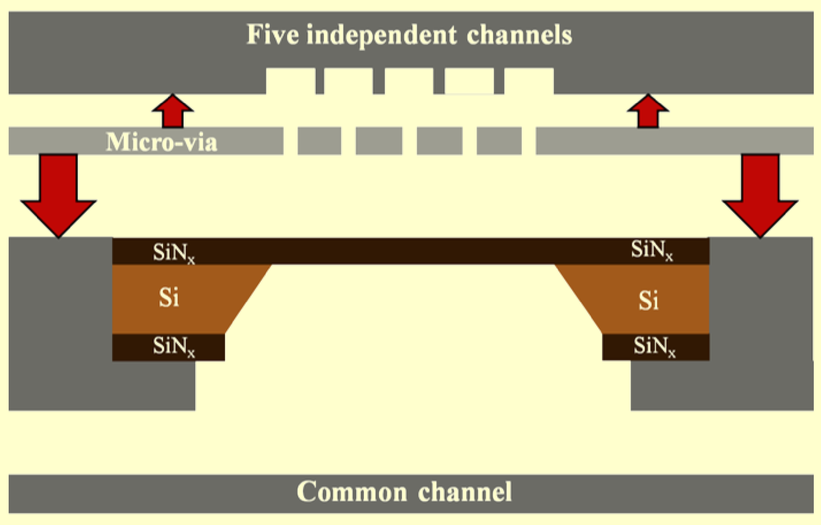
2) A thin layer of PDMS is spun around the chip to level its thickness



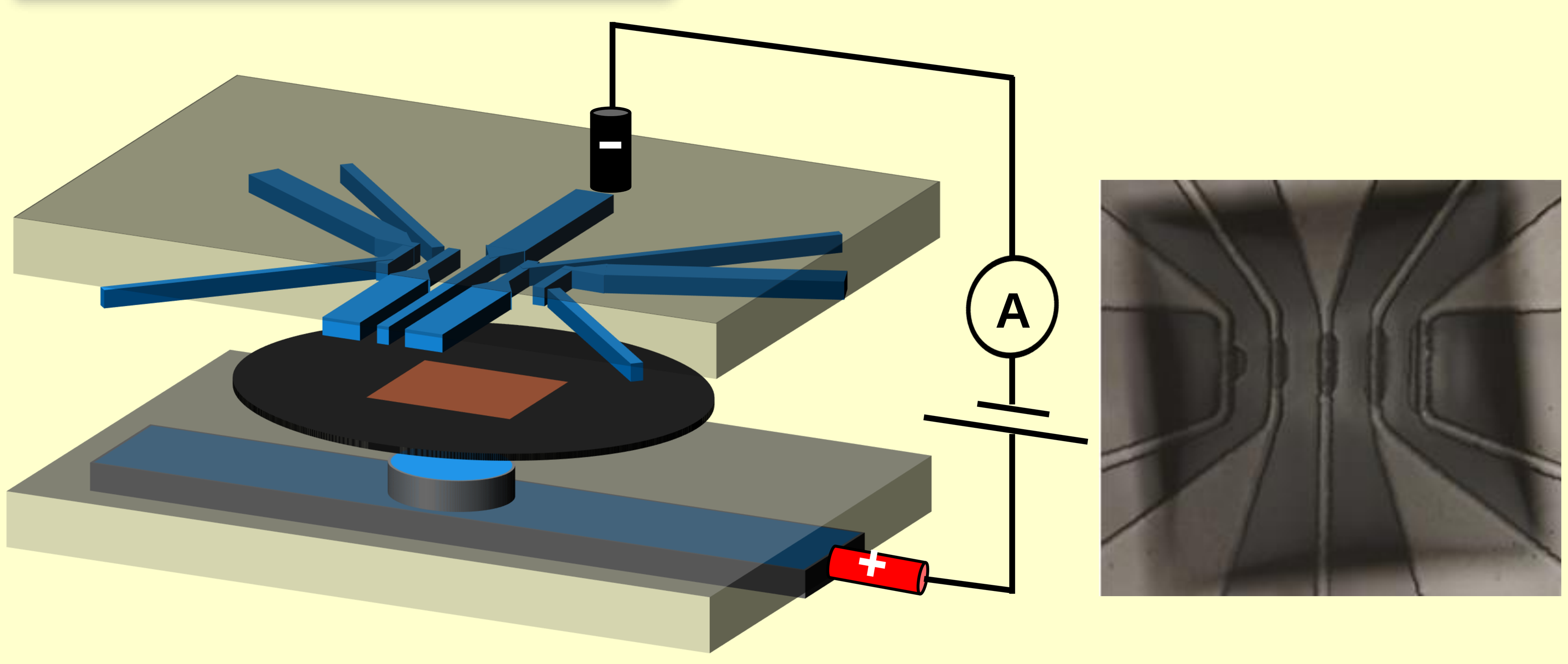
3) Five-channel device



4) Five-channel device with micro-*vias*



Assembled device



Results

Nanopore fabrication

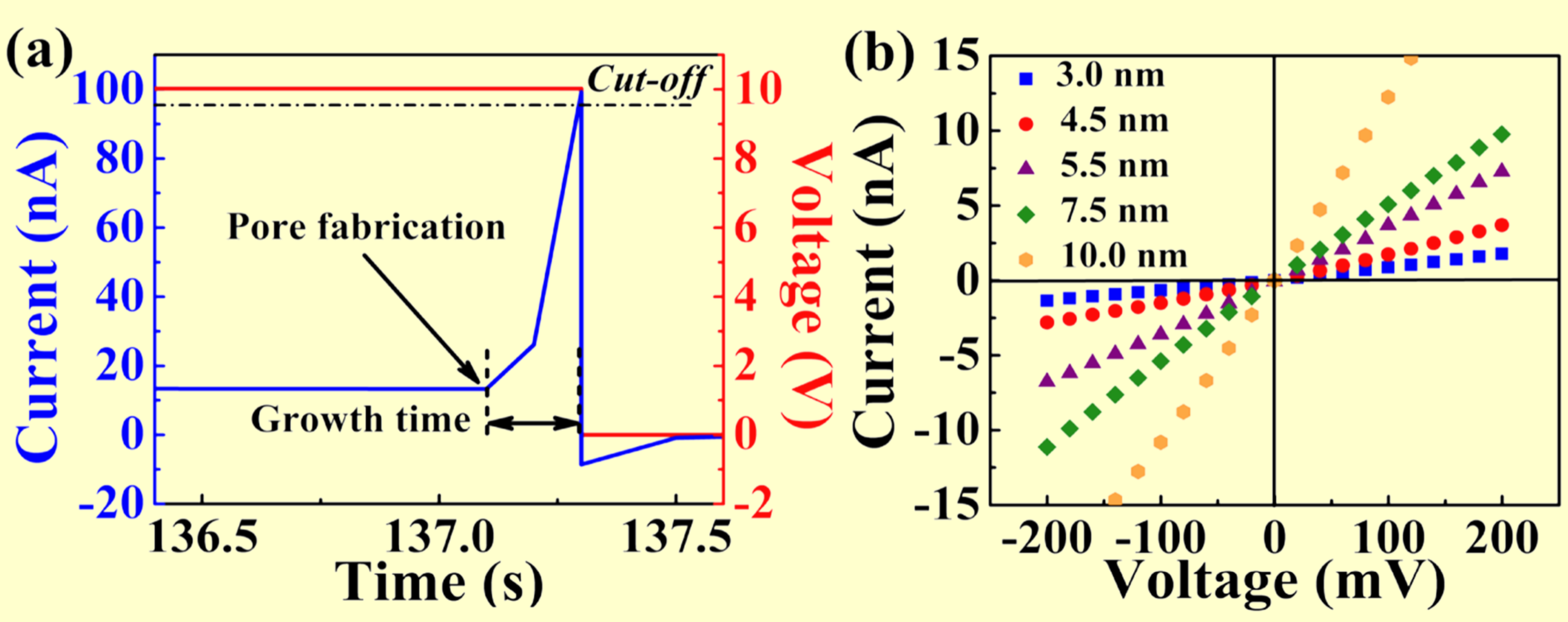


Fig. 1 (a) Nanopore fabrication is characterized by a sudden increase in leakage current through the membrane when a strong electric field is applied. (b) I-V curves allow for size determination of independently fabricated nanopores in a single device.

Results

Noise reduction

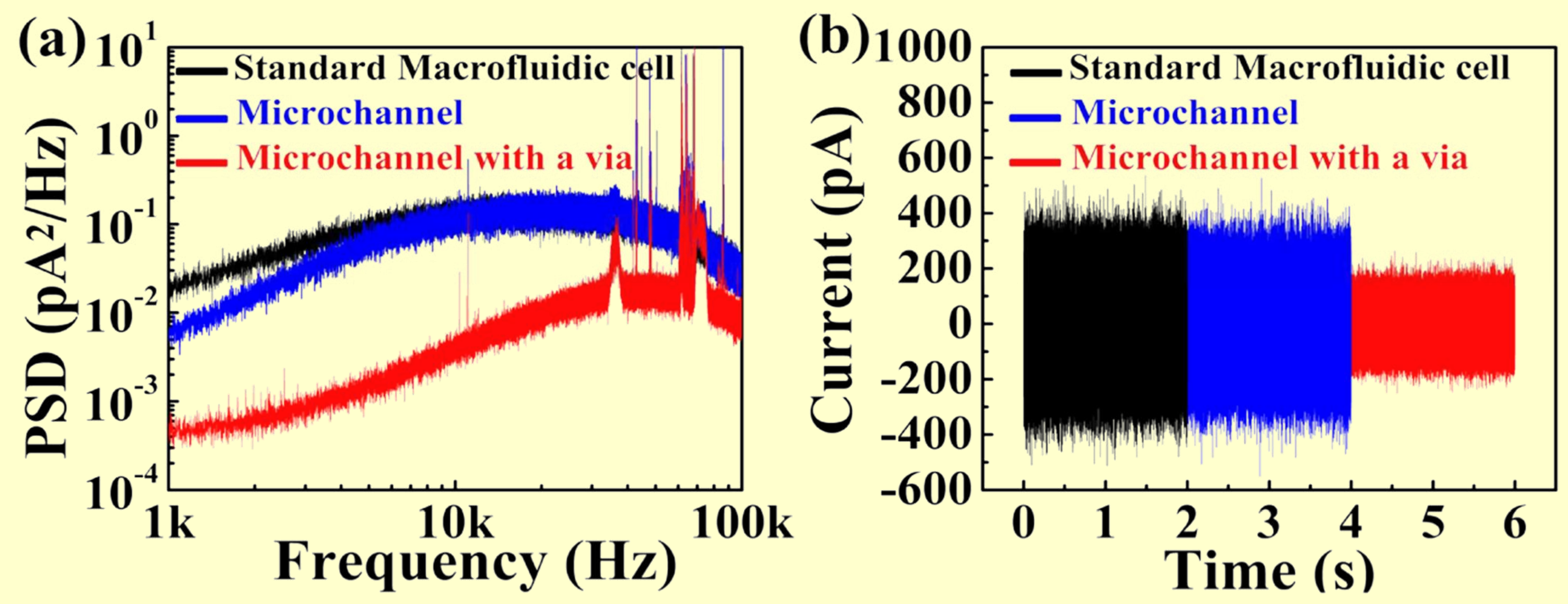


Fig. 4 (a) Power spectral density (PSD) plots and (b) current traces allow for electrical noise comparison between various fluidic configurations.

Biomolecular sensing

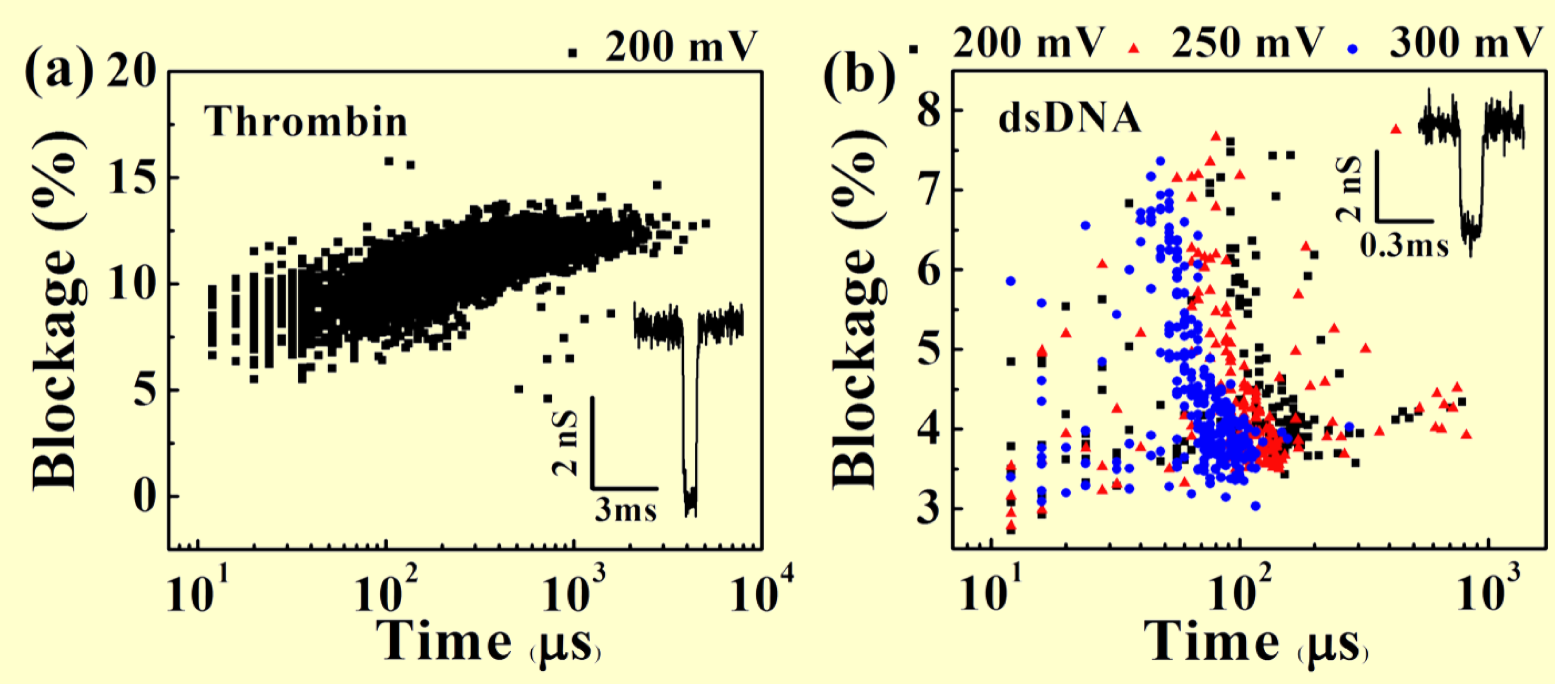


Fig. 5 Devices successfully sense (a) human α-thrombin (protein) and (b) 10 kbp DNA, which translocate through a nanopore producing an ionic current blockade. Each scatter point shows the duration and average conductance blockage of an individual translocation event (insets).

Achievements and Future Work

- Simplified fabrication and assembly for lab-on-chip devices
- Localized nanopores to specific regions of the membrane
- Reduced electrical noise for high-bandwidth recording

These achievements pave the way towards devices with:

- *Larger microfluidic arrays of nanopores*
- *Control over sample flow*
- *Integrated sample preparation and complex manipulations for analysis*

References

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