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PRODUCTION OF POLYMER NANOMEMBRANES BY SUPER DEEP PENETRATION METHOD

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Abstract. A new super deep penetration (SDP) method of polymer nanomembranes production was developed. Its advantages as compared to nuclear methods were discussed. They are connected with simplicity and low price of SDP application. SDP method implies the use of explosion for track membranes forming. As a result, a plurality of holes are formed in polymer matrixes. Removal of the residual particles of water-soluble salt is done by washing the pierced membrane with water.

Keywords: super deep penetration nanomembranes, polymer matrix, nuclear methods, water-soluble salt.

1. Introduction

Membrane technology is a rapidly growing field, gaining large economical and ecological importance. More effective as well known [1] are track membranes. A multitude of direct open pores in sheets of polymeric materials, formed by homogeneous bombarding of the sheet with a source of heavy energetic charged particles to produce damage tracks, have been described in [2]. On subsequent stages radiation damaged materials are removed by chemical etching, *i.e.* by immersing the irradiated solid in an etchant. Different chemical reagents (etchants) and etching methods are known [3]. As a rule the alkali solutions are used as etchants. They washout the destroyed materials and are highly toxic solvents [2]. All the above makes the industrial methods of track membrane production non-ecological and less technological. Besides, these methods demand the usage of expansive nuclear reactor or accelerators, for example, cyclotrons [1, 2]. The advantages of track membranes such as high pores density and unique selection are combined with negative factors, for examples, high absorption activity [1-3].

Based on the above stated, the use of the method of super deep penetration (SDP) for track membrane production is of great scientific and practical interest [4, 5]. This method permits to realize a complex of physical effects such as intensive electromagnetic radiation, intensive strain, pressure of 8–20 GPa, flows of “galactic” ions and so on [4, 6].

Thus, we can propose the use of SDP method for making of open pores in polymer matrix.

2. Experimental

A device for realization of the method is a shell in the form of a tube one end of which contains a cartridge with an explosive material and working substance in the form of a solution of water-soluble salts. Inserted freely into the other end of the shell is a holder that contains a membrane matrix to be treated in the form of a plate. The open end of the holder is closed by a cover which is attached to the holder, *e. g.* by screws, whereby the membrane matrix is secured in the holder. The shell with the cartridge that contains the explosive material and the working substance as well as the holder with the matrix of the material to be treated is placed into an explosion-proof chamber, and the explosive material is detonated to cause an explosion. As a result, the working substance is expelled from the cartridge by an explosive wave in the form of a high-speed jet and penetrates deep into and through the polymer material of the plate. Under the effect of the explosion, the holder with the polymer plate and cover is ejected from the shell into the explosion-proof chamber. The cover is disconnected from the holder, the matrix is extracted, and is subjected to treatments with water that dissolves the water-soluble particles or washes them out of the membrane matrix thus forming microscopic openings that pass through the polymer plate.

Then the polymer plate is sliced into thin pieces that can be used, *e. g.*, as filter plates.

In Fig. 1 vertical view of the constructed device for membrane production by SDP method is shown.

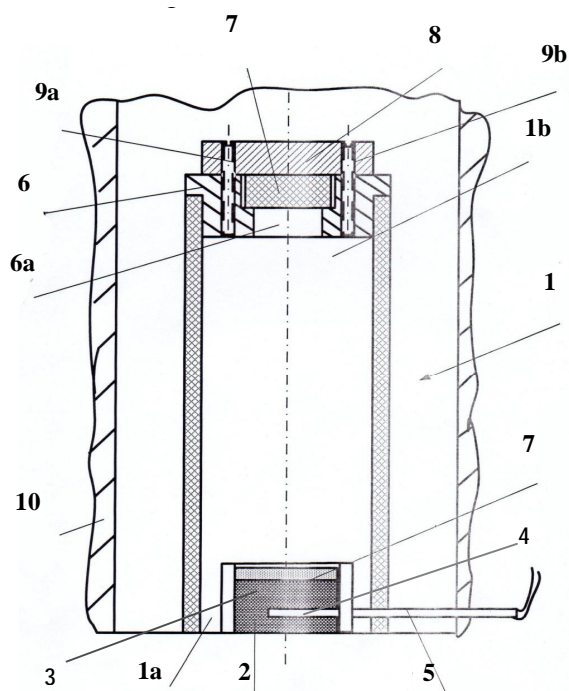


Fig. 1. Vertical view of constructed device

It contains a tubular shell 1 made, *e. g.*, of a plastic material such as polyvinylchloride. The tubular shell 1 has open ends 1a and 1b. The device also contains a cartridge with the aforementioned detonable explosive material 3 and the working substance 4 in the form of a saturated/supersaturated solution of at least one water-soluble solid salt. The cartridge is inserted into the open end 1a of the tubular holder 1. Reference numeral 5 designates a detonator that is used for detonation of the explosive material 3.

Furthermore, the described device contains a membrane holder 6 with an open-bottom cavity 6a for receiving a membrane matrix 7 that can be inserted into the cavity 7 of the holder 6 so that when the holder 6 is inserted into the shell 1, a major part of membrane surface remains exposed to the interior of the tubular shell. The membrane holder 6 is provided with a cover 8 attachable to the holder 6, *e. g.*, by fasteners, such as studs 9a and 9b shown in Fig. 1, for converge of the membrane matrix 7. The holder 6 with the membrane matrix 7 and the cover 8 is freely inserted into the opposite end 1b of the tubular shell 1.

The shell 1 with the holder 6 and the cartridge 2 is placed into an explosion-proof chamber 10.

As a polymer matrix we can use impact proof polyethylene, polypropylene, polycarbonate, and polyethylenephthalate.

Polyethylene has the density 0.94–0.95 g/sm³, and average melt index 7.5 g/10 min.

Polypropylene has the following properties: density 0.9–0.91 g/sm³; melting point 433–443 K.

Polycarbonate: density 1.2 g/sm³; melting point 418–423 K.

Polyethylenephthalate: density 2.1–2.2 g/sm³; melting point 593 K.

The structure of nanomembranes was investigated by scanning electron microscopy on the Auriga device of Zeiss company.

3. Results and Discussion

The method of SDP is carried out by using a matrix material of the membrane and special working substances which interact with the matrix in the form of a high-speed jet generated and energized by an explosion of explosive material. The special working substance comprises a saturated or supersaturated aqueous solution of water soluble organic salts, or a saturated or supersaturated aqueous solution of water soluble inorganic salts. The matrix material comprises an organic polymer material in the form of a solid plate.

For nanomembrane production by SDP method it is necessary to optimize the following parameters:

- the chamber size
- type and charge construction
- the explosion power
- the velocity of detonation
- the thickness of charge
- the type and dispersion of working substance
- the distance from charge end till polymer sample
- the solvents composition and regimes of their usage
- the material and the size of screen, *etc.*

The above mentioned parameters of explosion chamber were optimized to meet the demanded quality of nanomembranes. As a first step we chose the conditions of preservation of the sample during bombardment. The parameters of explosion chamber used previously for creation of open pores in ceramics matrix cannot be used due to the difference of elasticity modules of polymer material and ceramics. Therefore we produced a special protective steel screen with one central and several scattered holes. It provides partial consumption of impact wave energy.

For preservation of polymer sample during bombardment a special steel container with hole in the bottom was produced, through which the particles of working substances penetrate into polymer matrix; the ammonite of bulk density $0.8\text{--}0.9\text{ g/sm}^3$ was used as a charge.

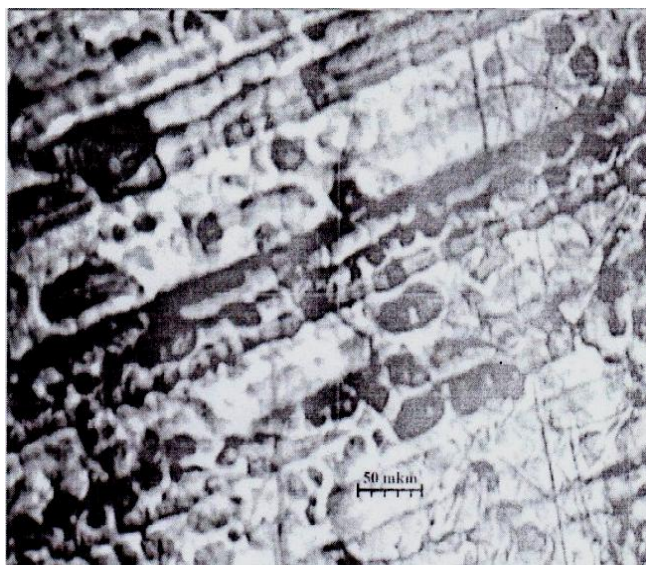
The explosion wave that has a detonating nature should impart a velocity in the range from 3800 to 4200 m/s to the solid particles of the working substance. The height of plastic tube is 200 mm. Removal of the residual trace particles of the solid substance from the membrane may be carried out in the running flow of water, leaving a plurality of small-diameter holes. As a

polymer matrix firstly we used impact strength polyethylene.

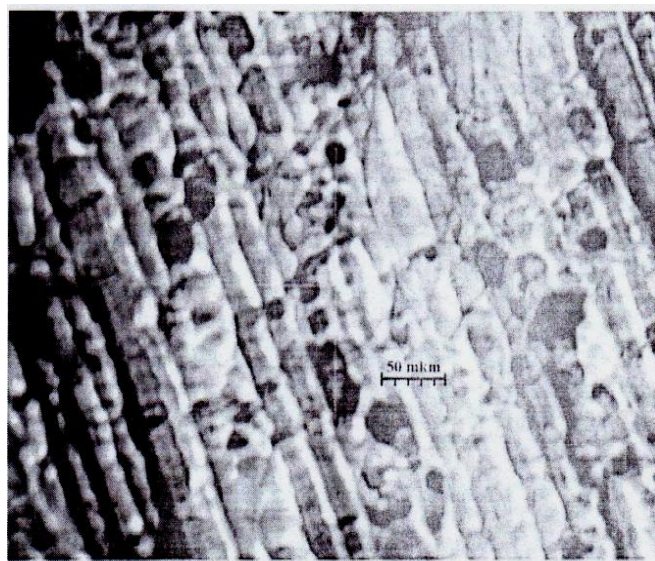
At the same time promising materials for production of polymer membranes by SDP method are polyethylenephthalate, polycarbonate and etc.

The solid plate of matrix polymer materials may have a total thickness in the range from 10 to 20 mm. After removal of the residue of the working substance, the solid plate is sliced into track membranes having a thickness from 5 to 50 μm by means of a microtome.

The microstructure of different parts (Figs. 2a and b) of membranes produced by SDP method is presented.



a)



b)

Fig. 2. Electronic microscope picture of the structure of nanomembranes based on polyethylene

The picture show section of samples taken parallel to the diameter of the polymeric cylinders by means of microtome. The black dots in the photographs represent the pores of the sliced samples, which have the diameter sizes in the range of of $80\text{--}100\ \mu\text{m}$. The actual diameters and the range of the diameters of the holes depend mainly on the velocity of the particles, diameter of the shell, and a distance from the cartridge with the explosive material and the particles to the membrane matrix material in the holder. The through holes produced in the track membrane by the SDP method are oriented in the direction of the jet particles and occupy from 10 to 20 vol % of the membrane material volume. The obtained membrane may find use in various fields of industry as conventional membrane filters for purification of liquid substances from solid contaminants.

4. Conclusions

The SDP method is very promising for production of nanomembranes based on polymer matrix. This method is cheaper, more simple and ecological as compared to nuclear industrial methods of track membrane manufacturing.

Its use excludes the application of highly toxic solvents. Simultaneously it permits to create polymer membranes with nanosize open pores and provides the absence of oxidation products, which can migrate into filtrate.

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ОДЕРЖАННЯ ПОЛІМЕРНИХ НАНОМЕМБРАН МЕТОДОМ НАДГЛИБОКОГО ПРОНИКНЕННЯ

Анотація. Розроблено новий метод надглибокого проникнення (НГП) для отримання полімерних наномембран.

Показано його переваги відносно ядерних методів: це відносна простота і низька вартість методу НГП. Для одержання трекових мембран методом НГП запропоновано використовувати вибух, внаслідок чого в полімерній матриці формується велика кількість дірок. Видалення з мембран залишкових частинок водорозчинних солей запропоновано здійснювати промиванням її водою.

Ключові слова: надглибоке проникнення, наномембрана, полімерна матриця, ядерні методи, водорозчинні солі.