

Nanoporous membranes: A new prospective

Mukesh Chander^{1*}, Sandeep²

¹Materials Science Lab., Department of Physics, Chaudhary Devi Lal University, Sirsa-125055, India

²Govt. Senior. Sec. School Sakra, Kaithal, Haryana-136027

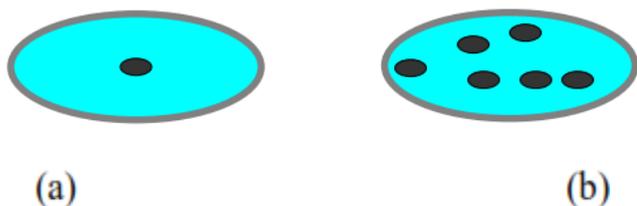
Abstract – The transport using nanopores single/multi-nanopores membranes offers many technological applications. In order for the membrane to be applied in membrane technology, it is necessary to make membrane from foils according to their use. In addition, the fabrication of nanopores in membranes must be economical, durable and scalable. Nanoporous membranes cover a wide range of materials such as inorganic (metals, ceramics etc.), organic (polymeric), or composite materials. Keyword: Nanopores, Separation

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1. INTRODUCTION

On the basis of geometrical shape of pores we can distinguish nanopores membrane in various types such as cylindrical, conical, biconical, and bullet. In addition, we can distinguish membrane with respect to the type of material used in foils. In general, we can synthesize two types of membrane:

- (i) Single pore membrane
- (ii) Multi-pores membrane.



Both types of membrane have their individual use in various fields of research as well as in general life.

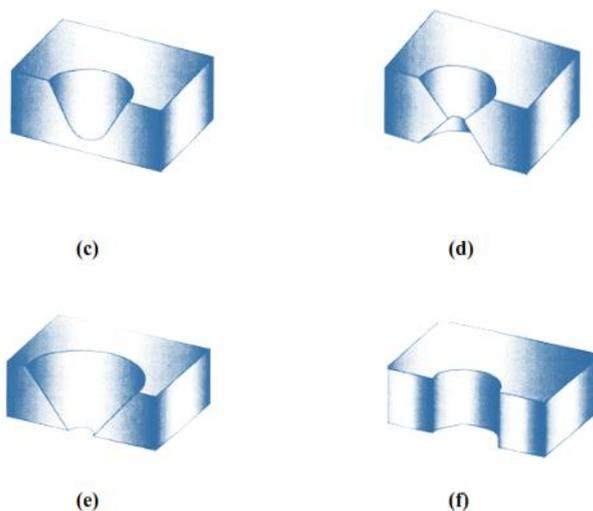


Fig. 1 Demonstration of membrane and shape of pores a) single pore b) multipores membranes and (c) conical (d) cylindrical (e) bullet and (f) biconical shape.

The transport using nanoporous (multi-nanopores) membranes used in various applications such as instance protein separation and purification, drug delivery and biomedical applications etc. [1]. In order for the membrane to be applied in membrane technology, it is necessary to make membrane from foils according to their use.

2. MEMBRANES MATERIALS

2.1 Anodized membranes

For the fabrication of anodized membranes, generally used materials are anodic aluminum

oxide (AAO) which is the most common nanoporous membrane materials. In addition, the production of these type of membranes include the anodization of aluminum substrates in an aqueous acidic solution [2]. The geometrical condition of nanopores can be well-ordered by tuning the anodization process. The nanopores in AAO membranes can be produced with 10–200 nm in diameter, pore length about several tens of μm and pore density of the order of 10^{11} pores cm^{-2} with the help of chemical mechanisms in the fabrication process.

2.2 Microfabricated membranes

Microfabricated membranes are synthesized with micro- and nano-fabrication processes. By this method we can manufacture cylindrical arrays of nanopores in silicon nitride (Si_3N_4) and silicon (Si) membranes. For producing an array of uniform cylindrical nanopores we can use focused ion beam (FIB) etching technique [3] in an ultrathin silicon nitride membrane. The production of silicon nitride and silicon membranes are costly and this is the main drawback of this technology.

2.3 Track-etched nanoporous membranes

Ion-track technique is the method employed for the production of nanoporous polymeric membranes. With this technique, we can quite easily control the pore size as well as pore geometry by changing the external conditions in etching process (etching time, temperature and etchant concentration). The density of the pores per unit area can be controlled by adjusting the density of projectile ions (ion fluence). The commonly used track-etched membranes include PC, PET, and PI of thickness ranging from 5–100 μm . Track-etched nanopores are randomly distributed and normally cylindrical or conical in geometry.

In polymer nanopores membrane, a conical nanopore have different diameters on both sides but cylindrical nanopore have the same diameter shown in Fig. 1. (c) and (d). Similarly other nanopores shape mainly changed their diameter as shown in Fig. 1. (e) and (f).

3. APPLICATION OF NANOPOROUS MEMBRANE

Biological nanopores are used in various applications in research of biophysics, biochemistry, and chemistry for sensing, detecting of individual atom and molecule [4]. Due to their different geometry and chemical configuration, nanopores are capable for utilizing in biological application for detection of atoms and molecules.

Solid-state nanopores are generally called synthetic nanopores in recent days. These nanopores membranes are the substitute of biological nanopores. This is due to the fact that they

are well stable with external conditions such as temperature, ionic strength, pH, and concentration. For molecular sensing, the detection of single molecule is recorded by current changes as they translocate through the pore.

3.1 Glass nanopipette

Glass nanopipettes are used for molecule sensing. In the fabrication process of glass nanopipettes, pipette pullers are generally used. Now a days the pipette pullers are commercially available. In synthetic process glass capillary tube is first heated with the laser. After that glass tube can be mechanically pulled until it breaks at the narrow neck, thereby forming two open-ended nanopipettes. In this process we can produce nanopipettes with opening diameter of several tens of nanometers [5].

3.2 DNA sequencing

For the purpose of DNA sequencing the electric field drive DNA molecules through nanopores and by using the time characteristic of nanopore ion current distinguish the size of DNA. This method can be divided into two types of materials (i) bio-nanopores DNA sequencing, and (ii) solid-state nanopores DNA sequencing [6]. The main disadvantage of bio-nanopore sequencing is that it pause and reverse DNA molecules which makes noise in the current-time signal and the signal misinterpreted [7]. But DNA sequencing with solid-state nanopores sensors can realize the parallel detection of DNA [8, 9]. In addition, solid-state nanopores DNA sensors are cost effective.

3.3 Protein detection

Recently, the short diameter $\sim 3\text{nm}$ solid-state nanopores successfully detected the ubiquitin protein and analyzed the connection between ubiquitin protein and protein. Solid state nanopore possesses high detection resolution for the molecule internal structure. Nanopore sensing and detection technology have been used in real-time detection of DNA protein interactions, protein-protein interactions, detection and diagnosis of diseases and detection of heavy metal ions and viruses.

3.4 Energy conversion

Energy conversion methods based on nanopores convert the energy existing in environment, such as mechanical, chemical, light, and electric into other forms and does not produce carbon dioxide, vibrations and noise [10,11]. The function of ion channels of cell membrane is the main inspiration of energy conversion with nanopores [12]. Due to the excellent performance of nanopores, such as tunable size and shape, chemical durability, thermostability, etc. [13], they can be used in energy conversion. Besides these practical applications,

solid-state nanopores can also be used in smart ion transport behaviors, such as ionic selectivity, ionic gating and ionic rectification, that provided extraordinary performance in energy conversion [14, 15].

3.5 Nanofluidic diodes and transistors.

As the asymmetric current flow in nanofluidic devices, it is comparable to the behavior of electronic diodes [16] and transistors [17]. The exception is that in nanofluidic devices ions of solution rather than electrons work as the charge carriers [18]. Implanted electrodes near the nanopores with a concentration gradient solution act as a controllable gate and effectively alter the flow of current through the nanopores. In addition, tunable voltage influences fluid transport and ionic current rectification [19].

3.6 Nanofluidic separations and sieving

Several mechanisms to separate the molecules are used now a days with improved resolution and separation speed. By using nanofluidic separations mechanism molecules are separated on the basis of charge with significantly reduced separation lengths [20]. For the separation of two fluorescent molecules, the shear-driven flow mechanisms used in nanopores generates high flow velocities for high-speed chromatographic separations [21].

3.7 Resistive pulse sensing.

Resistive pulse sensing (RPS) is a label-free, nondestructive method to detect/ analyzed individual particles/molecules. Transient decrement in ionic current, or pulses observed when particles pass through an electrically biased pores/nanofluidic devices and are proportional to particle size. Track etched nanopores technique have the ability to tune the pores size and shape and this features has increased the types of nanoscale particles that can be sensed[22].

3.8 Fabrication of nanowire

Template-based approaches combined with electrodeposition technique has been used to produce nanowires of different size and shape embedded nanopores of track-etched polymeric membranes. The nanoporous structures make it possible to tailor specific nanowires structures. The prepared nanowires were used in the fields including, nanoelectronics, plasmons, biotechnology, thermoelectrics, solar cells, sensors, catalysis etc [23].

4. CONCLUSION

Nanopores membranes are much effective now a day. These can be prepared with natural as well as artificial techniques. These are used in various

application like DNA separation, solid state electronics, biotechnology etc.

5. REFERENCES

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Corresponding Author

Mukesh Chander*

Materials Science Lab., Department of Physics,
Chaudhary Devi Lal University, Sirsa-125055, India

mukesh.chander86@gmail.com