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Physiochemical properties of crystalline etch products for CR-39 track detector after α-particles irradiation

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ABSTRACT

The effect of α- particles from radiation source Am-241 with activity 1μCi on the nuclear track detector - NTD type CR-39, dimensions (28x28x1.2) mm^3 were measured. The measurements included the changes in physical and chemical properties for the solution of etch crystalline products for CR-39 after irradiation by α-particles irradiation at two periodic times 0.3 h and 23 h for low and high doses respectively . The changes in organic compounds for etch products were measured by using of FTIR - spectroscopy and transmission electron microscope – TEM . FTIR – spectroscopy shown there was decrease in the values of transmission percent ratios - Tr of wave numbers 1787 , 2800, 839 and 1650 Cm^{-1} relative to wave number 792 Cm^{-1} respectively with increase of irradiation time of α-particles . The etch products after α-particles irradiation of CR-39 detectors were change to low molecular weight organ compounds as a results of degradation bonds and may be formed compounds 2.2-oxy diethanol and 2-propen as the reaction products . Also , shown from transmission electron microscope –TEM there was increase in the degradation amount of etching organic compounds with increase of irradiation time of α-particles . While the change in inorganic compounds for etch crystalline products after α-particles irradiation of CR-39 detectors were describe by using of polarized optical microscope - POM , which shown from its images there was broken in crystalline layers to small crystal with increase of irradiation time . The physiochemical properties which measured by FTIR spectroscopy and transmission electron microscope–TEM for organic etching products were better than the analysis of inorganic crystalline etching products by Polarized microscope-PM .

Keywords: CR-39, nuclear track detector-NTD, crystalline etch products, α- particles.

INTRODUCTION

CR-39 represent of one type of polymers which employed as a detectors in field of science and technology [1, 2 , 3] . one of these field was measurement the radiation effects for non-particle radiation as ionizing radiation[4] and particle radiation as ion beam , neutron and α-particle[5] , and so named since named nuclear track detector-NTD[6,7] . The main strength of these detectors is that the damage produced by the ionizing particle can be enlarged through chemical etching [8] . These enlarged tracks, and physical properties can be viewed under the optical microscope and fourier transform infrared spectroscopy – FTIR [9,10] .

Nuclear track detector – NTD type CR-39 is one of the trade names of the family of Poly Allyl Diglycol Carbonate – PADC etch track detectors. When it is etched in sodium hydroxide – NaOH solution , a variety of inorganic and organic compounds are formed as the reaction products , which also effect on the thickness of CR-39 [11, 12]. Many products were formed after CR-39 etched in NaOH solution as poly allyl alcohol , 2.2-oxy diethanol [13] , allyl alcohol , isopropyl alcohol , sodium carbonate , sodium bicarbonate , and CO_3^{-2} ions [14 , 15] as well as crystalline products as nahcolite (NaHCO3) , natrite ($Na_2CO_3{:}7H_2O$) , thermonatrite ($Na_2CO3{:}H_2O$) , natron ($Na_2CO_3{:}10H_2O$) and trona ($Na_2CO_3NaHCO_3$: $2H_2O$)[14]. When the physical and chemical products of crystalline etch products is changes with type of radiation damage. So, in the present work , we examined the

properties of crystalline etch products of CR-39 after irradiation with α- particles . The effect of α- radiation on CR-39 detector through their crystalline etch products was measured by analysis of organic compounds of these products from using of FTIR – spectroscopy [9] and transmission electron microscope –TEM [16] , when the analysis of inorganic compounds [17] of these products from using of polarized microscope.

MATERIALS AND METHODS

Three pieces sample of nuclear track detector-NTD type CR-39 was munched from Xuchang Tianhe Welding Products Co. , Ltd. Having dimensions (28 x 28 x 1.2) mm^3 . Two pieces samples of CR-39 were irradiated by α-particle from Am-241 source with activity 1μCi . One of these samples irradiated at 0.3 h (for low radiation dose) and another sample irradiated at 23h (for high radiation dose) . Third sample of CR-39 was un-irradiated as a control .

Three sample above were dissolved in 200 ml of 6:0 M sodium hydroxide - NaOH solution contained in a 300 ml Pyrex beaker . The beaker was placed in a water bath maintained at 70.2 - 70.3° C and shacked for 70 h to prepare a super-saturated solution of the etch products . The separation of organic compounds solutions for CR-39 during etching process for three sample above were sampled as EC , ER_1 and ER_2 for un-irradiated , 0.3 h α- irradiated and 23 h α- irradiated respectively .

EC , ER_1 and ER_2 were separated in pure forms by solvent extraction with 50 ml diethyl ether with the aid of 250 ml separating funnel for three steps , then the organic extracting evaporated at room temperature up to 2 ml concentrate sample , and the FTIR spectra in the range (4000 – 400) Cm^{-1} were recorded using NaCl sandwich cell on FTIR instrument , model - 8000 Shimadzu spectrophotometer . Separation of organic compounds was also analysis by transmission electron microscope - TEM , Model - Philips CM10 with an optimal operating voltage of 200 keV , to show the images of organic compounds after irradiation comparing with un-irradiated samples . The separation of inorganic compounds for EC , ER_1 and ER_2 by splitting the aqueous layer samples and left this layer to evaporate at room temperature to grow the formed inorganic products for 2 months , different needle crystalline for each sample were separated manually upon a glass microscope for image analysis by polarized optical microscope – POM , model Meiji MT9000. The texture of the compounds were observed using polarized light with crossed polarizer , the sample being prepared as a thin film sandwiched between a glass slide and a cover slip . A camera –Lumenera was installed on the polarizing microscope.

RESULTS AND DISCUSSION

Figure 1 shown the FTIR spectrum at the wave number rang 4000-400 Cm^{-1} for chemical etching products of EC , ER_1 and ER_2 samples for un-irradiated , 0.3 h irradiated and 23 h irradiated of CR-39 respectively . The FTIR spectrum for EC sample , show the presence of band at 1787.9 Cm^{-1} due to the stretching of carbonyl group of ester and band at 839 Cm^{-1} for out of plane bending , these two band also appeared for ER_1 while this two bands disappeared for ER_2, which can attributed to the decomposition of compound ER_2 by the action of radiation and converted to another compounds (alcohol and ether) . Other bands like aliphatic C-H stretching at 2800 Cm^{-1} and C = C stretching at 1650 Cm^{-1} having small effect relative to wave numbers 1787.9 Cm^{-1} and 839 Cm^{-1} .

As we see from figures all the functional group decreases this due to as we said the decomposition of compound to lower molecular mass alkane during etching of CR-39, as shown in figure 2 .

The FTIR spectra show the appearance of OH stretching group for samples EC , ER_1 and ER_2 , because the reactant and the products contain hydroxyl group. Also from the spectra we have bands for carbonyl stretching at 1787.9 cm^{-1} for sample EC and ER_1 and disappeared for sample ER_2 this can be explain as follows : sample EC contain two carbonyl groups, after radiation produce sample ER_1 which contain one carbonyl group, while sample ER_2 don't have carbonyl group as show in figure 2 .

Table 1 show the wave numbers and assignment for crystalline etch products for EC , ER_1 and ER_2 of CR-39 detector measured by FTIR spectroscopy , which shown the mains bonds still appear with increase of irradiation time at wave numbers 2800 , 1787 , 1650 , 839 Cm^{-1} as wall as to another wave numbers 3300 , 1402 , 1109 Cm^{-1} .

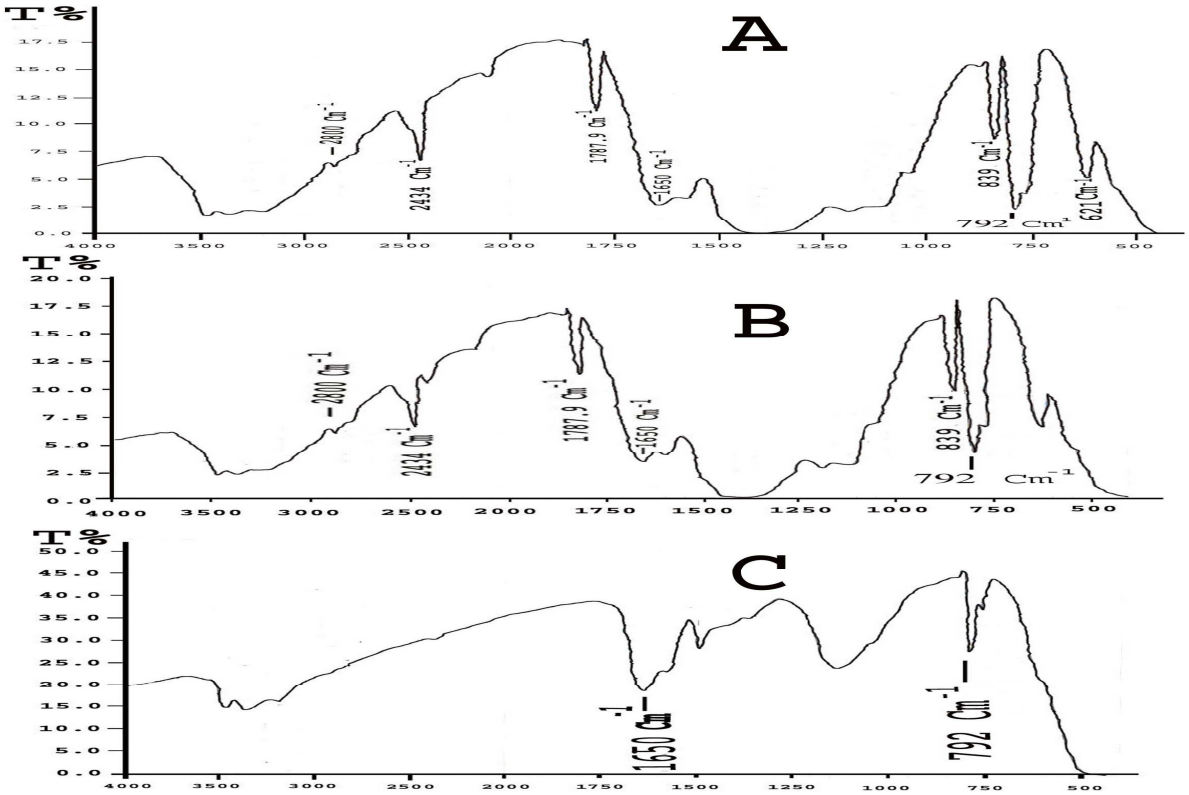

Fig. 1 : Transmission percent –T% from FTIR – spectrum at wave number range 4000- 400 Cm^{-1} for organic etching products of EC , ER_1 and ER_2 samples after α –particle irradiated of CR-39 detector respectively . A: un-irradiated , B: 0.3 h irradiated , C: 23 h irradiated

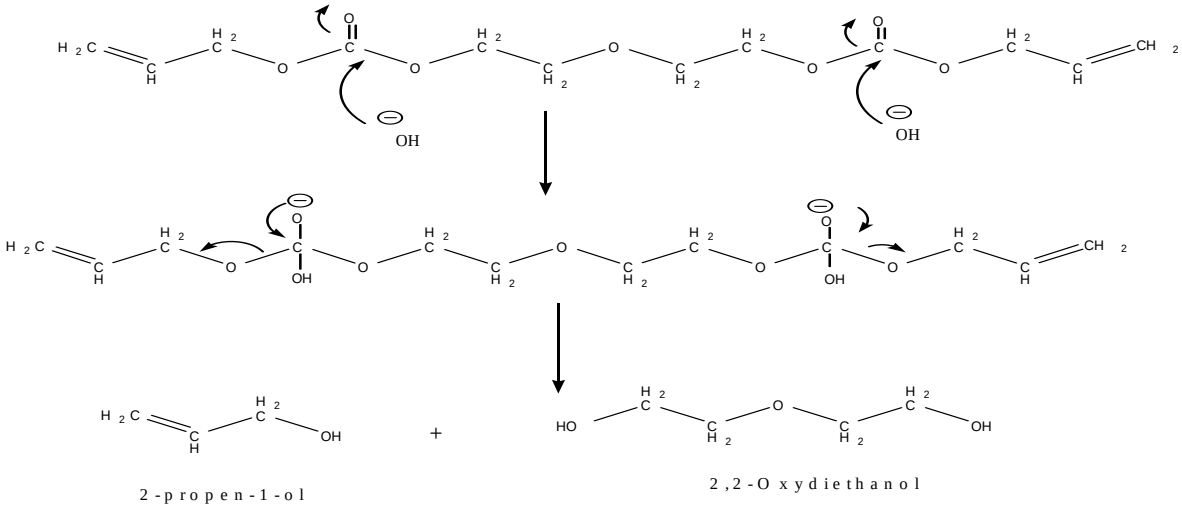

Fig. 2 : Scheme for the possible positions which are subjected to cleavage by the hydroxide ion [13] .

Table 1 : Wave numbers – Cm^{-1} and assignment crystalline etch products of for chemical etching products of CR-39 detector measured by FTIR spectroscopy as per Figure 1

ESC (Cm^{-1})	ESR_1 (Cm^{-1})	ESR_2 (Cm^{-1})	Assignment
3300 3193	~ 3300 3192	3348 3190	OH stretching C=C-H stretching
2800 2761	2800 2761	~ 2860 -----	Symmetric CH_2 stretching Symmetric CH_2 stretching
1787.9	1787.9	-----	C=O stretching
1650 -----	1650 -----	~ 1635 1577	C=C stretching of vinyl group OH bending
1402	1400	~ 1492 1367	C-H bending C-H bending
1109 1043	1109 1043	---- ~1134	C-O-C stretching C-O-C stretching
839 769	839 769	---- 794.6	C-H rocking out of plane C-H rocking out of plane

Figure 3 show the transmission ratio Tr of the wave numbers 1787 , 2800 , 839 and 1650 Cm^{-1} relative to wave number 792 Cm^{-1} for each samples of EC , ER_1 and ER_2 samples of CR-39 detector . Transmission ratios T_r of the wave numbers 1787 , 2800 , 839 and 1650 Cm^{-1} named to Tr_1 , Tr_2 , Tr_3 and Tr_4 calculated by following equations respectively .

$$^{*}Tr_1 = \frac{[T\%]_{1789}}{[T\%]_{792}} \quad , \quad Tr_2 = \frac{[T\%]_{2800}}{[T\%]_{792}} \quad Tr_3 = \frac{[T\%]_{839}}{[T\%]_{792}} \quad , \quad Tr_4 = \frac{[T\%]_{1650}}{[T\%]_{792}} \qquad (1)$$

The values of Tr_1 , Tr_2 , Tr_3 and Tr_4 were dropping with increase of time of irradiation of α- particles as shown in fig. 3 .

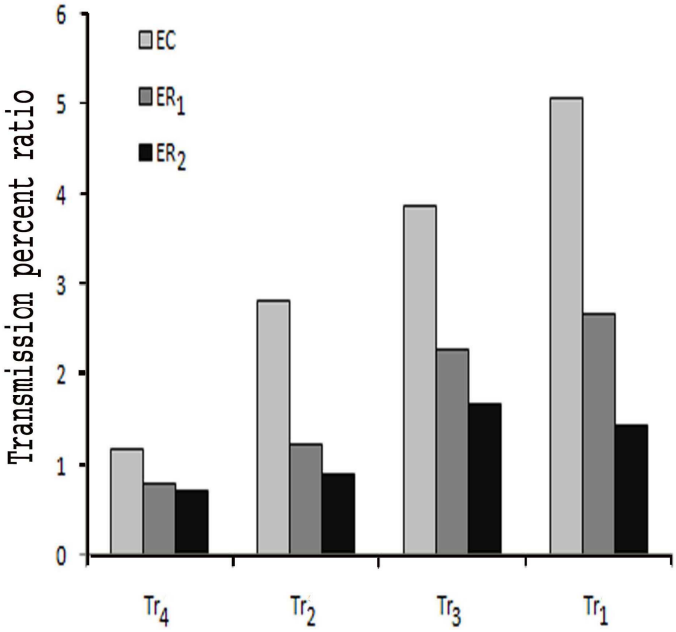

Fig. 3 : Transmission percent ratios Tr_1 , Tr_2 , Tr_3 and Tr_4 (1) for wave numbers 1787 , 2800 , 839 and 1650 Cm^{-1} relative to wave number 792 Cm^{-1} respectively . EC , ER_1 and ER_2 samples to un-irradiated , 0.3 h irradiated and 23 h irradiated for α – particle irradiation of CR-39 detector respectively

Tr_1 and Tr_3 for C=O group stretching and C-H group rocking respectively were a good agreement for radiation response better than Tr_2 and Tr_4 for CH_2 group starching and C=C respectively , figure 3 .

For high doses of α- radiation at time of irradiation more than 23 h represent degradation for all chemical etching products to low organic compound as appearing the stability of Tr_1 , Tr_2 , Tr_3 and Tr_4 after the irradiation time 23 h . And the degradation of organic compounds with increase of irradiation time was clear appearing in the images of transmission electron microscope - TEM as shown in figure 4 .

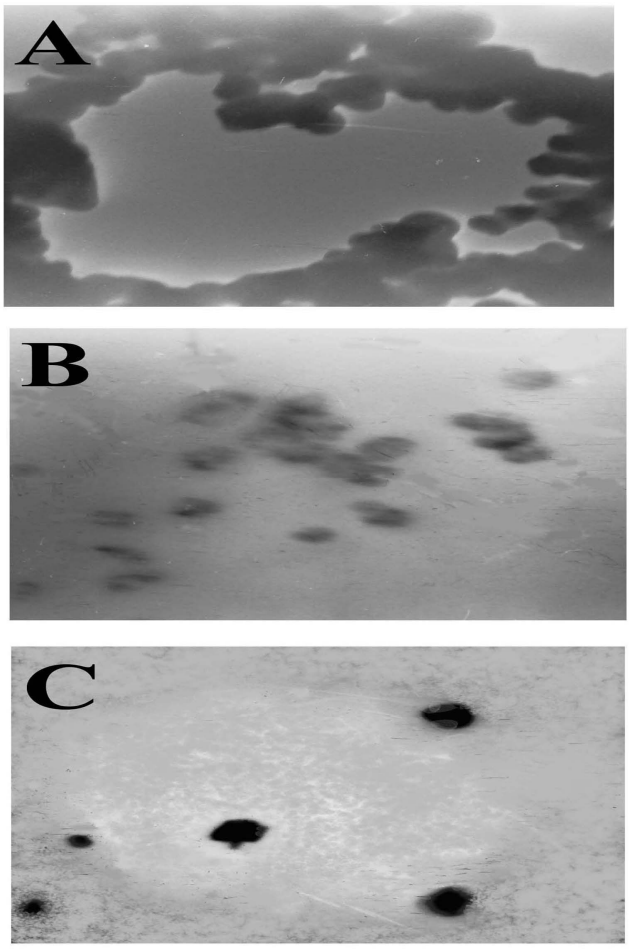

Fig. 4 : Transmission electron microscope –TEM* images for organic etching products of EC , ER_1 and ER_2 samples after α – particle irradiated of CR-39 detector respectively . A: un-irradiated , B: 0.3 h irradiated , C: 23 h irradiated .
** Transmission electron microscope –TEM model Philips CM10*

The average diameter ranges of organic compounds which measured by TEM for sample B and C were 70-90 nm . The α-radiation effect below irradiation time 0.3 h , figure 4 may be assessment the radiation effect for low doses by measured of relative transmission percent Tr_1 and Tr_3 for 1789 and 1650 Cm^{-1} respectively equivalent to image analysis process by programming software for diameter ranges . The POM - analysis of inorganic compounds of chemical etching products were appear these compounds as layers at un-irradiated samples as shown in the image A for EC sample , figure 5 .

When α-irradiation at time 0.3 h for ER_1 sample the crystalline layers were broke to small crystal as shown in the image B for ER_1 sample . while α- irradiation at time 23 h these small crystal were degradation to vary small crystal as shown in image C for ER_2 . The degradation of small crystals in image C , Figure 5 also may be measured by image analysis process using programming software to produce good agreements which reflected the effect of α- radiation on CR-39 detector. From this study shown the properties of chemicals etching products after α-irradiation CR-39 detector with α- particles for 0.3 h and 23 h was change depended on the time of radiation , and these properties measured by FTIR spectroscopy and transmission electron microscope –TEM for organic etching products were better than the analysis of inorganic crystalline etching products by Polarized microscope - PM .

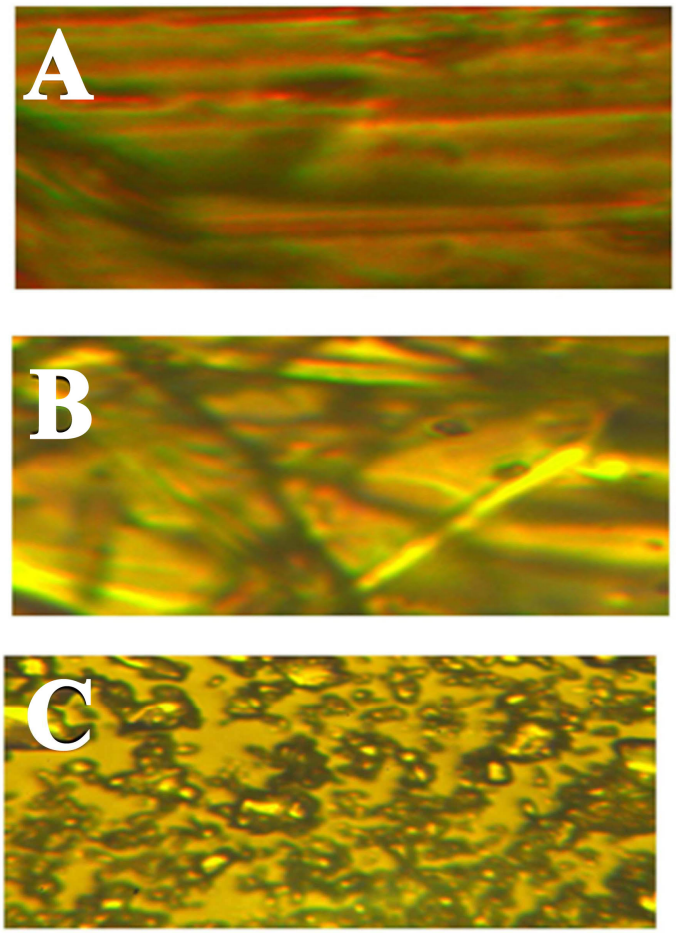

Fig. 5 : Polarized optical microscope – POM* images for inorganic crystalline etching products of EC , ER_1 and ER_2 samples after α–particle irradiated of CR-39 detector respectively . A: un-irradiated , B: 0.3 h irradiated , C: 23 h irradiated .
**Polarized optical microscope–POM , model - Meiji MT9000 .*

CONCLUSION

The physiochemical properties which measured by FTIR spectroscopy and transmission electron microscope–TEM for organic etching products for CR-39 track detector after α- particles irradiation were better than the analysis of inorganic crystalline etching products by Polarized microscope-PM .

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