Determination the effect of gamma radiation on CR-39 detector by analysis of photoelasticity images using MATLAB software

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Abstract: The effect of gamma radiation on CR-39 detector was determinate through the image processing for the photoelasticity images by using of MATLAB software. The maximum change different in CR-39 detector colors at photoelasticity technique was appear at the value 2 kN as a mechanical compression effect. It was adopted this value of mechanical compression on CR-39 detector to calculation the change in color percentage - C% for four colors red, green, magenta and yellow. It was found the increase of gamma irradiation dose -D(Gy) on CR-39 detector at the range (100 to 600 Gy) lead to change in color percentage - C% for four colors. The polynomial equation for red color was a good smooth relation compared with polynomial equations for green, magenta, where the yellow color behavior as a logarithmic relation. The red color relation used to determination the effect of gamma radiation on CR-39 detector due to the clear behavior between D(Gy) with C%. In this study, we can consider that the image processing for the photoelasticity images of CR-39 detector by using of MATLAB software was a good method to calculate the effect of gamma radiation on CR-39 detector compared with other methods in this field.

Keywords: gamma radiation; Solid state nuclear track detectors; SSNTDs, CR-39 detector; photoelasticity; MATLAB software; Image processing

1. Introduction

Solid-state nuclear track detectors –SSNTDs have much application in the fields of nuclear physics, high energy physics, nuclear engineering, environmental physics, and radiation dosimetry [1]. On the type of these detectors was CR-39 detectors named poly allyl diglycol carbonate -PADC represent the most widely used in many fields of physical science and industry. CR-39 detectors respond to the effect of radiation such as alpha particle [2], ultraviolet radiation [3], microwave [4] and gamma radiation [5].

The effect of gamma radiation changed in the physical properties of SSNTDs. There were two main changes in the properties of SSNTDs were happened after gamma irradiation [6]. The first change was free radicals produced in SSNTDs as a result of gamma irradiation caused by chain cross-linking. And that cross-linking leads to an increase in the molecular weight because of a large number of free radicals produced in SSNTDs. The second change was decreasing in molecular weight and substantially by chain scission leads to changes in the properties of SSNTDs material [7]. Both of these above processes may predominate depending upon the chemical structure of the SSNTDs and
the environmental properties under which the exposures to gamma radiation are performed [8]. The determination of these changes works by deferent techniques as the transmittance of optical absorbance at UV-visible, infrared-IR, and FTIR - spectroscopy [8,9].

Jyotsna et al. [10] show that the optical band gaps [5] of tuffak polycarbonate nuclear track detector activation energy of bulk etching and on optical properties of the detector were changes with gamma irradiation dose. The UV-visible technique used also for the measurement of gamma radiation dose, which indicated to the structural changes of the irradiated material.

The increase in gamma dose leads to a change in optical band gaps of some of the nuclear track detectors [11]. Shohachiro [12] used the photoelasticity technique to determine the effects of gamma radiation dose on optical and mechanical properties of epoxy resin. Where photoelasticity represents a non-destructive method used with gamma irradiation method to determine the thermal stresses in a thick-walled cylinder with a temperature gradient along the radius of some material [13]. Oswaldo [14] determine the number of stresses by analysis of color fringes automatically. When the stress of CR-39 and CN-85 detectors used to calculate the gamma radiation effect by determining the value of the penetration coefficient of (He-Ne) laser beam [15]. RGB (red, green and blue) colors component of photoelasticity technique was selected as the basis of the strategy by it offers more possibilities in the fringe evaluation process. Photoelasticity technique take in consideration for acoustic wave propagation by image analysis program which is written in MATLAB software [16]. Where the photoelasticity technique determined the stress analysis that utilizes a polariscope in conjunction with the optical system [17]. The polariscope makes patterns of fringe that depend on the external stress of the material. Photoelasticity technique appears the stress patterns allowing for stress analysis by using MATLAB software for fringe sharpening in conjunction and describes digital photoelastic algorithm simulated in a PC computer [18]. Analysis of the NTDs images of digital camera obtained by MATLAB software through recognition and particle measurements from NTDs parameters images analysis and 3D visualization to the image[19] and determination the NTDs parameters which irradiated by thermal neutron [20] and alpha particle [21]. Image processing analysis used in the photoelasticity technique to determine the pressure in samples and the values of the dark and light areas of the image used to analyze the effect on these samples [21].

Santos Kotila [22] calculate the relationships between the pixels in the image and the light intensity. Where Saravani [23] used MATLAB software to the determination of the number of the fringe order and their location by using of photoelasticity method. In this study, we will determine the gamma radiation effect on the CR-39 detector through images processing by MATLAB software to the images taken from the CR-39 detector by photoelasticity technique.

2. Materials and Experiments
2.1. Materials
Nuclear track detector-NTD type CR-39 (allyl diglycol carbonate ) detector was used with the geometry shape of CR-39 detector according to ASTM D 412 type C, thickness 1.2 Cm, density 1.32 g / Cm³, manufactured by Photolastic, Inc. 176, Lincoln Highway Malvern, Pennsylvania, and having a chemical formula C₆H₈O₉N₂.

2.2. Gamma irradiation
CR-39 detector was irradiation after exposed to gamma radiation from cobalt-60 source (Gamma cell 900, manufactured by the Bhabha Atomic Research Center-BHA /Trombay / Bombay / India ) with a dose rate of 0.40 Gy /min. The distance between the CR-39 detector and gamma source was 20 Cm. The range of gamma irradiation doses were (100, 200, 300, 400, 500 and 600 Gy ).
2.3. Mechanical compression effect

Mechanical compression was affected on the CR-39 detector at the range values (from 1.0 to 4.0 kN) by using of proving ring model H-4454.010, 5.0 KN, Humboldt Mfg. Co. The loading frame of photoelasticity technique which includes the proving ring and CR-39 the detector was shown in Fig. 1. The setup of the photoelasticity technique contained polariscope consists of a lump (monochromatic light source), polarizer, quart wave plat analyzer and the compression effect apparatuses on CR-39 detector with CCD camera was shown in Fig. 2. The basic principle of a polariscope is to place a CR-39 detector sample between a polarizer and an analyzer of the opposite polarization (e.g., horizontal and vertical linear polarizers), viewed in transmission [12]. The image of CR-39 detector sample during compression take by CCD camera as showing in Fig. 2.

Figure 1. Mechanical compression effect apparatuses on CR-39 detector by using loading frame of photo elasticity technique. (1) Loading frame, (2) Loading ram, (3) Proving ring, (4) CR-39 detector.

Figure 2. Setup of photoelasticity technique with polariscope includes of lump, polarizer, quart wave plat analyzer (left -QL and right- QR) and compression effect apparatuses on CR-39 detector with CCD camera.
2.4. Image processing

The images of the CR-39 detector are captured using a digital camera 16 Megapixel. Where the images (pixel unit) was a store in PC computer at the form (png, file). The processing for the CR-39 detector images was analyzed by using MATLAB program version R2013b (8.2.0.701) for 64 bit (win 64). The application of image processing in MATLAB program was used to analyze the images provided from the digital camera for the CR-39 sample. In the present work, we have developed a program to calculate the color percentages C% of four colors (red, green, magenta and yellow).

3. Results and Discussion

The mechanical compression effect from 1kN to 4kN on CR-39 detector lead to change in color percentage - C% of CR-39 detector. The type of colors which have more pronounced were magenta, green, yellow and red. The maximum response of C% for these colors appear in mechanical compression at the value 2 kN. This value of mechanical compression effect on CR-39 it was adopted for determination the effect of gamma radiation in CR-39 detector without other values for the range from 1kN to 4kN. The images which produce from photoelasticity technique to the irradiated CR-39 detector were capture in CCD camera as shown in Fig. 3. When the images were saved as (png, file) and analysis by image processing of MATLAB software. The final output of image processing of MATLAB software gives the values of color percentage -C % for four colors objects which appear in the image of irradiated CR-39 detector. Fig. 3 show the image of irradiated CR-39 detector at the irradiated dose -D(Gy) 500 Gy and 600 Gy which measure by photoelasticity technique at 2 kN mechanical compression compare with the un-irradiated CR-39 detector. The image processing for irradiated CR-39 detector from 100 Gy to 600 Gy were calculated by MATLAB software. The process of the images analysis for irradiated CR-39 detector with 500 Gy and 600 Gy compared with un-irradiated sample was shown in Fig. 4. Fig. 5 shows the relation between all colors percentage-C% (magenta, green, yellow and red) which calculated by image processing of MATLAB software with the effect of gamma irradiation dose-D(Gy) in CR-39 detector during the mechanical compression effect at 2 kN. The behavior relation between color percentage -C% and gamma radiation dose -D(Gy) for CR-39 detector was polynomial equation for colors (magenta, green and red). When this relation was a logarithmic equation for yellow color as shown in Table 1.

The range of gamma irradiation dose - D(Gy) for green, yellow and red colors was (200 - 600 Gray). Where this range was (200-500 Gray) in magenta color. The polynomial relation in red color was better than at green and magenta colors. And the behavior of color percentage - C% with gamma irradiation dose- D(Gy) in red color was much response to gamma irradiation in CR-39 detector. So the relation equation between color percentage –C% and gamma irradiation dose - D(Gy) for red color may be used to determine the effect of gamma radiation on CR-39 detector after calculating the value of color percentage –C% for red color objects at 2 kN mechanical compression effect. The change in the four-color percentage -C% may be depend on the chain cross linking of CR-39 detector as result of gamma irradiation [7]. The increasing in the molecular weight since a large number of free radicals which produced in CR-39 detector as a result of gamma irradiation [7] may be related too to the increase in the color percentage - C% for the three colors (green, magenta and yellow). For the comparison of the previous works we found no study dealing with the relationship between color percentage - C% of photo elasticity technique of gamma irradiated CR-39 by using image pressing of MATLAB software.

The decreasing in molecular weight by chain scission which leads to changing in properties of CR-39 detector may be related to decreasing in the red color percentage -C% which obtained in this study. The image processing for MATLAB software to the image produce by photoelasticity technique was more than efficient compared with other methods which depends on stress-strain relation for CR-39 detector and isochromatic fringes witness the state of stress in each point of photo elasticity grains [15].
Figure 3. The change in colors objects (red, green, magenta and yellow) at 2kN mechanical compression effect when irradiated CR-39 detector with gamma irradiation dose -D(Gy) at 500 Gy and 600 Gy compared with un-irradiated CR-39 detector.

Figure 4. Image processing by MATLAB software for the images of photoelasticity technique during 2kN mechanical compression to the CR-39 detector which irradiated by 500 Gy and 600 Gy, compared with un-irradiated detector sample. The analysis of image possessing was done on colors objects (red, green, magenta and yellow).
Figure 5. Relation behavior of color percentage -C% for four colors (a) red, (b) green, (c) magenta and (d) yellow after calculated by MATLAB software with the effect of gamma irradiation dose-D( Gy) on CR-39 detector during mechanical compression effect at 2kN.

| Color     | Rang of gamma irradiation dose | Relation equation | Type of equation |
|-----------|--------------------------------|-------------------|-------------------|
| red       | 200-600                        | D(Gy) = 0.32 C² - 25.7 C + 628.9 | polynomial       |
| green     | 200-600                        | D(Gy) = 0.023 C³ + 1.86C² + 56.4C - 80.3 | polynomial |
| magenta   | 200-500                        | D(Gy) = -0.46 C² + 28.3 C + 80.8 | polynomial       |
| yellow    | 200-600                        | D(Gy) = 101 ln C + 240.9 | logarithmic      |

CR-39 detector.
D (Gy ): irradiation dose on CR-39 detector
C: Color percentage C% of One of the four colors (red, green, magenta and yellow).

4. Conclusions
The image processing by MATLAB software from the photoelasticity images of the CR-39 detector which used in this study has an accurate calculation of the effect of gamma radiation on the CR-39 detector. The determination of the gamma radiation effect after calculation of the color percentage -C% by image processing represents a more efficient method compared with other methods that use the numbers of fringes for stress-strain relation. This method can be generalized with other nuclear track detectors - NTDs in the fields of the determination the physical properties of materials, as well as
can be used this technique to identify the specifications of the industrial parties being studied in biomedical departments.

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