THE NOVEL TRACK RECORDING APPARATUS FROM SSNTD FOR RADON MEASUREMENT

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The novel ENEA-INMRI Image Analyzer system has been tested in semi-automated mode for a computer-assisted alpha track counting of electro-chemically etched (ECE) and chemically etched CR-39 Solid State Nuclear Track Detector (SSNTD) chips. A track recognition program based on the Java-Image J processing software was developed. Experimental tests have been carried out to maximize the Field of View (FOV) value of the novel apparatus using appropriate optical magnification and digital video camera resolution. Experimental data on digital Charge Couple Device (CCD) camera and the Image J software performance, in particular a comparison of fixed and variable threshold option, are presented.

Key words: image analyzer system, solid state nuclear track detector.

1. INTRODUCTION

Solid-State Nuclear Track detectors (SSNTDs) are thin plastic sheets of different materials capable to record alpha tracks. Because of their integral signal registration and insensitivity to low LET radiations they play an important role in radon passive integrated measurements. Detectors are subject to a chemical or electro-chemical process making alpha-particle tracks visible by optical means. The chemical etching process produces much smaller tracks. The etched SSNTD’s chips are viewed under transmitted light mode of an optical microscope and the images are captured by the camera attached to the microscope.

One problem in the evaluation of SSNTD is the determination of the track integral density value. Track density analysis and detection of the chip surface is based on Field of View (FOV). The FOV size depends on objective magnification M and CCD camera resolution. The FOV size optimization depends on applications:


small FOVs are more suitable for track parameter estimation, large FOVs are more useful for track counting, e.g. aimed at exposure estimation with radon passive integrated measurements.

An automated technique for a computer-assisted alpha track counting system is required for a large number of fields counted per detector. The detection technique based on a single field can be used when the FOV’s area covers a large detector surface at low optical magnification to provide better statistical measurement. Generally, this technique is used in track counting for SSNTD electro-chemically etched.

2. METHODS AND TECHNIQUES

The ENEA-INMRI Institute developed an integrated experimental system for radon measurement and standardization. This system, in particular, includes an analyzer system for SSNTD’s applications (Sciocchetti et al., 1994). The evaluation of track density is based on an optical microscope equipped with a Charge Couple Device (CCD) camera, a computer controlled stage and an autofocus drive (Fig. 1a). An analog photo video camera was embodied in the former automatic track counting apparatus (Fig. 1b).

A track recognition program based on the public domain Java-Image J processing software was developed (Rasband &Image J, 1997-2011). An ad-hoc applet allows the acquisition of track density (cm$^{-2}$), exposure (kBq h/m$^3$), and radon concentration (Bq/m$^3$). The acquisition software allows capturing and storage microscope images segmented in FOVs. The CCD camera allows a set of seven resolution values (range: from 640x480 to 2048x1536). The stored images are analyzed by means of the Image J (Image Processing and Analysis in Java) freeware software (NIH) (Sabyasachi, 2012; Immè, 2012).

Fig. 1a – The novel ENEA-INMRI Image Analyser system fitted with CCD camera.
The user has to select the gray value threshold for the track readout. This is easily done via the “Threshold” button on the large buttoned Image J control bar. Variable dual threshold is evaluated automatically by standard routine Image J software.

The experimental apparatus also includes the Piston Radon Exposure Monitor (PREM), developed at the ENEA-INMRI laboratory and patented (Fig. 1c) (Sciocchetti et al., 2005). The PREM holder features the unique characteristics of an experimental device fitted with a built-in START & STOP exposure switch based on push-pull sampler. The device can be used for testing the response of CR-39 SSNTD films. Polyallyldiglycol carbonate (PADC) is a well-known SSNTD and is commercially available as the CR-39 detector. CR-39 chips of different sizes: 25 x 25 mm², 13 x 37 mm² and 10 x 10 mm² can be located inside the sensitive volume of the holder.

In this paper we present the ENEA-INMRI Image Analyzer system performance tested in semi-automated mode for a computer-assisted alpha track counting of an Electro-Chemically Etched (ECE) and chemically etched CR-39
SSNTD chips. A comparison of analog and digital video camera performance has been carried out with a reference set of CR-39 SSNTD chips processed with the ECE etching technique. The Image J software performance, in particular a comparison of fixed and variable threshold option. Experimental data on digital Charge Couple Device (CCD) camera and are presented.

3. COMPARISON OF ANALOG AND CCD DIGITAL CAMERA PERFORMANCE

Comparison of CCD and analog camera performances has been carried out with the analysis of electrochemically etched CR-39 thin circular chips (diameter size: 32 mm). Experimental data was based on 10 groups of 20 chips each one, exposed inside the INMRI-ENEA radon chamber at different exposure levels. Four track readouts for each exposed detector have been carried based on analog and digital camera at 50 and 125 total magnification (objective and video camera magnifications). The analysis has been based on the semi-automated track density readout of a Reference Surface around the CR-39 chip center.

\[
\text{Percentage difference} = \frac{D_d - D_a}{\frac{D_d}{2}} \times 100. \tag{1}
\]

Figure 2a shows comparison of variation of percent difference versus exposure of the average track density counted with digital \(D_d\) and analog camera \(D_a\), using 50 (lower curve) and 125 (upper curve) total magnification.

![Figure 2a](image_url)

Fig. 2a – Percentage difference versus exposure.
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Fig. 2b – Track density readout vs exposure based on CCD camera (red label) and on analog camera (blue label) with the same total magnification 50.

Figure 2b shows comparison of experimental data based on analog camera with 2.5x objective magnifications and on CCD camera with 1.6x objective magnification for the same overall magnification 50.

3.1. ANALYSIS OF THE INFLUENCE OF FIXED AND VARIABLE THRESHOLD OF JAVA-IMAGE J TRACK RECOGNITION APPLET ON THE NOVEL IMAGE ANALYZER PERFORMANCES

All data of Figures 3-7 are based on experimental conditions of 2.5x optical magnification and FOV area 20 mm² and the same CR-39 chip (TASL detector 25 mm x 25 mm).

Fig. 3 – Probability distribution of track density based on random scanning of the overall detector surface (550 readouts on the total SSNTD chip surface).
Performances of the novel image analyzer have been tested with the analysis of chemically etched CR-39 SSNTDs exposed for an exposure run inside the ENEA Radon Chamber. Figure 3 shows probability distribution versus track density intervals based on the random scanning of a single chip surface (TASL detector 25mm x 25 mm). Abscissa values show track density grouped according an interval class value of 100 tr/cm².

The analysis has been carried out with the acquisition of a representative sample of 550 readouts on the overall SSNTD’s chip surface at experimental conditions of 2.5x optical magnification and FOV’s area of 20 mm². Frequency track density distribution is bimodal for fixed threshold in the 1000–3000 tr/cm² range (blue label), and unimodal for variable dual threshold in the 1000–1900 tr/cm² track density range (red label).

Figure 4 shows correlation of track density distribution based, respectively, on fixed and variable threshold. Track density distribution based on variable threshold is equal to track density distribution based on fixed threshold, when the variable threshold is above 48. It corresponds to 0-1900 track density range of bimodal distribution of Figure 3. The small “cloud” above the main distribution shows a data set based on variable threshold lower than 48, which corresponds to the 1900–3200 track density range of Fig. 3 bimodal distribution.

Fig. 5 shows that for variable threshold values above 48 there are two overlapping track density distributions. For variable threshold lower than 48 the track density evaluation based on fixed threshold is higher. This effect is evidenced in Figure 4.
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Figure 6 shows correlation between percentage variation of threshold difference and related percentage variation of track density difference.

Fig. 5 – Track density distribution based on fixed and variable dual threshold.

Fig. 6 – Variation of track density percentage difference (%) vs threshold percentage difference.

Fig. 7 – Variation of threshold percentage difference vs track density percentage difference.
Figure 7 shows correlation between percentage variation of threshold difference versus percentage variation of track density difference.

Threshold and track density difference has been evaluated as follows:

\[
\left( \frac{T_f - T_v}{T_f + T_v} \times 2 \right) \times 100
\]  

(2)

where \( T_f \) is the fixed threshold and \( T_v \) is the variable threshold.

The track density difference has been evaluated as follows:

\[
\left( \frac{D_f - D_v}{D_f + D_v} \times 2 \right) \times 100
\]  

(3)

where \( D_f \) is the fixed threshold and \( D_v \) is the variable threshold.

3.2. ANALYSIS OF THE INFLUENCE OF ANALYZER SYSTEM PARAMETERS ON TRACK DENSITY READOUT

Experimental tests have been carried out on the same CR-39 SSNTD’s chip. The basic parameters of analyzer system performance are: objective optical magnification, CCD camera resolution, FOV’s area and dual threshold settings.

Fig. 8 – Track readout per FOV based on variable threshold vs the FOV’s area (mm²).
Figure 8 shows that track readout with variable threshold is proportional to the FOV’s area for the 2.5x, 4x, 6.3x objective magnification. Figure 9 shows that track readout with fixed threshold is proportional to the FOV’s size only for the 2.5x objective magnification.

Figures 10 and 11 show track density (tr/cm²) versus FOV’s area (mm²) on the same CR-39 chip. Figure 10 shows that variable dual threshold mode allows a constant track density per FOV interval also for the 4x optical magnification and readout is more efficient with respect to readout based on 2.5x optical magnification.

Fig. 9 – Track readout per FOV based on fixed threshold vs the FOV’s area (mm²).

Fig. 10 – Track density per FOV based on variable threshold vs FOV’s area (mm²).
4. FINAL REMARKS

FOV’s area can be optimized with a procedure based on two parameters: optical magnification and CCD camera resolution. The INMRI-ENEA CCD camera allows seven resolution values.

Experimental data shows that, for the same FOV’s 2.5x objective magnification, track density distribution based on variable threshold of Image J option is equal to track density distribution based on fixed threshold, when the variable threshold is above 48.

The 2.5x objective magnification allows operating with higher FOVs at low track density. The 4x objective magnification allows a more efficient track density per FOV readout only for a small FOV’s area range.

The random scanning of the detector surface based on image acquisition with variable threshold shows that track distribution is homogeneous on the chip’s surface. The track density distribution is unimodal at experimental conditions 2.5x and FOV area 20 mm².

REFERENCES

