Nuclear Instruments and Methods in Physics Research A 619 (2010) 211–215

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Micro-collimator fabricated by alpha-particle irradiation of polyallyldiglycol carbonate polymer film and subsequent chemical etching

V.W.Y Choi, E.H.W. Yum, K.N. Yu *

Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong

ARTICLE INFO

Available online 25 October 2009

Keywords:
Solid-state nuclear track detector
SSNTD
Alpha particle
PADC
Collimator

ABSTRACT

In the present paper, we propose a method to fabricate a "micro-collimator" with a thickness of 15 μm. A commercially available PADC film with a thickness of 100 μm was first chemically etched with NaOH/ethanol solution to obtain a thin PADC film. This thin PADC film was then irradiated by 5 MeV α particles through a "macro-collimator" with a thickness of 5 mm and a hole diameter of 1 mm. This PADC film with latent tracks was then further etched in aqueous NaOH solution to form the micro-collimator with a thickness of 15 μm and etched-through air channels were all confined to a circular area with 1 mm diameter. Verifications were performed by checking the etched α-particle tracks formed on a test PADC film from α particles having traveled through a 20 μm support substrate attached to the 15 μm micro-collimator (both substrate and micro-collimator also made of PADC). The results are discussed.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Alpha-particle radiobiological experiments involve irradiating cells with α particles and require accurate positions where the α particles hit the cells, the latter being essential for dosimetric determination. In many of the α-particle radiobiological experiments, it is only feasible to control and quantify the α-particle energies incident on the cells if the α particles pass through the substrate to strike the cells which are in contact with the substrate, instead of passing through the fluid layer above the cells, which has a variable thickness (see Refs. [1–3]). As regards the determination of the number and energy of α particles actually incident on the embryo cells, there can be two approaches. The first one is to make use of a microbeam facility. Here the hit positions and the energies of the incident ions can be controlled. Another approach is to use a radioactive source to provide the α-particle irradiation and to use a solid-state nuclear track detector (SSNTD) as a support substrate to record the hit positions and the energies of the incident α particles. Although the procedures involved in the second approach are a little bit more tedious, they do not involve the expensive and sophisticated equipment associated with the microbeam facility. The SSNTD employed as the support substrate should be thin enough to allow passage of α particles with nominal energies (e.g., those from ^{241}Am source). A review on SSNTDs has been given by Nikezic and Yu [4].

Polyallyldiglycol carbonate (PADC) is a well-known SSNTD and is commercially available as the CR-39 detector. PADC films have gained their popularity as support substrates for cell culture in that they are transparent, biocompatible [5] and are not dissolved in the alcohol used for sterilizing the substrate. However, the thinnest commercially available PADC films are ~100 μm thick and are thus not thin enough. Gaillard et al. [1] fabricated ultra-thin PADC films as support substrates for cell cultures but these films were not commercially available. Fabrication of these thin PADC films would require specialized expertise and dedicated equipment, which might not be easily available to all laboratories trying to perform α-particle radiobiological experiments. As a result, it is desirable if sufficiently thin PADC films can be fabricated from thicker commercially available PADC films, e.g., those with a thickness of 100 μm. Chan et al. [2] prepared thin PADC films from commercially available CR-39 SSNTDs with a thickness of 100 μm by etching them in 1 N NaOH/ethanol at 40 °C to about 20 μm.

For a more convenient and accurate dosimetric determination from the α-particle tracks developed on the support substrate upon chemical etching, the incident particles should all be preferably close to normal incidence with respect to the support substrate. For exceedingly oblique incidence, it will be difficult and tedious to determine precisely whether the alpha particles have actually hit the target areas. As such, it is desirable to collimate the α particles so that only those close to normal incidence can strike the support substrate. However, such a collimator should preferably be very thin to minimize the energy loss of the α particles when they travel through the air column in the collimator.

* Corresponding author. Tel.: +852 2788 7812; fax: +852 2788 7830.
E-mail address: peter.yu@cityu.edu.hk (K.N. Yu).

0168-9002/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2009.10.120

Collimators commonly used in the laboratory might not be ideal for such purposes. For example, for these collimators, the minimum diameter of the mechanically drilled cylindrical bore is ~1 mm. To maintain its function to restrict α particles close to normal incidence, the collimator should have a minimum thickness of ~5 mm. The long air column involved will impose severe limitations in the thickness of the support substrate in such a way that the residual energy of α particles exiting the support substrate can still be useful for radiobiological experiments. For example, consider the case where we have a PADC support substrate with a thickness of 28 μm. If the collimator has a thickness of 5 mm, after traveling an air column of 5 mm and passing through 28 μm of PADC, the energy of the α particles would have dropped to ~150 keV, which would be no longer suitable for α-particle radiobiological experiments. However, if a collimator has a thickness of 15 μm, the energy of the α particles would only have dropped to 1.23 MeV, which would still be very useful for α-particle radiobiological experiments.

In the present paper, we propose a method to fabricate a "micro-collimator" with a thickness of 15 μm through α-particle irradiation of a PADC film and subsequent chemical etching. The feasibility of the fabricated micro-collimator was also tested, and the results are discussed.

2. Methodology

2.1. Fabrication of the micro-collimator

2.1.1. Preparation of thin PADC films

Thin PADC films were prepared from commercially available PADC films (from Page Mouldings (Pershore) Limited, Worcestershire) with a thickness of 100 μm using the method proposed by Chan et al. [2]. The 100 μm PADC film were first cut into pieces with a size of 1.8 cm × 1.8 cm. These were then chemically etched in a 1 N NaOH/ethanol solution at 40 °C, for which the bulk etch rate was about 10 μm/h [6]. During the chemical etching of PADC films in NaOH/ethanol, the byproduct sodium carbonate was accumulated on the surface of the films, which would slow down the etching rate [6]. Therefore, the films had to be rinsed with distilled water every two hours to ensure an efficient etching process. The PADC films were etched to a thickness of 41 μm, which was monitored using a micrometer (Mitutoyo, Japan) with an accuracy of ±1 μm.

2.1.2. Alpha-particle irradiation of the thin PADC film through a macro-collimator

The 41 μm PADC film fabricated as described in Section 2.1.1 was irradiated by α particles with a collimator, which was a rectangular block made of acrylic resin with a thickness of 5 mm and had a cylindrical bore with a diameter of 1 mm at the centre. We hereafter refer this 5 mm thick collimator as the "macro-collimator", so that it can be differentiated from the collimator with 15 μm thickness to be fabricated in this work, which will be referred to as the "micro-collimator". The 41 μm PADC films were irradiated by 5 MeV α particles through the macro-collimator for 15 min. The α-particle source employed in this work was a planar ^{241}Am source (with 5.49 MeV main energy under vacuum and an activity of 0.115 μCi). The irradiated PADC film was then mounted by epoxy (Araldite® Rapid, England) onto a plastic sheet with a 1.4 cm × 1.4 cm rectangular opening at the centre.

2.1.3. Micro-collimator

Latent tracks were left in the PADC film after irradiation by α particles. Subsequent chemical etching could increase the track depth and enlarge the track opening (i.e., increase the major and minor axes of the diameter of the tracks) (see e.g., Ref. [4]). The mounted PADC film was etched on both sides in 6.25 N NaOH/water with 5% alkyldiphenyloxide disulfonate (surfactant DOWFAX 2A1, Dow Chemicals) under 70 °C for 11 h, and the thickness of the PADC film became 15 μm. The surfactant was added to increase the ratio between the track etch rate to the bulk etch rate [7], so that more cylindrical tracks can be formed (i.e., tracks with steeper walls). The etched PADC film with the thickness of 15 μm became our micro-collimator.

2.2. Testing the micro-collimator

To test the applicability of the micro-collimator, we employed it in an experimental setup as shown in Fig. 1(b), which mimicked a realistic one as shown in Fig. 1(a) used in the irradiation of cells or zebrafish embryos [2,3]. In the realistic irradiation setup shown in Fig. 1(a), the zebrafish embryo or cells are irradiated inside a Petri dish, with a hole at the bottom covered by a support substrate made by a PADC film. A micro-collimator is inserted between the α-particle source and the support substrate so that only those α particles close to normal incidence onto the micro-collimator can pass through. In the setup shown in Fig. 1(b) which mimicked the realistic one shown in Fig. 1(a), the zebrafish embryo or cells were replaced by another PADC film which was used to record the α particles after they passed through the support substrate, and we referred this PADC film as the α recorder. In real irradiation experiments, these α particles will strike the zebrafish embryo or cells.

In the present experiments, a thick PADC film with 1 mm thickness was employed as the α recorder, while a thin PADC film

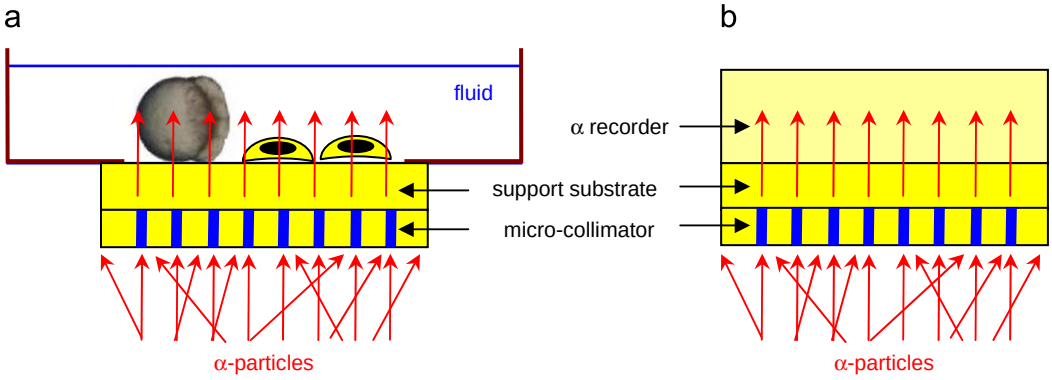

Fig. 1. (a) Schematic diagram showing the irradiation of a zebrafish embryo or cells inside a Petri dish, with a hole at the bottom covered by a support substrate made by a PADC film. A micro-collimator is inserted between the α-particle source and the support substrate so that only those α particles close to normal incidence onto the micro-collimator can pass through. (b) Same as (a) except that the zebrafish embryo or cells are replaced by a PADC film which is used to record the α particles after they have passed through the support substrate. In real irradiation experiments, these α particles will strike the zebrafish embryo or cells.

Download English Version:

https://daneshyari.com/en/article/1827187

Download Persian Version:

https://daneshyari.com/article/1827187

Daneshyari.com