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Role of ion track filters in environmental surveillance

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Abstract

Ion track filters (ITFs) are produced by physiochemical treatments to thin films of polymers and mica irradiated by heavy ions. These ITFs have many applications in the fields of science and technology. In the present investigation, the developed ITFs from polycarbonate films have been used to filter bacteria of various types in water. It is observed that the electric conduction through these filters depends upon the concentration of contaminants and pore diameter of filters. Filtration experiments were carried out using both single and multipore filters. Other applications related to environment surveillance have also been reported. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Ion track filters; Polymers; Bacteria; Heavy ions

1. Introduction

The technique that led to the development of etched track membranes was first discovered by Price and Walker (1967) in the USA. They observed fine pores due to fission fragments in 12 μm thick layer of synthetic mica. This raised immediate interest among physicists because such microscopic pores provide convenient confining media in various domains of research where spatial dimensions can play a vital role, e.g., superfluidity (Gamota, 1973), superconductivity (Possin, 1971), ultrafiltration (Quinn et al., 1972), etc. Since 1972, fission fragments from various radioactive sources have been used for the commercial manufacture of nuclear track filters up to 10 μm track length. Heavy ion accelerators are promising alternative for generating these filters.

During the past several years various new microporous membranes and filters have been developed for use in fields of science and technology, viz., health, medicine, air pollution, beverage industries, development of microtubules, material science characterization, etc. (Spohr, 1990, 1998; Fleischer, 1997; Virk et al., 1998). These filters are generally made from polymeric materials, ceramics and minerals. Ion track filters (ITFs) are mainly divided into two categories: (a) single-pore filters and (b) multipore filters. Single-pore filters can be produced from the accelerator by controlling the beam optics and fluence of the heavy ion beam. Commonly used materials for production of ITFs are Makrofol-KG, Kapton-H, PVDF, mica films, cellulose nitrate, CR-39, Lexan polycarbonate, etc. For the present study, the samples of polymer films have been irradiated by different heavy ion beams from the UNILAC accelerator at GSI, Darmstadt, Germany.

Conventional filters normally consist of porous foams or of bonded fibers and their function depends on several mutually interconnected processing parameters. In contrast, ITFs are defined by very few and almost independent parameters, viz., thickness of film, pore diameter and areal density of pores. These can be altered in a desirable manner. ITFs offer distinct advantages over the conventional filters. The main advantage lies in their well-defined pore size.

Seal (1964) separated circulating cancerous cells from blood, making use of the fact that cancer cells are larger and more rigid than normal blood cells. Water contamination is one of the major causes for microbial disease. Kapton filters of suitable size have been tried to get clean water free from all suspended particles (Khan et al., 1989). These filters have been applied to purify industrial oil from solid components in order to minimize the risk of elemental current breakthrough (Ganz et al., 1989). In the present investigation, *Escherichia coli* and colon bacilli bacteria were grown

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by using Luria broth technique. The malignant blood cells of size 7–15 μm were collected from Shri Guru Ram Das Hospital and Research Institute, Amritsar.

2. Experimental technique

The samples of Makrofol-KG having thicknesses of 30, 60 and 100 μm were irradiated by ^{132}Xe and ^{238}U ions from GSI at an angle of 90° with respect to the surface. The fluence was varied in the range 10^4 to 10^5 ions/cm^2. These irradiated foils were etched in 6 M NaOH at 70°C for various intervals of time. Single and multipore filters were developed in this way. After washing and drying, these etched samples were scanned under a Carl Zeiss binocular optical microscope. The pore diameters were measured using a calibrated graticule. Multipores (10^2–10^4/cm^2) of diameter 5 and 10 μm and single pores of diameter 2 and 4 μm were used for this investigation.

2.1. Culture of bacteria

The method used for the growth of bacteria, i.e., *E. coli* and colon bacilli is Luria broth. For the preparation of culture, the media required are; Trypton 5 g, yeast extract 10 g, NaCl 10 g and distilled water 500 ml. After weighing the required amount of the media, it was dissolved in a 500-ml conical flask containing distilled water. This solution was dissolved into five equal parts in 250-ml flasks and the stains of colon bacilli and *E. coli* were added into each flask by the method of inoculation. All the flasks were kept in a shaker overnight at 30°C and thus the newly grown bacteria can be seen under an optical microscope. Upon knowing the size and shape of the bacteria, its identification can be done.

2.2. Conduction through ITFs

The conduction effects through these filters have been observed on various liquids, viz., polluted water containing *E. coli* and colon bacillus, normal water, contaminated blood, etc., by using the conductivity cell (Fig. 1). The cell is designed in such a way that this filter acts as a partition between the two chambers. The membrane partition served as a barrier to bacteria and cell migration and the change in

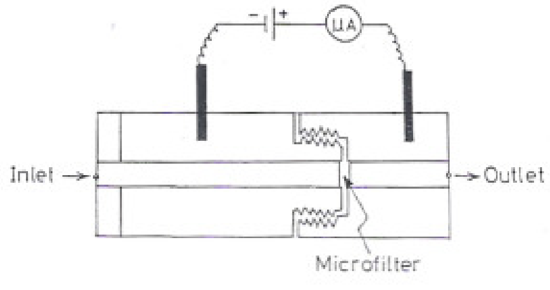

Fig. 1. Block diagram of conductivity cell.

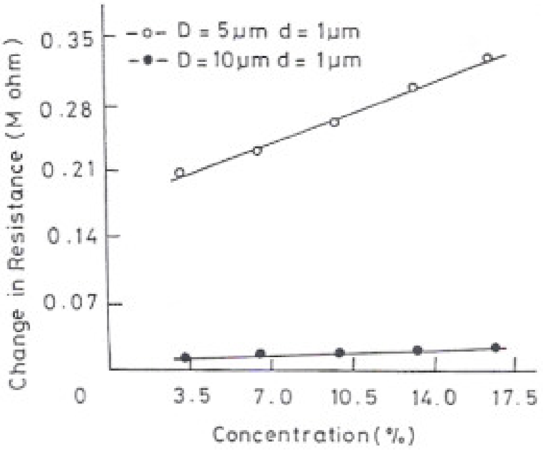

Fig. 2. Variation of change in resistance with the concentration of pollutants (*E. coli* and colon bacillus) using singlepore ITF for water sample.

current shows the resistance to the flow of the contaminants through the pores of different diameters. The resistance through the pores of different diameters is measured using Ohm's law and the change in resistance, ΔR (Fleischer et al., 1975), with respect to pore diameter is obtained using formula $\Delta R = 4\rho d^3/\pi D^4$ and the corresponding resistivity of the solution is found by $\rho = RA/l$, where R is the resistance, A the area of cylindrical shaped conductivity cell and l is the length of the hole inside the cell. The resistance through the pore is highly sensitive to geometry and is proportional to d^3/D^4, where d is the diameter of the particle and D is the diameter of the pore. The variation of change in resistance with concentration and pore diameter for water samples is shown in Figs. 2–4.

It has been observed that conduction is reduced progressively with increasing concentration of contaminants provided one side of the cell is filled with the medium, i.e., polluted water, and the other side is filled with unpolluted water or normal saline solution. Thus the change in resistance relative to concentration increases only if negative polarity is given to the medium and positive polarity to the unpolluted water or normal saline solution. The change in resistance encountered by the bacteria and cells through a 10-μm pore is found to be lower than that through a 5-μm pore in case of a single pore filter, and in the case of multipore filters, 4-μm pore was found to conduct better than 2-μm pore.

2.3. Separation of Escherichia coli and colon bacilli

There exists quite a number of methods to eliminate bacteria: heating, irradiation with UV light, γ-ray exposure, bactericide and filtration with traditional filters. These methods are not quite satisfactory because heating and γ-ray exposure induced decomposition of effective components and produced harmful compounds; unwanted bactericides are harmful to health. UV sterilization is effective only to the bacteria in air and in a very thin surface of water. Most

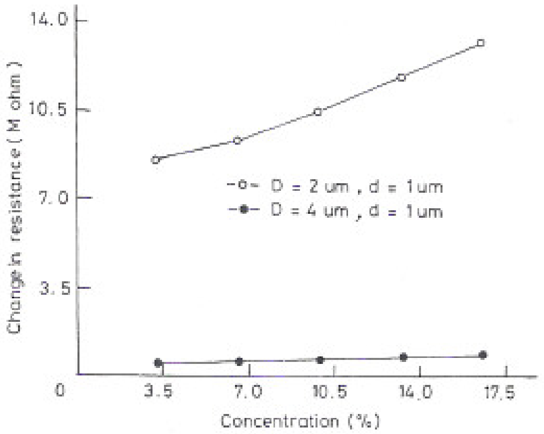

Fig. 3. Variation of change in resistance with the concentration of pollutants (*E. coli* and colon bacillus) using multipore ITF for water sample.

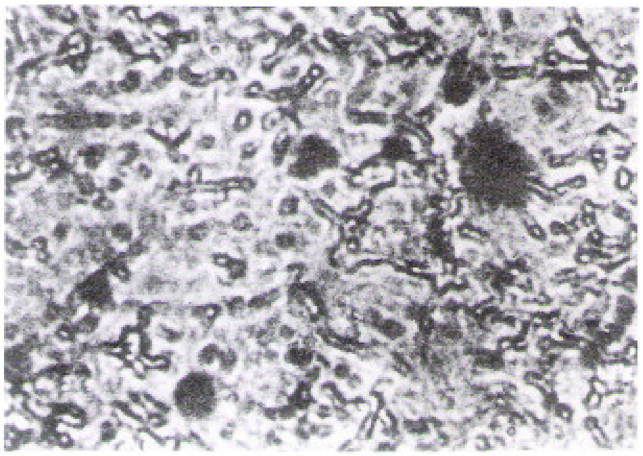

Fig. 5. Photomicrograph showing filtered *E. coli* and colon bacilli by ITFs.

widely used filter types are fiber filters and membrane filters. One shortcoming of these filters is that their pore sizes are not uniform in dimension, whereas the ITF is an ideal filter type. Its superiority over any other filters is its uniform pore size, which makes it able to remove all bacteria bigger than its pore size. The pores of microfilter are cylindrical and perpendicular to the surface of the filter. In order to investigate the filtration behavior of ITFs in the process of liquid filtration, we used Makrofol-KG polycarbonate having a pore diameter of 2 μm. The bacteria used in present investigation for filtration is *E. coli* (ball shaped) and colon bacilli (rod shaped) both having diameters of 1 μm. It is commonly found in contaminated water. In order to make water suitable for human consumption, bacteria has to be removed. Fig. 5. shows the microphotograph of filtered *E. coli* and colon bacilli separated by microfilter of 2.0 μm pore size.

2.4. Miscellaneous applications of ITFs in environment and industry

The first commercially manufactured ITFs were made of plastic foils by the Nucleopore Corporation, USA. These

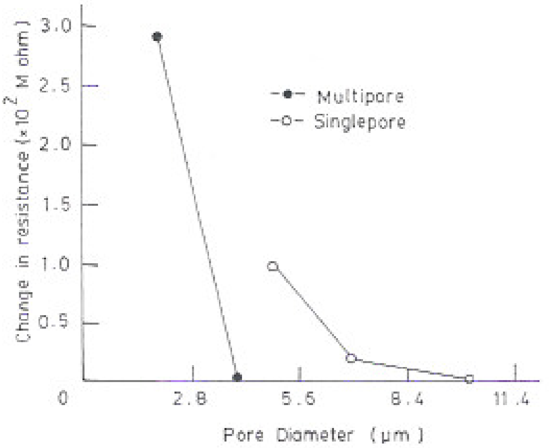

Fig. 4. Variation of change in resistance with pore diameter for water sample.

microfilters have been used to study the behavior of aerosol particles in environmental air near a working place at an industrial plant producing reactor fuel elements. Depending on their size, chemical and physical properties, these aerosol particles can be filtered by means of cascade fractionators with microfilters of different pore sizes (Brandt et al., 1986). Track membranes are widely employed for the investigation of the erythrocyte cell deformability. Membranes with a pore diameter of 5 μm are an ideal test object for this purpose (Nose and Malchesky, 1981). By measuring the rate of the blood passing through the pores, the size of which is a bit smaller than that of the red blood corpuscles, one can make an accurate description of their state. Another example of filtering liquids with track filters is the purification of crystallizing solutions. Flerov and Mchedlishvili (1987) have reported that high selectivity of track membranes ensures the effective concentration and purification of virus culture, for example, rabies virus. This is the basis for applying track membranes in environment contamination studies, pharmaceutical preparations, microflora and microfauna purity, etc. (Flerov and Oganessian, 1989).

In order to expand the area of applications of nuclear track membranes, an attempt has been made at GSI, Darmstadt to provide the environmental responsive ion track membranes (Hemker et al., 1990). The pore size in the membranes can be increased or decreased by changing the pH, temperature or electric field, etc. In this way it is possible to control a flow through the membrane, which is carried inside living organs under various inner and outer conditions. One of the possible approaches to realize such a sophisticated membrane is to combine ion track membrane with polymers of different characteristics responding to these environmental conditions. Hydrogels are known to possess the ability to change their volumes when environmental stimuli such as temperature, pH, electric field are imposed. There is a lower critical temperature at which an abrupt change in volume of gels occurs. The combination of such thermo-responsive ion pore membranes makes it possible to provide control of microflow by changing temperature (Omichi et al., 1993; Yoshida et al., 1997). They can also be used for desalination of seawater by reverse osmosis and purification of aviation fuel used in airplanes.

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