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ScienceDirect
Radiation Measurements
Radiation Measurements 43 (2008) S128–S131
www.elsevier.com/locate/radmeas

Optical appearance of alpha-particle tracks in CR-39 SSNTDs

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Abstract

The optical appearance of etched alpha-particle tracks in CR-39 SSNTDs under the transmission mode of the optical microscope were studied. The mean grey levels revealed using a digital camera installed on the microscope, together with the major and minor axes were systematically determined for tracks from alpha particles with different incident energies and angles. The grey level properties for the same track could vary to large extents, which could be corrected using optimum operation conditions of the camera. Differentiation among recorded tracks was then automated using a computer program, for which the grey levels, major and minor axes values were used as inputs and from which the angle and energy of the incident alpha particles were given as the outputs. The accuracy of the determined alpha-particle energy is 0.5 MeV.

Keywords: CR-39 detector; Alpha particles; Tracks; Ray tracing; Grey level

1. Introduction

Solid-state nuclear track detectors (SSNTDs) have found wide applications (Nikezic and Yu, 2004) such as for radon and progeny measurements. However, automation in differentiating among recorded tracks due to alpha particles with different incident energies is rarely investigated. Optical properties such as grey level properties, major and minor axes are useful in automatic track measurements.

Formation of track images in SSNTDs actually depends on light scattering and reflection (Nikezic et al., 2005), so optical properties are potential quantitative variables to distinguish among various types of tracks. In the present work, the first objective is to obtain consistent grey level properties for the same track under different exposures of the camera installed on the microscope, which is used for track observation. The second objective is to identify useful variables for quantitative comparisons with the experimental data. The third objective is to make use of those variables to develop a computer program for automation in differentiating among recorded tracks due to alpha particles with different incident angles and energies.

2. Methodology

2.1. Sample preparation

CR-39 SSNTDs were employed in this study and they were purchased from Page Mouldings (Pershore) Limited (Worcestershire, England). The CR-39 detectors had a thickness of 1000 μm, and were cut into pieces with an area of $1 \times 1\,\mathrm{cm}^2$ before use. Separate CR-39 detectors were systematically irradiated for 15 min with alpha particles with energies from 1.5 to 4.5 MeV in steps of 0.5 MeV and with angles from 40° to 80° in steps of 10°. The alpha source employed was a planar ^{241}Am source (activity = 0.1 μCi and main alpha energy = 5.49 MeV under vacuum). Normal air was used as the energy absorber to control the alpha energies incident on the detector. Incidence of alpha particles was restricted to the chosen incident angle (with reference to the detector surface) with the help of a collimator.

After irradiation, the detectors were etched in a 6 N aqueous solution of NaOH (etchant) for 6 h at 70 °C. The temperature was kept constant by a water bath with an accuracy of ±1 °C. The detectors were then taken out from the etchant and rinsed

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doi:10.1016/j.radmeas.2008.03.030

with distilled water immediately in order to stop the reaction between the detectors and the etchant. The detectors were dried completely and then used for analysis.

2.2. Analytical methods

2.2.1. Optical microscope

An optical microscope operated in the transmission mode was used for observation of tracks. The light coming from the bottom of microscope to the detector was set to the brightest and all lenses were cleaned using alcohol before capturing of images. The images were recorded in the JPEG format by a digital camera (Olympus DP 11) installed on the microscope.

One-touch white balance (WB) setting with a high picture quality (HQ) and sensitivity (ISO) value of 200 was used. The WB setting enabled the camera to record pictures by eliminating the effects of the surrounding light. However, the auto-WB setting was unable to display the track image clearly for too much brightness (overexposure) or too much darkness (underexposure). Under these conditions, the auto-setting cannot offer the optimum brightness for the track image. The one-touch WB setting allowed the camera to store the illumination light conditions in memory, so that the optimum brightness condition could be stored and used for recording of tracks.

Inconsistency of grey level properties of the same track under different exposures was studied, and tackling of this problem through locking the auto-exposure time for each image recording was explored. The optimum mode for observation of tracks was then identified as shown in Section 3.1.

2.2.2. Grey level determination

The software used to determine the grey level properties of the track images is Adobe® Photoshop® (Adobe® Photoshop® CS and ImageReady CS ver. 8) software. The user of the software could define the track boundary to obtain the grey level distribution, including the mean, standard deviation, minimum, maximum and median of the grey levels.

2.2.3. Measurement of major and minor axes

The lengths of major and minor axes were determined by the free software ImageJ (Image processing and Analysis in Java version 1.29x, available on the webpage: http://rsb.info.nih.gov.ij/). Calibration was carried out before measurements. An image of a calibration ruler (0.01 mm per division) was captured under the microscope and used for scale setting.

2.3. Computer programs

An in-house computer program was developed and used to distinguish among different types of tracks from their grey level numbers, major and minor axes. The information was input into the program which would then output the incident angle and energy as the results.

The computer program TRACK_TEST (Nikezic and Yu, 2006) (available at http://www.cityu.edu.hk/ap/nru/test.htm) was also used to obtain the lengths of major and minor axes for comparison with the experimental values. The program was developed by Nikezic and Yu (2003a) and was based on equations derived for three-dimensional consideration of track development (Nikezic and Yu, 2003b) The incident alpha-particle energy (in MeV), bulk etch rate (in μm/h), etching time (in h) and the incident angle (in degree) were input to the program. The outputs from the program are the track depth, major and minor axes. Furthermore, the program also shows the track profile and the shape of the track opening.

The light intensity here was presented by the "intensity number" (Nikezic et al., 2005; Yu et al., 2007) with 256 intervals. Intensity number 0 represents completely dark (no transmission through the detector) while 255 represents completely bright (total transmission).

3. Results

3.1. Consistent grey level measurements

As mentioned above, the problem of inconsistent grey level properties for alpha tracks with same track under different exposures should be solved in order to use the grey level properties in quantitative comparisons. The exposure of the digital camera installed on the microscope was the main concern of this problem, and finding the optimum operation conditions of the camera formed our first task.

Table 1 shows the measurements of grey level properties of the same track at five different positions inside the camera field of view (fov). The order of recording the same track at different positions is as follows: (1) Centre of the camera fov, (2) top right-hand side (T-RHS) of the fov, (3) right-hand side at the bottom (B-RHS), (4) left-hand side at the bottom (B-LHS) and (5) top-left hand side (T-LHS). The column (A) in Table 1, which corresponds to the case without locking of exposure time, shows that the variation of grey level properties was large due to exposures at different positions of the camera fov. This was in fact expected due to different brightness conditions at different positions of the same detector.

We tried to solve this by locking the auto-exposure time, i.e., keeping the same exposure time for recording each track image. The results for locking of exposure time (1/13) are shown in column (B) of Table 1, which shows a reduction in the

Table 1
The grey level properties of the same alpha track with 2 MeV incident energy and 50° incident angle at five different positions in the camera field of view: (A) without locking of exposure time; (B) with locking of exposure time

Position	Mean		Median	
	(A)	(B)	(A)	(B)
Centre	113.1	100.5	110	98
T-RHS	93.7	93.6	90	90
B-RHS	97.3	96.5	94	93
B-LHS	97.4	98.7	93	95
T-LHS	99.5	99.2	95	96