Supporting Information

A Flexible Nanoporous Template for the Design and Development of Reusable Anti-COVID-19 Hydrophobic Face Masks

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Attachment of the Polymeric Membrane on an N95 Mask

The membrane is expected to be attached on the N95 face mask by simply attaching the edges (*e.g.*, using tape). We expect the edges of the tape to reach the inner side of the mask. To replace the membrane, it would be removed using the side of the tape reaching the inner of the mask (portion of the mask that is unexposed to the outer environment and therefore uncontaminated) and thrown away. Another membrane would be attached on the same N95 mask (see Figure S4 showing a rough sketch of the idea).

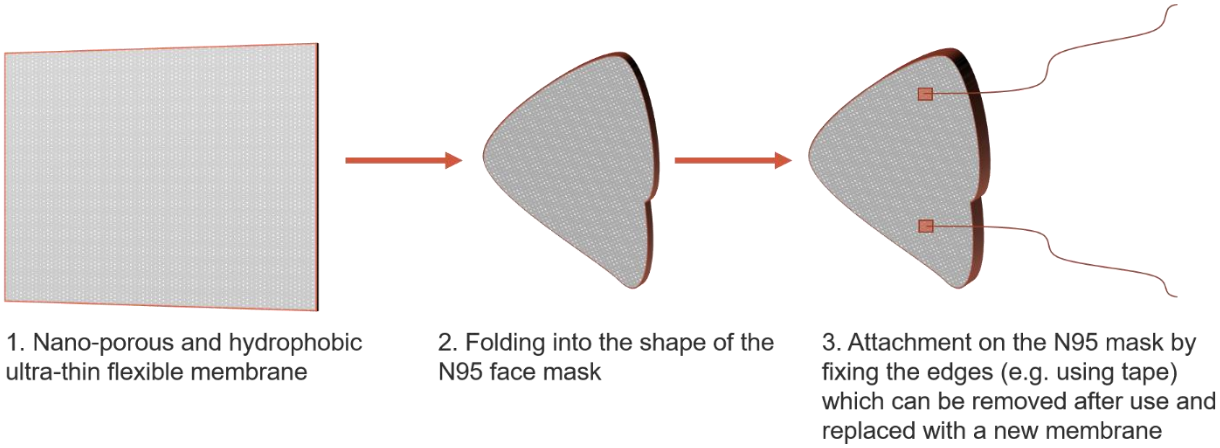

Figure S4. Schematic showing the use of the nanoporous membrane fabricated on an 8-in wafer on a reusable N95 mask after folding it. The membrane can be replaced after every use.

Polyimide-Based Membrane Fabrication and Release

The 10 µm polyimide (PI) layer was prepared using PI 2611 from HD Microsystems which was spin-coated on a Si (100) wafer for 30 s at a speed of 2000 rpm. An SiO_2 layer is used on the Si wafer before coating the PI because of its lower bonding energy with PI than Si, which eases the process of peeling off the membrane. PI requires several curing stages including soft-baking, intermediate curing, and final curing at various temperatures. Soft-baking is conducted at a temperature of 90 °C for 90 s, whereas intermediate curing is performed at a temperature of 150 °C for a period of 90 s, and the final curing step is performed at a temperature of 300 °C for a duration of 30 min. It should be noted that the temperature should be steadily ramped from 150 °C to reach 300 °C at the rate of 240 °C/h. The PI is etched in an Oxford reactive ion etching (RIE) tool using O_2 plasma. After etching the nanopores, the edges of the PI film on the Si wafer were cut using a scalpel (to make a circular pattern as shown in Figure S2), then using a pointed tweezer, the mechanically robust PI film was released. This membrane would then be attached on the N95 mask.

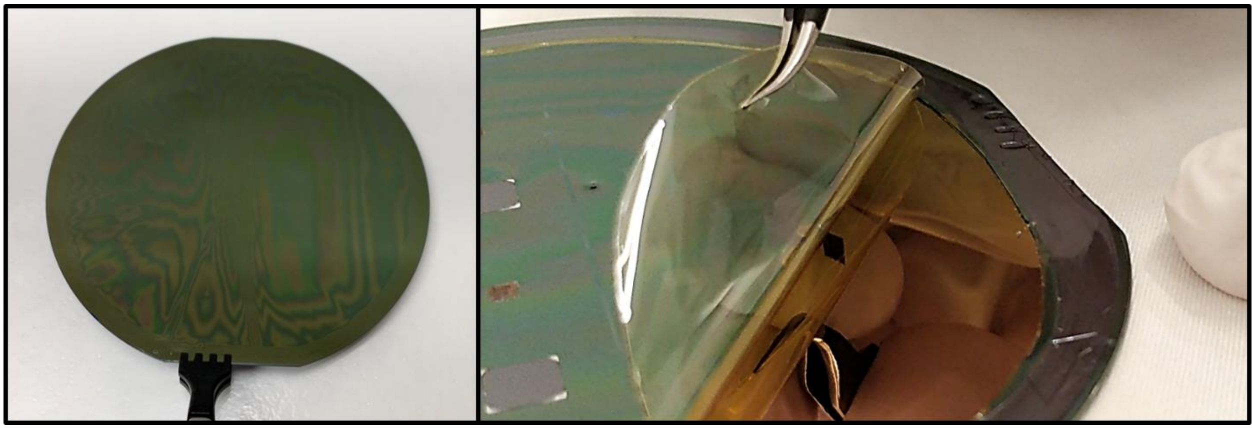

Figure S2. Polyimide thin layer coated on a 4-in silicon wafer and cured (left). Polyimide-based nanoporous membrane during the release from the wafer (right).

Large-Scale Scanning Electron Microscopy of the SOI Template and Polymeric Membrane

Large-area scanning electron microscopy (SEM) images of the nanoporous Si-based template and PI layer are shown in Figure S3 and S4, respectively. We have previously developed and demonstrated the etching of a 10-µm PI film using O_2 and CF_4 gases in an RIE tool where an Al or Cu sputtered thin film was used as the hard mask (*Small* **2019**, 15, 1804385, *npj Flexible Electronics* **2018**, 2, 13). The PI etching cycle consists of 2 steps, first an O_2 plasma step is used to etch the PI followed by a shorter step of O_2 with CF_4 gases to remove the residues; each cycle etches several microns of PI. In the case of the membrane development, the SOI template is coated with Cu to enhance its selectivity to the PI during the PI etching step. The Cu layer can also be "replenished" where after every few uses as a shadow mask, the template can be coated again with a Cu thin film to maintain its reusability.

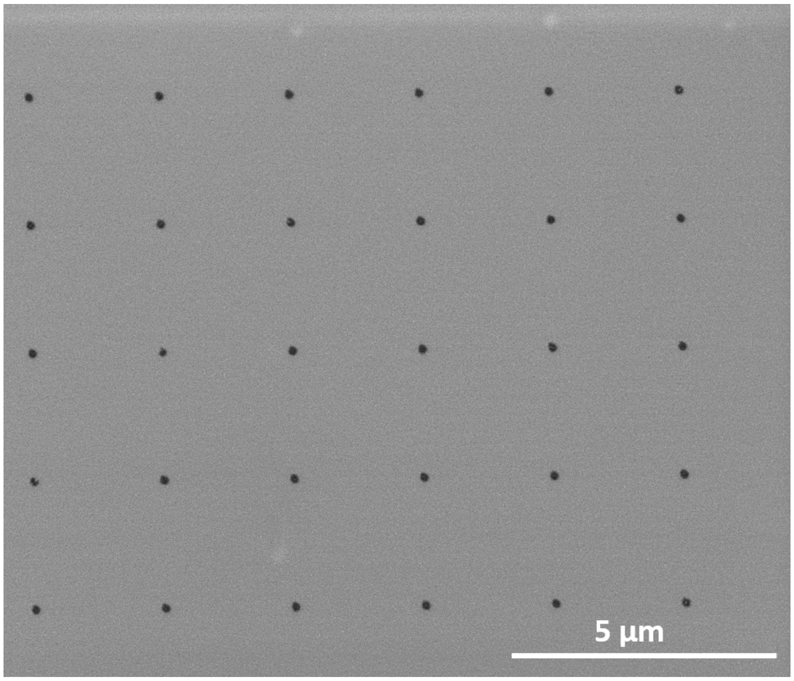

Figure S3. Scanning electron microscopy image of an SOI template with 100-nm pores.

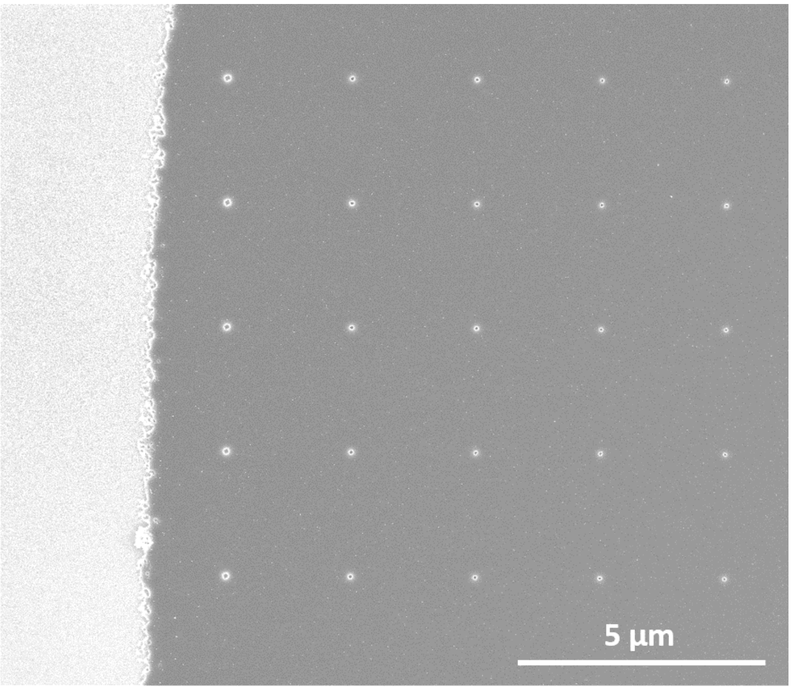

Figure S4. Scanning electron microscopy image of a nanoporous membrane with pores size ranging from 100 nm up to 160 nm.

Mechanical Resilience of the Polyimide-Based Membrane:

Polyimide has been widely used in aerospace and microelectronics applications and, more recently, in flexible electronics due to its excellent mechanical strength, thermal stability, and chemical properties over a wide range of temperatures (-20 °C to 400 °C). In our previous work, we have developed flexible three-dimensional (3D) integrated circuits based on thin PI film (10 µm) where through-polymer-vias have been filled with Cu to achieve electrical connection between the thin-film-based devices integrated on both faces of the polymeric substrate with excellent mechanical properties.

The mechanical resiliance of a similar polymeric thin layer (10 µm-thick PI) was studied by our group in a previously published paper (Small **2019**, 15, 1804385), where we performed a bending test up to 10,000 cycles with a bending radius of 1 mm which is far smaller than the needed applied bending radius during the attachment on the mask. Negligible effects were observed on the thin-film-based sensors, which were fabricated on the PI film. This finding also confirms that the PI film is intact and is mechanically robust enough to be enable its attachment on the mask with no loss of quality.