Preparation of diode-like single-ion track-etch membrane using combination of chemical and electro-stopping

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Particle track etching has found diverse uses in science and technology [1]. Production of porous membranes stands out among other applications of the track-etch technique. In the past decade special attention was paid to the study of track-etch nanopores in poly (ethylene terephthalate) (PET) with respect to their ability to mimic biological ion channels (e.g. [2, 3]). Artificial cylindrical channels of few nanometers diameter and 5 or 10 micrometer length exhibited electrical and electro-kinetic properties similar to those observed earlier for biological membranes. One should realize however that the dimensions of artificial nanopores prepared by the track-etch method differ strongly from typical dimensions of biological ion channels e.g. the length of a pore in a PET membrane is app. 10 000 larger than biological channel length. We have aimed therefore at preparing a track-etch pore with dimensions closer to biological ion channels. One way to do that is based on preparation of a strongly asymmetric track-etch whereby the short and narrow part at the tip of the etch pit determines the electric properties of the whole channel.
For this purpose, a single-ion irradiated PET film is inserted into an electrolytic cell (see Fig. 1) and etched from one side in 9 M Na OH while bathing the other side in a mixture of 2M KCl and 2M HCOOH (1:1 by volume), electrically retracting the OH^- ions from the tip of the etch pit during pore break-through.

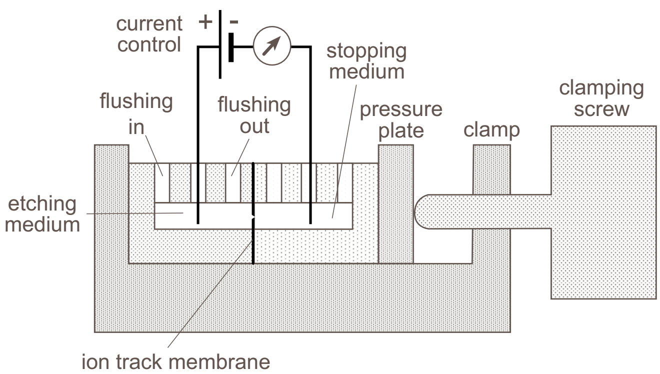

Fig. 1 Cross section of the electrolytic cell used for one-sided etching of ion track membranes. The clamping mechanism ensures a reliable seal (>10^{12} Ohm) between the chamber halves and the membrane.

The process results in the conically shaped pore having wider entrance of app. 800 nm in diameter (measured by SEM) while the diameter of limiting the transport tip is app. 2 nm (on the basis of PEG permeation). The structure and nature of the tip will be the subject of further investigation.
The electrical properties of the membrane were determined under symmetric bathing conditions of pH and KCl concentration. The current-voltage (I-V) characteristic was measured by stepping the voltage between –5 and +5 V. Each measured point corresponds to the current averaged over the dwell time (5 to 10 seconds). An example of observed asymmetric diode-like current-voltage characteristic has been shown in Fig. 2.

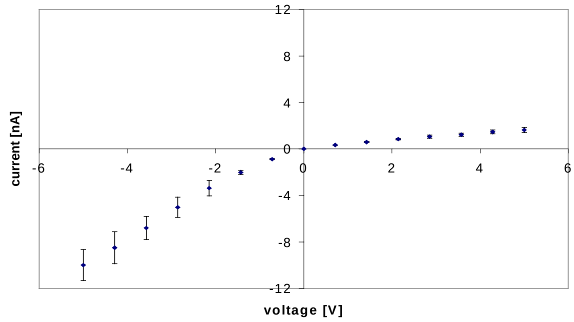

Fig. 2 Intrinsic asymmetry of voltage-gradient stopped single pore membrane. Current – voltage characteristic in symmetric concentration and pH conditions at 0.1 M KCl and pH = 7.

The observed diode-like behavior can be controlled by pH, electrolyte concentration and the pore dimensions. The phenomenon is reproducible and very stable: the same membrane can be studied for many days.
The obtained results have suggested that the one-sided etched pore in a PET membrane can serve as a model of a biological channel. Additionally the diode-like behavior of the membrane enables to use it as an electrical valve.

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