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Short Communication

Effects of etching time on alpha tracks in solid state nuclear track detectors

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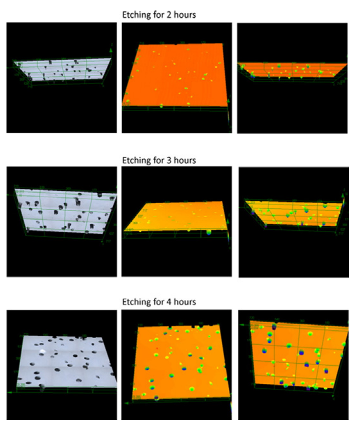
HIGHLIGHTS

- Modern microscope imaging can detect and image smaller size tracks seen for example at 3 hours etching time.
- Shorter etching times may give rise to fewer coalescing tracks as each track has a lower diameter.
- Etching for periods less than four hours merits investigation although must be done with caution and a knowledge of potential impact on results.
- This may improve accuracy in assessing the number of tracks over a shorter etching period.

GRAPHICAL ABSTRACT



Solid State Nuclear Track Detectors (SSNTDs) are used extensively for monitoring alpha particle radiation, neutron flux and cosmic ray radiation. Tracks in SSNTDs formed by radiation particles, are normally etched for about 4 h to enable microscopic analysis. This study examined the effect of etching time on the appearance of alpha tracks in SSNTDs. Etching times of 2 to 4 h were compared and marked differences were noted in resultant track area. The median equivalent diameters of tracks were 20.2, 30.2 and 38.9 μm for etching at 2, 3 and 4 h respectively. Our results indicate that modern microscope imaging can detect and image the smaller size tracks seen for example at 3 h etching time. Shorter etching times have the potential to improve accuracy in assessing the number of tracks as this may result in fewer coalescing tracks.

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ABSTRACT

Solid State Nuclear Track Detectors (SSNTDs) are used extensively for monitoring alpha particle radiation, neutron flux and cosmic ray radiation. Radon gas inhalation is regarded as being a significant contributory factor to lung cancer deaths in the UK each year. Gas concentrations are often monitored using CR39 based SSNTDs as the natural decay of radon results in alpha particles which form tracks in these detectors. Such tracks are normally etched for about 4 h to enable microscopic analysis. This study examined the effect of etching time on the appearance of alpha tracks in SSNTDs by collecting 2D and 3D image datasets using laser confocal microscope imaging techniques. Etching times of 2 to 4 h were compared and marked differences were noted in resultant track area. The median equivalent diameters of tracks were 20.2, 30.2 and 38.9 μm for etching at 2, 3 and 4 h respectively. Our results indicate that modern microscope imaging can detect and image the smaller size tracks seen for example at 3 h etching time. Shorter etching times may give rise to fewer coalescing tracks although there

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Alpha tracks
Radon

is a balance to consider as smaller track sizes may be more difficult to image. Thus etching for periods of less than 4 h clearly merits further investigation as this approach has the potential to improve accuracy in assessing the number of tracks.

1. Introduction

Solid State Nuclear Track Detectors (SSNTDs) are used extensively to provide data on various types of charged particles (Mozzo et al., 1996), and therefore used in neutron detection and dosimetry (Palacios et al., 2011), cosmic-ray physics (Tommasino, 2004) and medical applications such as boron neutron capture therapy (Smilgys et al., 2013). SSNTDs can also be used to monitor radon concentrations (Phillips et al., 2004) in the home and workplace.

Exposure to radon gas (^{222}Rn) and associated ionising decay products can cause lung cancer in humans (Darby et al., 2005) and it is thought to be the cause of about 1100 lung cancer related deaths each year in the UK (Gray et al., 2009). In the USA the Environmental Protection Agency (EPA) suggest that around 21,000 lung cancer deaths per year (with 160,000 deaths linked to smoking) are the result of exposure to radon. Of this number 2900 occur among people who have never smoked, and hence it is viewed by the EPA as the number one cause of lung cancer among non-smokers (see News Release, January 13th 2005, Surgeon General National Advisory on Radon). The work of Darby et al. (2005) and others also highlights the fact that there is a synergistic effect between radon and smoking. The EPA note that a never smoker exposed to around 48 Bq m^{-3} (1.3 pCi/L) of radon has a 2 in 1000 chance of lung cancer. A smoker on the other hand also exposed to radon has a 20 in 1000 chance of dying from lung cancer.

Alpha particles from the decay of radon form sub-microscopic tracks in the detectors. In order to allow these latent tracks to be seen with optical microscope techniques (Durrani, 1997) they must be enlarged by etching (either chemical or electrochemical). From the track density per unit of time of being irradiated, the particle fluence on the SSNTD can be assessed. Track density will provide information on for example radon concentration in the atmosphere, but this may not be enough information for the desired application. An assessment of the energies of the incident particles may be required to for example, reconstruct proton energy spectra, which can be related to neutron energy spectra.

A variety of etchants can be used in the etching process such as potassium hydroxide and sodium hydroxide. We have used a caustic soda solution. Some others have added alcohol to their solution which increases the etching speed, but it also decreases the detector sensitivity (Durrani, 1997; Tommasino, 1997). Tommasino (1997) concluded that the important factors in controlling etching speed were temperature and the concentration of the etching fluid.

Currently etched detectors are usually assessed with optical microscopy and 2D surface image analysis and counted with semi-automatic/image analysis–based techniques (see Nikezic and Yu, 2015).

We have previously shown that confocal microscopy can be used for non-destructive 3D visualisation of etched SSNTDs (Wertheim et al., 2010a, 2010b; Wertheim and Gillmore, 2014). In these studies we observed that adjoining tracks can coalesce into non-circular areas which require distinction from artefact and hence might affect assessment accuracy. There have been few studies of the effect of etching on track appearance in 2D and by destructive cutting of the detectors. Examples include Dörschel et al. (1996, 1997) who broke SSNTDs to reveal lateral images of tracks for direct measurement. The assessment of the tracks was carried out using a Nikon microscope with the LUCIA image analysis system. Ng et al. (2007) polished the sides of SSNTDs to reveal cross-section of tracks, and then imaged them using a digital camera processing the image with ImageJ. Replicas of tracks were then made using an epoxy resin and assessed using a profilometer.

2. Aim

The aim of the study was to examine the effect of etching time on the 2D and 3D appearance of alpha tracks in SSNTDs using confocal microscopy.

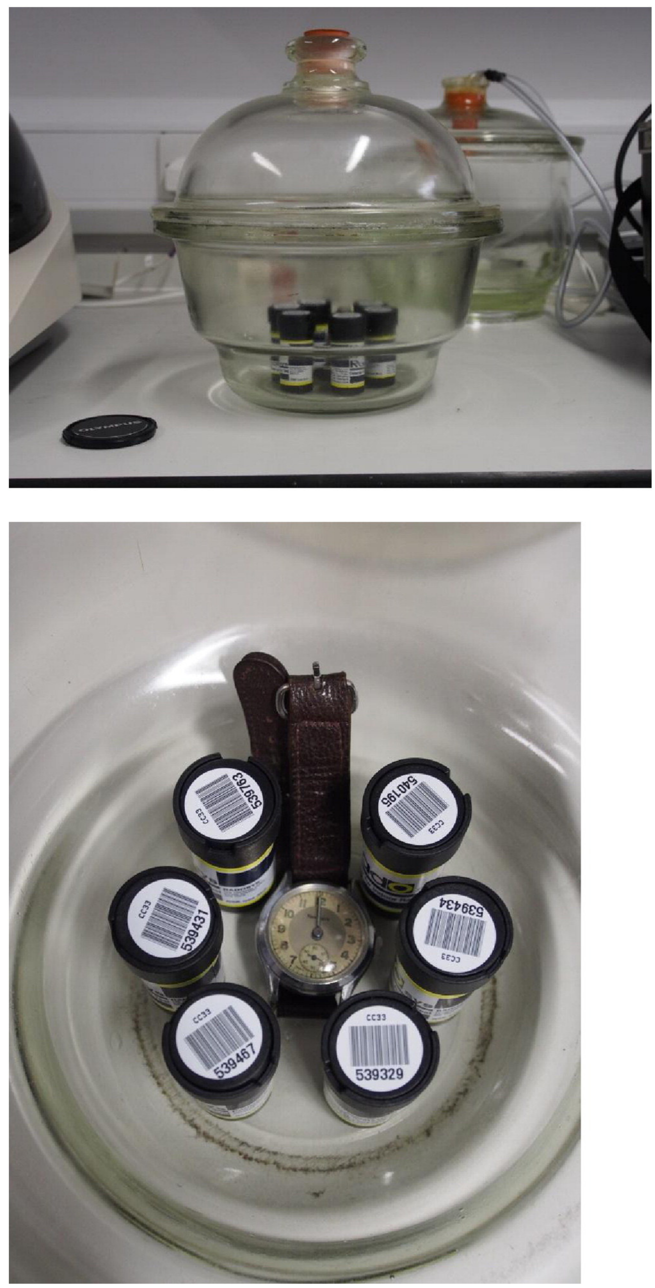

Fig. 1. Glass desiccation chamber adapted for radon and watch experiment. The join and plug were sealed using vacuum grease. SSNTDs were spaced as evenly as possible around the watch being tested.

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