

## Diode-like ion track asymmetric nanopores: some alternative methods of fabrication

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The interest in the fabrication of nanopores with pre-determined geometries has lately grown which is motivated by a possibility of modeling biological channels and using nanometer-sized pores as single-molecule sensors for the detection and analysis of biopolymers [1,2]. Attempts to approach geometric characteristics of the channels in biological matter have led to the development of conical nanopores produced by electric field assisted one-side etching of polymer foils irradiated with swift heavy ions [3]. In this report, we present a surfactant-controlled etching method which allows production of asymmetric track-etched nanopore membranes with diode-like ionic conductivity, i.e., similar to conical pores. The asymmetry of pores is provided by self-assembly of surfactant molecules at the pore entrances on one side of a membrane during chemical etching. The other side of the membrane is exposed to ultraviolet irradiation prior to etching which excludes protective effect of the surfactant. By varying the alkali concentration in the etchant, control over the pore shape has been achieved. Tip opening angles as large as 15-20° have been obtained. The rectification ratios in electrolyte solutions turned out to have great values in the case of pores with a highly-tapered profile and tip opening diameters of 30-50 nm. As compared with conical geometry, the highly tapered pores with bullet-like tips have a much shorter effective length ("sensing zone") and may be an alternative to existing methods of production of resistive-pulse sensors. Another etching technique has been developed for the production of nanopores for atom beam projection nanolithography [4]. To increase the angle aperture, one side of a membrane is exposed to a surfactant-containing alkali solution, while the other is treated by a surfactant-free solution with a higher alkali concentration. Examples of nanostructures fabricated in this way are presented.

[1] C.A. Pasternak *et al.* *Radiat. Meas.* **25** (1995) 675.

[2] K. Healy *et al.* *Nanomedicine* **2**(6) (2007) 875.

[3] P. Yu. Apel *et al.* *Nucl. Instrum. Meth. Phys. Res.* **B184** (2001) 337.

[4] V.I. Balykin *et al.* *JETP Letters* **84** (2006) 466.