Rapid nanopore fabrication over wafer size using helium ion beam and automation for biomolecule detection

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Solid state nanopores in thin membranes hold great promise for label-free biomolecule detection such as DNA. Several techniques including focused electron-beam of a transmission electron microscope have been reported to fabricate such kinds of nanopores. Helium ion microscope (HIM) has been proven as another important method to make nanopores with pore size less than 10nm in a silicon nitride membrane or graphene layer. [1,2] For practical nanopore fabrication and device integration, it is challenging to control pore size, fabricate nanopores over wafer size with many chips and have good repeatability. Here, we demonstrate control of pore size, rapid nanopore fabrication over wafer size with automation software and good repeatability on a silicon nitride membrane using HIM.

It is easy to control nanopore size using different exposure time in a HIM system. As shown in Fig. 1, the nanopore sizes could be changed from 14nm to 5nm with exposure time change from 2.5s to 0.3s for ion beam current 1.0 pA. The pore shape is almost circular in shape.

We also tested an automation program including stage motion and milling for pre-cut chips over a wafer size to investigate mass production of nanopore chips. Each chip (4mm×4mm) has a circular silicon nitride membrane (diameter 6.5µm) in the center opening. Our results showed sufficient accuracy to automate stage motion to centere membrane on each chip with less stage settle time (<1min) over a wafer with 8×7 arrays of chips. The repeatability of nanopore fabrication was also investigated with automated stage motion and milling to define nanopore arrays over a distance of 400 nm on the same chip. It took 17min to finish 6×5 arrays of nanopore formation. As shown in Fig 2, the pore size has very good repeatability for an average 5nm of nanopore size.

With HIM and automation, it will become practical to fabricate chips with nanopores for biomolecule detection in a fast, controllable and reproducible way over wafer size.

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[1] J. Yang, D. Ferranti, L. A. Stern, C. A. Sanford, J. Huang, Z. Ren, L-C. Qin and A. R. Hall, Nanotechnology **22**, 285310 (2010).

[2] Y. Deng, Q. Huang, Y. Zhao, D. Zhou, C. Ying and D. Wang, Nanotechnology **28**, 045302 (2017).

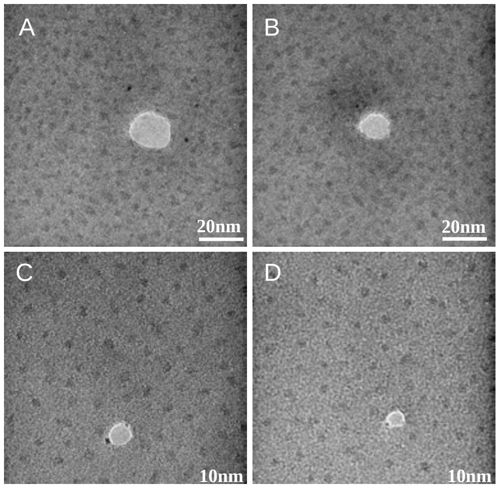

Figure 1: TEM images of four examples of different pore sizes with different exposure time:(A) 14nm, 2.5s; (B) 10nm, 1.5s; (C) 8nm, 0.5s; (D) 5nm, 0.3s.

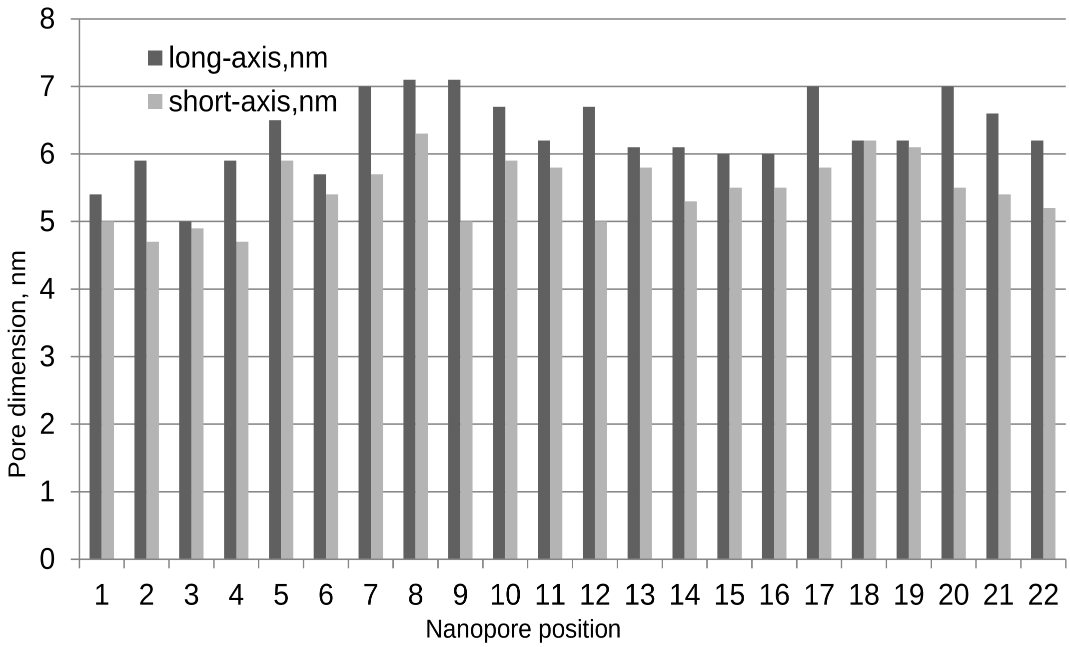

Figure 2: Pore dimension measurement for 22 nanopores.