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Fabrication and high-resolution transmission electron microscopy characterization of nanopores in silicon nitride and 2D materials

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Background
Solid-state nanopores are an emerging technology for single molecule sensing of biomolecules including DNA, RNA, and proteins [1]. They provide a more resilient alternative to tradition biological nanopores, which are sensitive to temperature, pH, and other environmental factors. Specifically for solid-state nanopores, 2D materials provide a good foundation that is easy to modify, robust, and reusable [2,3]. 2D materials have unique properties that only appear when bulk materials are reduced to the nanoscale. Specific attributes can be generated in the 2D material and alter the dynamics of molecules travelling through the nanopores. Materials of interest include graphene, hexagonal boron nitride (h-BN), and transition metal dichalcogenides (TMDCs).

Methods
Different techniques for manufacturing solid state nanopores are investigated. These include transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM), and helium ion microscopy (HIM). From these microscopy methods, nanopores are created in SiNx membranes as well as in 2D materials.

Results
Pores in the range of tens of nanometres are milled into SiNx using the HIM. Single nanopores as well as arrays of nanopores were created to investigate various milling parameters (Figure 1. A, B). DNA translocations were observed by ionic current measurements, validating the presence and function of the nanopore. For 2D materials, a scaffold of SiNx must be used to create freestanding 2D materials. Graphene and h-BN are transferred onto HIM milled or gallium focused ion beam (FIB) milled holes in SiNx membranes. The resulting membranes are imaged with high resolution TEM (Figure 1.C).

Conclusion
Electron microscopy and ion beam milling are promising techniques for the production of solid-state nanopores. Various pore geometries will continue to be explored and methods will be developed to create novel nanopores in 2D materials. The combination of 2D materials results in unique properties in nanopore structures which would otherwise be difficult to achieve without the use of electron microscopy and nanostructuring.

Graphic:

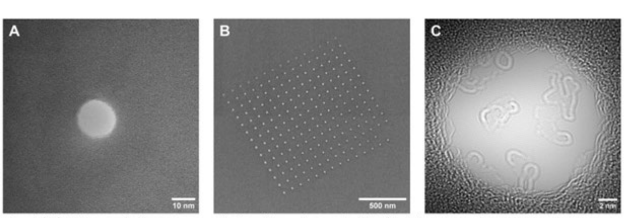

Figure 1: (HR)-TEM images of various nanopores milled into SiN_x membranes using HIM. A) A single nanopore of 15 nm diameter in SiN_x. B) An array of 225 nanopores (15×15), used to compare dose and dwell time parameters. C) Monolayer graphene transferred onto a HIM-milled nanopore of 15 nm diameter. The lattice of the graphene can be seen, as well as traces of carbon contamination.

Keywords:
Nanopores, 2D materials

Reference:

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