Development of Scalable Fabrication Methods for High-precision Membranes

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Microfiltration membranes play an important role in various applications and processes. However, the currently available track-etched polymer membranes suffer from their random structure and statistical hole diameter, while standard precision membranes are typically stiff and brittle and are made using expensive silicon semiconductor processes. In response to these challenges, scalable and cost-effective fabrication processes for large area and flexible high-precision membranes were developed. The processes allow the fabrication of the membranes from a variety of different metals and polymers and can be customized for various applications.

Microfiltration membranes are an integral part of many systems and processes, where they are mainly used to filter or up-concentrate cells or micro-particles, with polymeric track-etched membranes representing the current industry standard. However, these types of membranes struggle with several drawbacks: Their pores suffer from uneven distribution, vary in terms of their diameter and they randomly overlap. Additionally, they have severely limited pore density (porosity) and their geometry is bound to being cylindrical in shape, which is unfavorable in many cases. High-precision membranes based primarily on silicon semiconductor processes have long been recognized as alternative technologies capable of overcoming the limitations of track-etched membranes – but they also come with a catch, as the used materials are typically stiff and brittle and they present a significantly increased cost per unit membrane area, when compared to track-etched membranes.

In response to these challenges, we have developed scalable and cost-effective fabrication processes for large area and flexible high-precision membranes. These fabrication processes overcome the issues associated with polymeric track-etched & high-precision membranes by combining and improving their best features – and as an additional bonus, the processes also allow the fabrication of the membranes from a variety of different metals and polymers.

In our process, microstructures are first prepared using standard lithography methods. The generated structures are then transferred into a suitable metal by electroplating which either yields the desired metal membrane (Figure 1) or a metal tool. The metal tool is then used in an embossing approach for the fabrication of polymer membranes (Figure 2). While this process is currently performed on small scale using a sheet-to-sheet method, it has a high potential for later upscaling to roll-to-roll production.

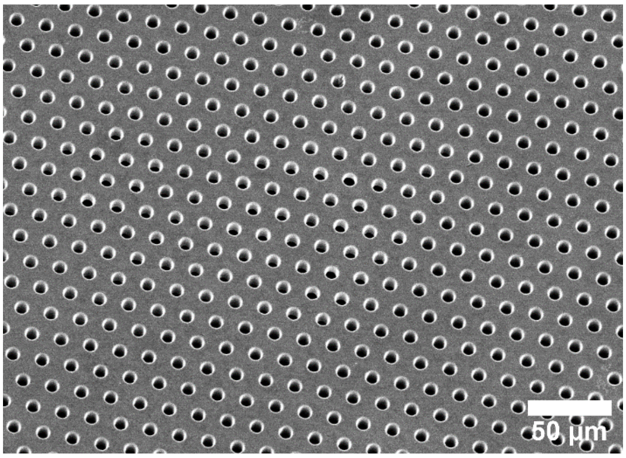

Figure 1: Metal membrane example (SEM micrograph).

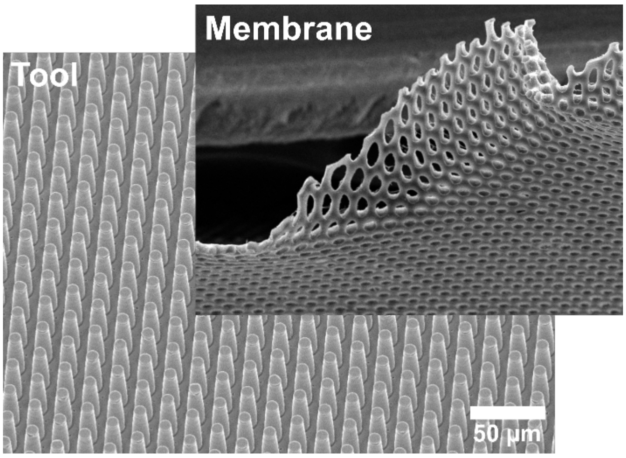

Figure 2: Example of a metal tool and the generated polymer membrane (SEM micrographs).

In the shown examples high-precision membranes with 7.2 µm cylindrical pores, 23% porosity and 20 µm thickness were realized which are designed for the isolation of circulating tumor cells (CTCs) from the blood of cancer patients. However, the membranes are not limited to filtration applications but could be used as a key component in diagnostic devices or organ-on-chip systems. In addition to tailor-made micro-pores, the surface chemistry and nano-topography of the membranes can be tuned for specific purposes.

Key advantages:

- Precisely shaped and aligned pores
- Tunable surface properties
- 2-4 times higher porosity than industry standard
- Scalable and cost-effective processes

Possible application fields:

- Cell isolation and analysis
- Point-of-care diagnostics
- In vitro models and organ-on-chip
- Biological sample preparation
- Downstream processing