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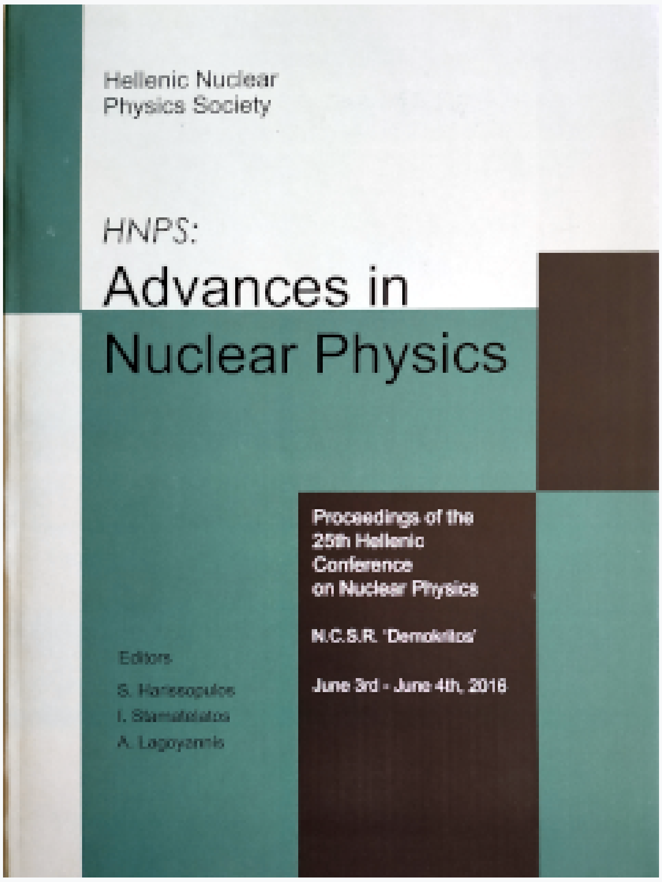

Validation of the ImageJ package for alpha track counting on Solid State Nuclear Track Detectors

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Validation of the ImageJ package for alpha track counting on Solid State Nuclear Track Detectors

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Abstract In the present work, an alpha spectroscopic method using CR39 nuclear track detectors is being evaluated, elaborating on track parameters from different alpha particle sources. The freely-available, Java-based ImageJ software was used to obtain the major and minor axis length, the area and the mean gray level of the recorded tracks. A multi-paramater approach based on Principal Component Analysis of the data was subsequently applied and succeeded in grouping the recorded tracks according to alpha-particle energy. The methodology was further applied for the separation of radon progeny on CR39 detectors exposed in a radon chamber.

Keywords CR-39, image analysis, alpha-particle spectroscopy, radon

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INTRODUCTION

Solid State Nuclear Track Detectors (SSNTDs) are suitable for recording tracks from low-energy alpha-particles. The geometrical parameters of the tracks are associated with the particles' energy and angle of incidence. However, developing an alpha spectroscopic method based on SSNTDs is not a trivial task, as previous studies have shown the absence of a linear relationship between the track axis and the energy of the incident particles [1-3]. Optical parameters, such as the gray scale level of the tracks, convey additional information on the track depth, which increases monotonically with the energy and angle of incidence of the alpha particles [2]. A multi-parameter approach that combines both geometrical and optical characteristics seems promising for the energy discrimination of alpha particles from different emitters. Such a methodology might be useful in studies of exposure to airborne radon progeny, aiming to differentiate between the ^{218}Po and ^{214}Po radionuclides.

In this work, an alpha spectroscopic method using CR39 SSNTDs is being evaluated, elaborating on track parameters from different alpha particle sources. The method is based on the appropriate statistical handling of data obtained from the freely-available, Java-based ImageJ software [4], which can perform most image processing and analysis tasks.

EXPERIMENTAL DETAILS

CR-39 SSNTDs (Track Analysis Systems Ltd, Bristol, UK) were irradiated inside a vacuum chamber with alpha particles from a ^{241}Am source (E_α=5.49 MeV) and a triple ^{239}Pu-

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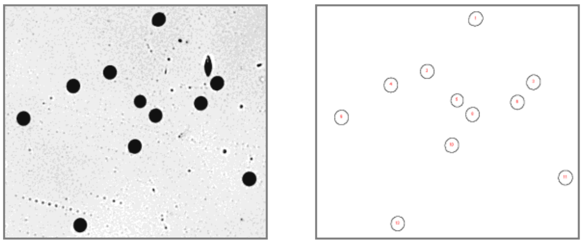
^{241}Am-^{244}Cm source (E_α=5.15, 5.49 & 5.80 MeV, respectively). CR39 detectors were also exposed over a 20 d period in a chamber containing a ^{222}Rn-emitting ^{226}Ra source. After irradiation, the CR-39 detectors were etched in a 6 N aqueous NaOH solution at 70°C for 7 h, were subsequently removed from the etchant, rinsed under tap water and air-dried. Tracks were observed in a Zeiss optical system and analyzed using ImageJ. After setting the required track characteristics (major and minor axis, area, circularity and gray level), the measurement routine is executed and results are reported (Fig. 1). Only circular tracks, corresponding to normal incidence on the detector surface were considered in this study.



	Area	Mean	Min	Max	Perim.	Major	Minor	Angle	Circ.
1	815	5.491	0	139	106.569	34.542	30.041	35.198	0.902
2	798	4.937	0	138	104.569	32.460	31.301	22.300	0.917
3	823	5.070	0	138	105.397	33.262	31.504	48.013	0.931
4	810	4.625	0	134	105.397	32.431	31.801	38.047	0.916
5	664	4.747	0	139	94.912	29.171	28.982	21.119	0.926
6	796	4.892	0	137	104.569	32.185	31.490	40.812	0.915
7	832	4.987	0	138	106.569	33.143	31.962	17.155	0.921
8	792	5.561	0	139	103.983	32.263	31.256	51.010	0.920
9	826	4.458	0	138	105.740	32.694	32.168	41.130	0.928
10	815	3.850	0	136	105.154	33.155	31.298	46.217	0.926
11	835	4.240	0	139	106.811	33.135	32.086	20.022	0.920

Fig. 1. Image processing and analysis of alpha-particle tracks from a ^{241}Am source, using ImageJ. Left: Acquired image. Center: Analyzed tracks after threshold determination. Right: Analysis results.

RESULTS AND DISCUSSION

Spectroscopic Analysis

The tracks formed after irradiation with the ^{241}Am source, show a gaussian major axis length distribution, centered at 14.2 μm (Fig. 2a). This peak, corresponding to 5.49 MeV alpha particles, is also identified in the distribution obtained from the triple source. In the latter case, two additional gaussian functions are fitted to the distribution, centered at 13.8 and 14.6 μm, which can be attributed to 5.80 MeV (^{244}Cm) and 5.15 MeV (^{239}Pu) alpha particles, respectively.

The optical characteristics of the recorded tracks are based on gray level analysis using a scale from 0 (no light transmission, completely dark track) to 255 (total transmission, completely bright track). The biplots shown in Fig. 2b confirm the expected trend for lower gray level - higher alpha particle energy - smaller tracks, and *vice versa*. Furthermore, they indicate that, compared to track geometry, the gray level is a more determinant parameter for energy separation.

A multi-parameter approach, by means of Principal Component Analysis (PCA), was employed for CR39 exposed to the ^{241}Am source and to the triple source. By including ImageJ values for the major (MJ) and minor (MN) axis length, the track area (AR) and the mean gray level (GL), PCA succeeded in grouping the recorded tracks according to alpha particle energy (Fig. 3). Group separation in the case of the triple source is dominated by the track gray level.

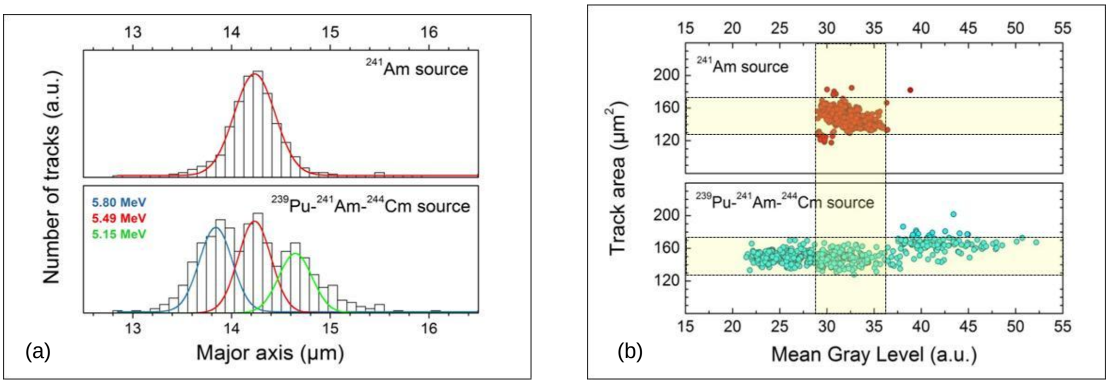


Fig. 2. (a): Histograms of major axis lengths. (b): Track area dependence on mean gray level.

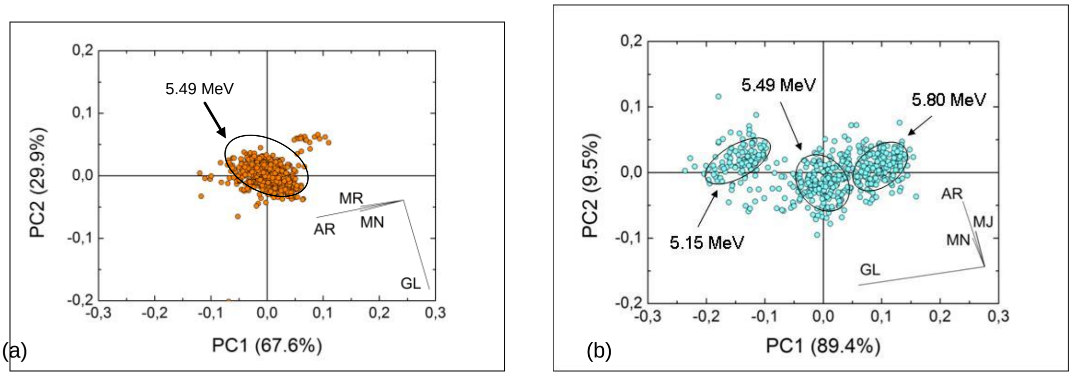


Fig. 3. A PCA score-plot of the alpha tracks recorded with (a) the ^{241}Am source and (b) the triple source. Ellipses are drawn to illustrate grouping according to incident alpha particle energy. Inset: Variable loadings' plots showing the effect of the analyzed track parameters on the projection of tracks in the PC space (see text for variable abbreviations).

Radon progeny separation

A typical Rn spectrum acquired by means of a CAM-PIPS detector (Fig. 4a) shows two distinct peaks arising from ^{214}Po (6.0 MeV) and ^{218}Po (7.7 MeV) deposited on the detector's surface, while ^{222}Rn alpha particles produce a continuous spectrum up to 5.5 MeV.

Analysis of the CR39 detectors, by applying appropriate tracks' selection criteria, also succeeds in differentiating Rn progeny, as evidenced in the obtained distribution of major axis lengths (Fig. 4b, top). The dependence of the track area on the mean gray level, further points to two groups of tracks that share common characteristics (Fig. 4b, bottom).

A PCA based on various geometrical track parameters coupled with gray levels, yields two diffuse groups of tracks, which however are clearly separated along the PC1 axis (Fig. 5). The group attracted toward negative PC1 scores is characterized by high area and high gray level values, corresponding to 6.0 MeV ^{218}Po alphas particles. The second group is attributed to 7.7 MeV ^{214}Po alpha particles.

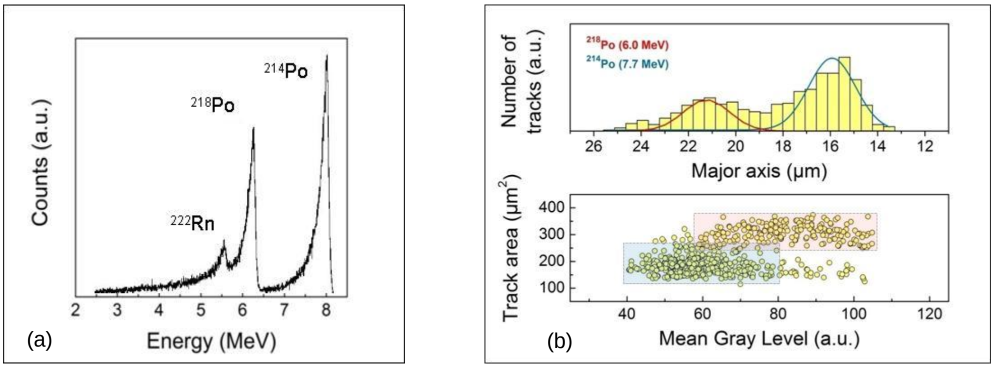


Fig. 4. (a) Alpha particle spectrum acquired in the Rn chamber using a CAM-PIPS detector. (b) Data from the CR39 detectors exposed in the Rn chamber.

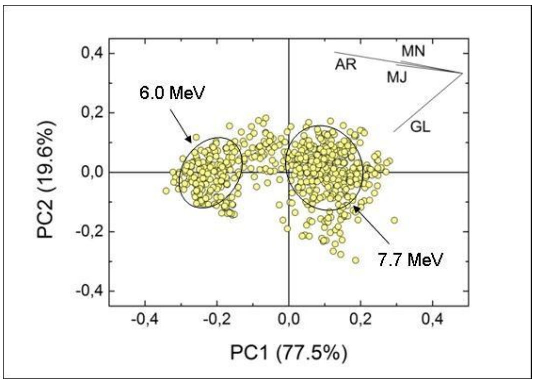


Fig. 5. A PCA score-plot of the alpha tracks recorded in the radon chamber. The tracks originating from ^{214}Po and ^{218}Po alpha particles are separated primarily due to differences in track area followed by differences in gray level.

CONCLUSIONS

Alpha tracks recorded on CR39 SSNTDs were analyzed by applying appropriate track selection criteria with the ImageJ software. Geometrical and optical track parameters were thus obtained and explored for the energy separation of alpha particles emitted from radioactive sources. The analyses showed that a multivariate statistical analysis succeeds in discriminating tracks from different alpha emitters. The methodology was successfully applied to the separation of radon progeny on CR39 detectors exposed in a radon chamber. Studies to extend the method to LR115 SSNTDs are currently underway.

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