

Use of High-Technology Track-Etched Polymer Membranes in a Wide Range of Industries

by Henri Hanot

High-technology membranes intended for the detection of microorganisms are used in the pharmaceutical, cosmetic, and food industries (Figure 1). In the diagnostic field, the membrane is used as a control barrier in glucose sensors. Lastly, the membrane is used for the detection of cancerous cells. The membrane discussed here, developed within the Laboratory of High Polymers of the Catholic University of Louvain (UCL-POLY, Louvain la Neuve, Belgium), and produced by **it4ip** (Seneffe, Belgium), is used to create monolayer cells when a suspension is filtered through it. This monolayer is then transferred onto a microscope glass slide. This permits the histologist to perform a much more detailed analysis compared to the previous technology of randomly transferring the cells to a microscope glass slide. Since multiple layers are often present, the diagnosis was less precise.

What is a membrane?

A membrane is a thin, porous film (polymeric, metal, paper, etc.) through which a fluid (liquid, gas) is filtered in order to carry out a separation. Types of filtration are subdivided according to the size of the particles or technology used (Figure 2).

Microfiltration uses pores ranging between 0.1 and 10 μm . The membranes of microfiltration thus elimi-

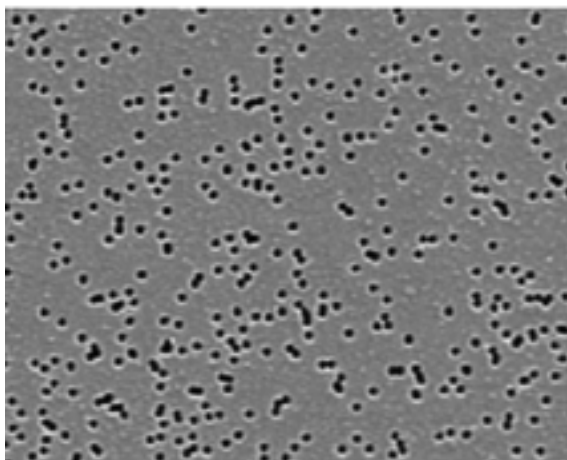
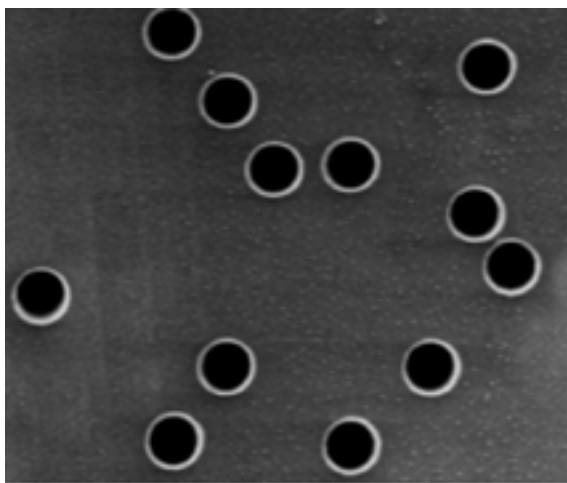


Figure 1 Two surface images of extreme (very small and very large) track-etched membrane “catches” at the same magnification: 5- μm pore size (400,000 pores/cm²) (top) and 50-nm pore size (1 billion pores/cm²) (bottom).

nate all of the bacteria. Viral contamination is partially retained by this process, although the viruses are much smaller than the pores of this type of membrane. Indeed, the viruses can bind to bacterial biofilm. Microfiltration is thus used in many treatment processes where particles of a diameter larger than 0.1 μm must be eliminated.

Ultrafiltration, used for complete elimination of viruses, uses pores from 0.001 to 0.1 μm .

The recently developed technique of nanofiltration is currently used primarily in the processes of water purification, such as softening (particle and salt removal), dye removal, and elimination of micropollutants.

The last type of filtration to consider is reverse osmosis.

One application: An artificial pancreas

More than 80 million Europeans suffer from type 1 diabetes. This form of diabetes is characterized by insufficient insulin secretion, resulting in hypoglycemia. The condition is responsible for long-term complications such as coronary diseases, renal problems, and loss of vision. Transplantation of the pancreas is possible, but the number of donors is limited and problems arise due to the toxicity of the immunosuppressive drugs used, not to mention the risk of rejection.

The approach discussed here consists of encapsulating small islets of Langerhans in a porous biocompatible synthetic matrix (the implant), which stops the immunizing cells but permits the passage of insulin and glucose. The technology simulates natural insulin secretion by the organism and decreases the risk of rejection of the implant as well.

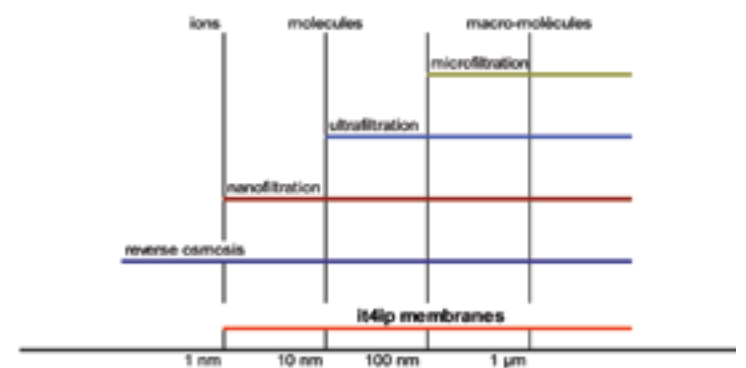


Figure 2 Different types of separation processes.

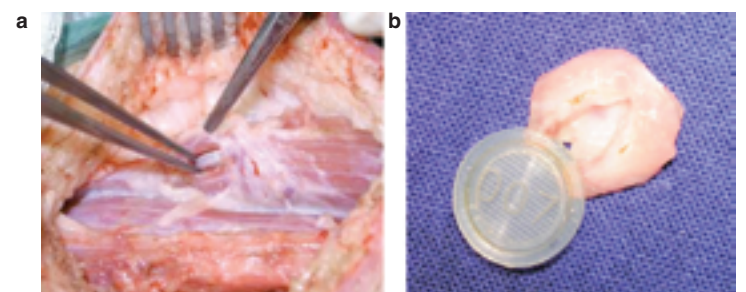


Figure 3 Implant a) transplanted in a pig and b) removed after 47 days (Stattice Sante, EU Granted Project BARP+#NMP3-CT-2003-505614). Figure courtesy of Prof. P. Bertrand, PCPM-UCL, Louvain la Neuve, Belgium.

The membrane is used in the implants because it controls the flow of insulin, glucose, and nutrients while effectively protecting the small islets from a potential attack by immunoglobulins or other contaminating agents.

An artificial pancreas incorporating the membrane was tested successfully on laboratory animals (Figure 3). Transposition on a human scale and the associated clinical tests are expected to take place in late 2007.

Membrane technology

There are various processes for the production of porous membranes, for example, vegetable or metal fiber agglomeration and polymer or metal perforation.

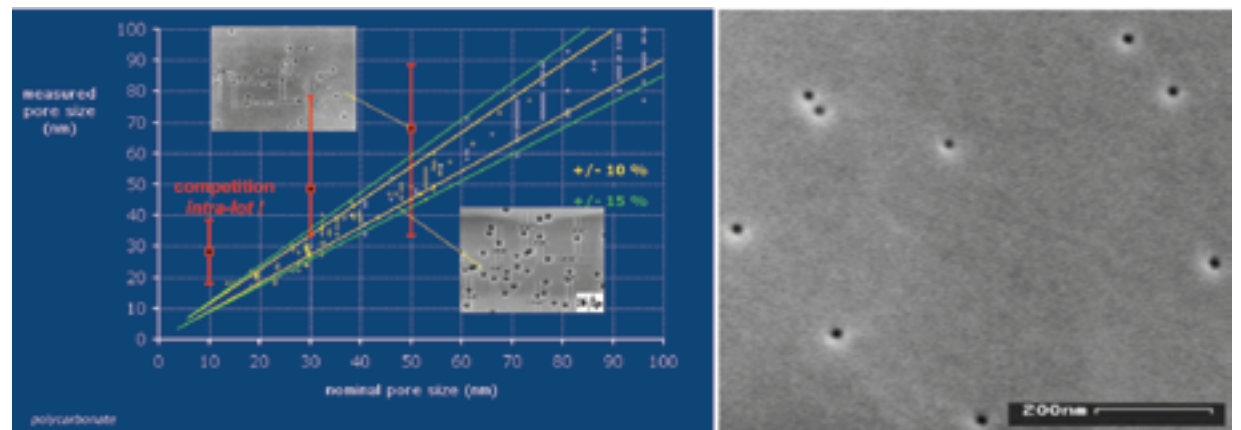


Figure 4 Left: comparison of the distribution of pore sizes (interbatches) of **it4ip** membrane compared to a batch of commercial membrane of nominal size 10 nm, 30 nm, and 50 nm (in red). Whereas the **it4ip** 50-nm membrane presents pores from 45 to 55 nm, the commercial membrane shows pores from 35 to 90 nm. This broad distribution of pore size prevents any precise separation because particles from 80 to 90 nm will be able to cross the membrane. In comparison, the use of the **it4ip** membrane of nominal similar size prevents the passage of any particle larger than 55 nm. Right: Surface of an **it4ip** polycarbonate membrane (pore size: 15 nm).

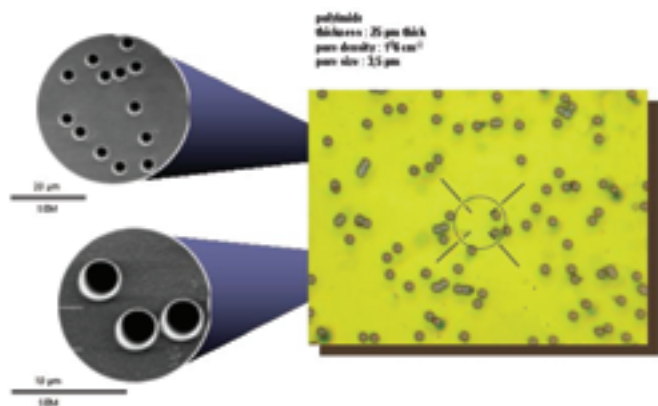


Figure 5 Polyimide track-etched membrane.

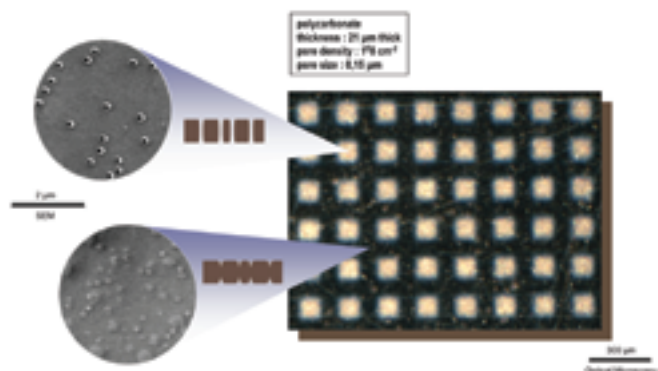


Figure 6 Patterning created in polycarbonate.

The **it4ip** technology uses perforation of thin polymeric films: The film is bombarded with heavy energetic ions produced, for example, by a cyclotron. The chemical bonds of polymer are initially damaged by the heavy ions, then, secondly, the weakened zones are chemically etched, resulting in the name “track-etched” membranes.

This technology, called 1st Generation, is used mainly for the realization of microporous membranes 10–20 µm thick, with pores between 0.1 and 10 µm that are randomly distributed. The polymers used are polycarbonate (PC) and polyethylene terephthalate (PET). This technology was developed in the mid-1980s by Prof. Legras and his team at UCL-POLY. In 1989, a first spinout, CycloPore, was created. Membranes of this type are marketed by **it4ip** under the nonexclusive license of the UCL, primarily in the biomedical sector.

Since 1996, technology has progressed considerably, and new possibilities have opened up in the field of nanotechnology. Indeed, new polymers are available that make it possible to control the geometry of the pores and their distribution at the same time (Figure 4). In addition, it is currently possible to fill the pores with metals or other polymers and, through this process, obtain nanowires or nanotubes. These various tools make it possible to produce nanoobjects (films, supported thin layers) or nanostructures for a broad variety of high-technology applications in fast-growth nanotechnology markets. This technology, called 2nd Generation, is patented.

The use of polyimide (PI) permits optimal use of the membrane up to 430 °C (PC and PET cannot be used beyond 120 °C). Moreover, the chemical and physical resistance properties of PI are much better (Figure 5). The PI track-etched membrane makes it possible to foresee ultraprecise separation under extreme temperature conditions or chemical stress. Finally, PI is a well-known polymer in the field of electronics.

The precise distribution of the pores makes it possible to create porous networks surrounded by non-porous zones (Figure 6). This technology makes it

possible to consider applications in the field of multipurpose sensors and multiple-well plates. The number of analyses carried out in such a microobject would be very high, with reduced analysis costs, reduced analyzer weight, and a drastic increase in the number of analyses carried out starting from a microvolume. For example, all blood analyses could be carried out in less time using only one drop of blood (space applications, combat situations, general day-to-day hospital use, and lab-on-a-chip).

The company has also developed a method of pore creation in a thin layer deposited, for example, on electronic circuitry. Thus, each cavity of a network of pores can be used as a nanoreactor for a specific analysis whose reaction can be controlled by means of circuitry. A major application is lab-on-a-chip technology.

In practice, two possible applications have been considered:

- Starting from a chip, several products are analyzed for one identical reaction
- Starting from a drop of the product to be analyzed (for example, blood), several different analyses are carried out on the chip.

The combination of the various properties of the membranes makes it possible to create various types of products for a large variety of applications.

For example, the nanopores can be used like nanomolds. They are filled with metals or alloys (using electrodeposition) in order to create nanowires. These nanowires can then be collected after dissolution of polymer or can be used in situ. Nanowires of 100 nm are used as nanoelectrodes. Nevertheless, the properties of the smaller nanowires are very different from macrowires and are useful in the field of magnetic sensors, for example, in the storage of MRAM (magnetic random access memory) data.

When the pores are filled with conducting polymer, polymeric nanotubes or nanowires can then be collected, which exhibit exceptional properties compared to the macroscopic properties of the material. They can also be used in situ in the biochemical sensor field.

Figure 7, “catches” under the scanning electron microscope, demonstrates how the nanopores (top center) are used like nanomolds to create metal nanowires or polymeric nanotubes. These nanowires can be used as electron emitting tips in high-technology screens or in microwave filters, for example. Lastly, the technology of nanonetwork creation allows the precise alignment of nanowells, and thus precise filling and reading of the cells with an automatic multiple-well reader.

Future applications

A wide range of industries can benefit from the products mentioned here: the transport industry, for integration in magnetic sensors and radars; telecommunications, for systems of absorption of microwaves, while passing by screens for portable electronics; the energy sector, in the development of fuel cells; as well as the health sector.

The company provides research and development services and takes part in applied research projects in partnership with its customers in order to develop applications and market the technology. It also develops prototypes and

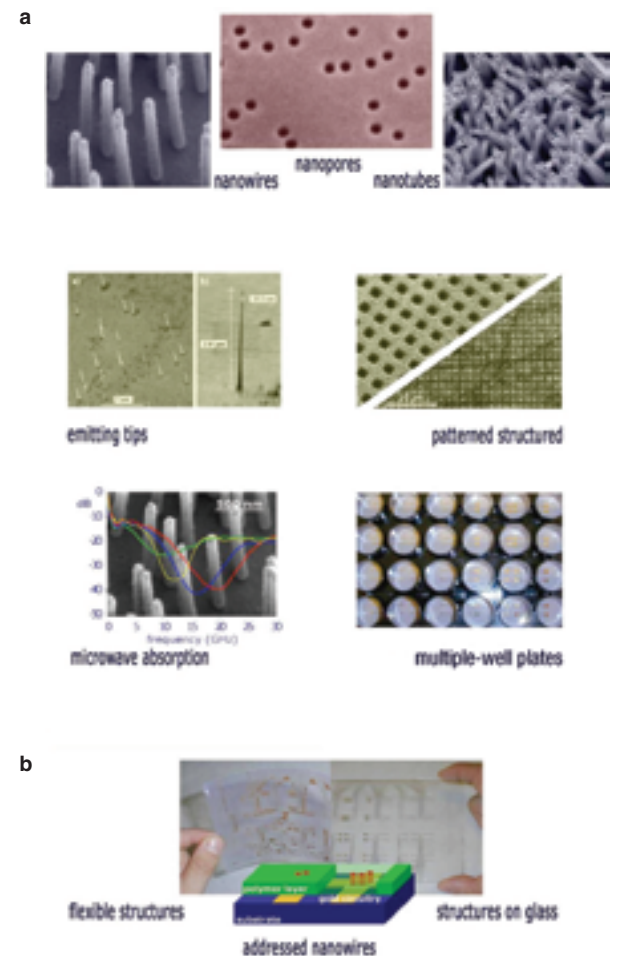


Figure 7 a) The **it4ip** technology toolkit; b) assembled structures.

small-to-medium pilot products. The company works in close cooperation with the Research Center of Cyclotron (UCL) and with the GANIL (Caen, France) for the irradiation of polymeric films. Membrane production is carried out in a controlled clean environment applying ISO 9001:2000 quality standards.

Additional reading

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