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Estimate the Optimum condition for CR-39 using two etchant solution

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ABSTRACT

The aim of this research is to compeer the optimum conditions for etching CR-39 by using two kind of etchant solution NaOH+H_2O, KOH+H_2O with various normality and various etching time after irradiated with 3 MeV α-Particles from an ^{241}Am source during (3 min) by calculation bulk etch rate V_B , track etch rate V_T, etch rate ratio V, track length L, and length growth rate dL/dt. The same etchant solution have same mechanism but the different in the value of optimum condition ,the efficiency η have also been determined using experimental data of NaOH+H_2O and KOH+H_2O solution , the best values 72%, 55% at normality 6N,7N respectively ,then exponential relation was found between the bulk etch rate V_B and the solution normality, From FTIR result can studied the relation between the removable thicknesses with the transmittance of the CR-39 detector in the other word we can calculate the bulk etch rate V_B.

Keywords: CR-39, NaOH, KOH, FTIF, transmittance.

INTRODUCTION

CR-39 is an excellent nuclear track recording highly isotropic ,homogenous relatively stable to environmental condition ,very sensitive to ionizing radiation ,and can detect protons of energy up to 10MeV in energy and has a wide range several tens of MeVfor α-particle detection[(1)].Much-work has been done to study proportion of CR-39,the track recording efficiency depend on the processing condition and can be modified ,to some extends by the processing condition adopted .This includes etchant type ,a strength temperature, and etching time[(2)].chemical etching is the most common method used for enlarging the size of the latent tracks ,the etchants which have been most commonly used are aqueous alkaline solution of NaOH and KOH with concentration of 1 to 12M [(3)].The main strength of these detectors is that the damage produced by the ionizing particle can been larged through chemical etching These enlarged tracks, and physical properties can be viewed under the optical microscope and fourier transform infrared spectroscopy – FTIR[(4)].

Aqueous solution of the hydroxides of alkali metals viz, NaOH, LiOH and KOH have been extensively studied as etchant for CR-39 detector[(5)], a new etchants were studied with an aim to find etchant that would yield desirable results. As a NaOH four new etchant, were discovered, these included NaOH dissolved in 1-Propanol, NaOH dissolved in Ethanol, NaOH dissolved in methanol + water[(6,7)].

Chemical etching works on the principle that once a material is placed in a suitable etching , the solution preferentially attacks the damaged core of the track and penetrates along its length with a velocity V_T while the surrounding undamaged material is attached at a lower rate of V_B , the bulk etching velocity [(8)].

The aim of this study is to compeer the optimum conditions for CR-39 by using two type of etchant solution NaOH/H_2O and KOH/H_2O for different normality and to evaluate some track parameters such as track diameter D ,track length L, track growing length dL/dt ,removed thickness bulk etch rate V_b, track etch rate V_T and etch rate ratio V for different etching time.

Fundamentals:

a- Bulk etch rate (V_B)

Bulk etch rate is one of the crucial factor controlling the track development in SSNTDs [(8)]. Due to the chemical reaction between the etching solution and the detector material the thickness of the detector become less ,so bulk etch rate (V_B) given as :-

$$V_B = \frac{\Delta h}{2\Delta t} ----(1)$$

Where Δh is the different in removed longer for two faces of the detector and Δt is the different in etching time.

b-Track etch rate (V_T)is the track etching along the particle trajectory .
A track is formed when V_T/V_B ,and calculated as a relation below :-

$$V_T = V_B \frac{(4h^2 + D^2)}{(4h^2 - D^2)} ------ (2)$$

Where D is the track diameter and h is the removed thickness .
Track growing rate V_D given as :-

$$V_D = \frac{D}{t}\left(\frac{\mu m}{h}\right) ------ (3)$$

When D is the track diameter in µm at etching time t in hour.

c-Etch rate ratio, (V function) ,is :-

$$V = \frac{V_T(T)}{V_B} ------ (4)$$

Track length growth can be written as:-

$$\frac{dL(t)}{dt} = V_T(t) - V_B ---- (5)$$

EXPERIMENTAL BASIS:

CR-39 detector samples of dimensions 1×1 cm^2 and a thickness of 1000 µm from (Tast-Ltd UK), were irradiated with 3MeV alpha particles from ^{241}Am source for 3min ,After irradiation ,the CR-39 detectors were etched in an aqueous alkaline solution of NaOH and KOH with concentration of 4 to8 N ,at 70^{o}C ,The etching process was applied sequentially in time intervals of 6h at maximum. During the etching treatment the concentration and purity of the retching solution were controlled regularly and refreshed after3h usage .After chemical etching, the detectors were removed from the etchant, rinsed with distilled water and dried in air .After drying the track diameters have been measured with a Nikon optical microscope linked to the digital camera type MDCE-5A connected to a computer to work with specific program. Three sample of CR-39 detector analysis using Fourier transform infrared spectroscopy (FTIR) by opus_ 65 FTIR spectroscopy in the range (4000 – 400) Cm^{-1} first sheet of CR-39 un-etched (control) , other sheet etching in 6N at 70^{o}C for 6 and 12 h[9].

RESULTS AND DISCUSSION

To decide whether or not the etchant is better, one needs to study its chemical etching properties comprehensively knowledge of the bulk etch rate V_B is useful for obtain the true track length of heavy ion in the detector medium. Further, the track etch rate V_T is the best observable quantity which provides us a measure of the damage intensity. From the knowledge of V_B and V_T, etching efficiency η can be calculated. After measurement of the amount of removable thickness using optical microscope, the bulk etch rates of the CR-39 detectors etched in different normality of NaOH/H_2O, KOH/H_2Osolution were determined, which summarized in Fig (1), we can see that the bulk etch rate increases with the normality of NaOH/H_2O and KOH/H_2O , reaches a maximum at N=8N .The differences between the bulk etch rates obtained in the present work and these reported in[10] are likely due to the direct and indirect measurement methods employed in the two works [10,11].

Fig's (2,3,4,5) shows the V_D, track length L, length growth rate dL/dt, and V_T with etching time we can observe the same relation for two solution , the different only in its parameter value, from the length growth rate noting that the tracks length increase with etching time until reaching the maximum value have such limit extend constant value with increase the time of etching[12]. The relation between Etch Rate Ratio V with residual range of alpha particles in CR-39 which is evident from fig(6), the shape is similar to the Bragg curve, the height of the maximum of the V close to the initial particle energy[12].

The efficiency η are the most important parameters in deciding the choice of an etchant for the CR-39 detector .therefore studied etching efficiency η as a function of etchant concentration at different etching time ,Our results showed that an etchant concentration of about (6 ,7)N for NaOH and KOH at 70^{o}C respectively yields maximum value of η shown in fig (7), These results given in table (2) are a good agreement with the published work[13,14]. Exponential growth of V_B with morality was found in all investigated cases, the data are given in fig (8) and in table (2).

$V_B = 0.34e^{0.241N}$for NaOH
$V_B = 0.351e^{0.274N}$ for KOH
2- Compare results from FTIR Spectroscopy chart.

FTIR spectroscopy has been found to be an important technique to understand the changes in the molecular bonds after irradiation and etchant. The changes have been estimated from the relative increase or decrease in the intensity of the typical bands associated to the functional group present in the polymers. FTIR spectrum shows an overall increasing in transmittance value which attributed to chain scissoring and cross linking of the bands.

Fig (9) show the compeer FTIR charts of the three sheet of CR-39 , a-un-etched b-etched for 6h ,c-etched 12h ,There are difference between them ,the transmittance of CR-39 increases with time of etching, The FTIR spectra show overall increase in intensity of the typical bands after irradiation and etchant , in the other word change in the removal thicknesses of CR-39after etchant ,or the bulk etching rate V_B as a function of transmittance of CR-39 .
Figs (10,11) showed the FTIR charts of the un-etched CR-39 sheet and etched for 12h.

CONCLUSIONS

1-the CR-39 has the same etching mechanism in both etchant, exponential equation was found between V_B and normality.
2- The result obtained in the present work aggress with the results of other researchers.
3-FTIR Spectroscopy is a powerful analytical technique that has been utilized as a quantitative measure for the removal thicknesses of CR-39 then the bulk etch rate V_B .

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NaOH/H_2O solution	KOH/H_2O solution

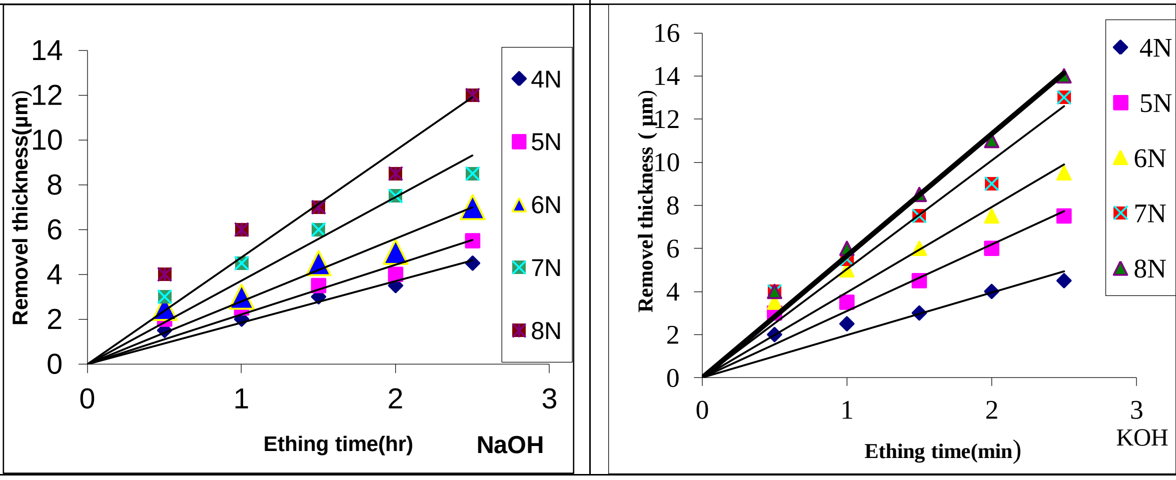

Fig (1) shows the Average Removal thickness as a function of etching time for CR-39 detectors were etched in NaOH and KOH with different normality.

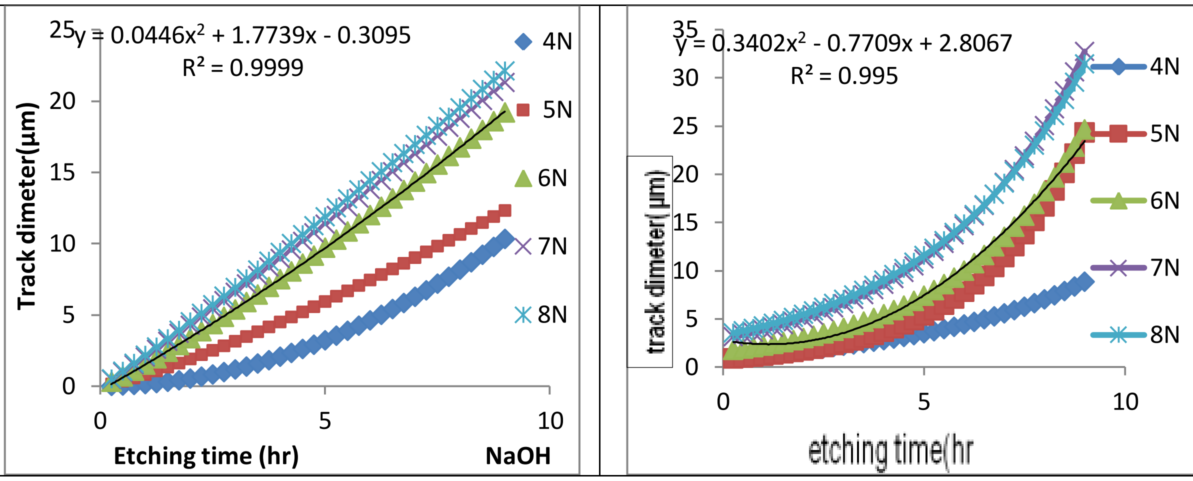

Fig (2) Average alpha particle track diameter as a function of etching time for CR-39 detectors were etched in NaOH and KOH with different normality at 70°C

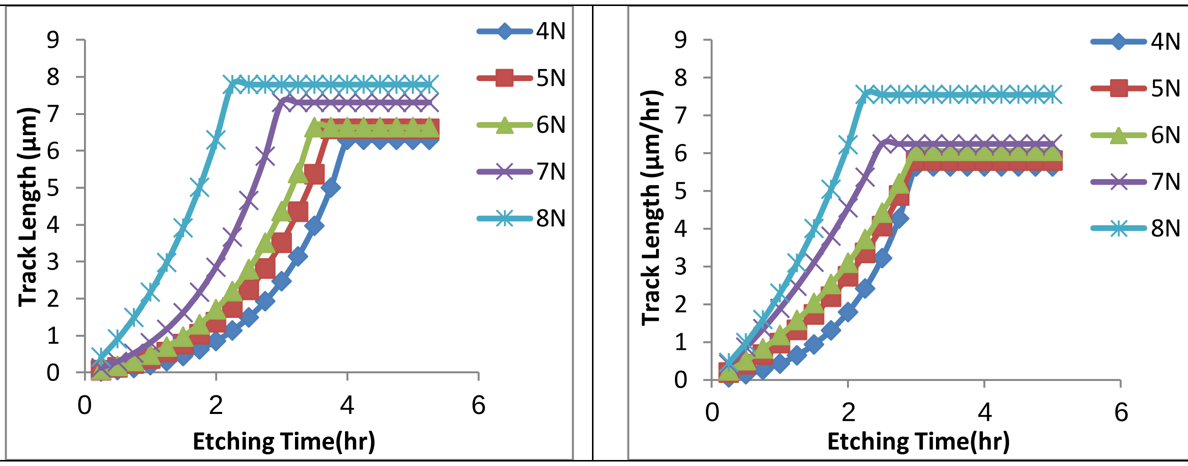

Fig (3) Track length as a function of etching time for CR-39 detectors were etched in NaOH and KOH for different normality's

NaOH	KOH

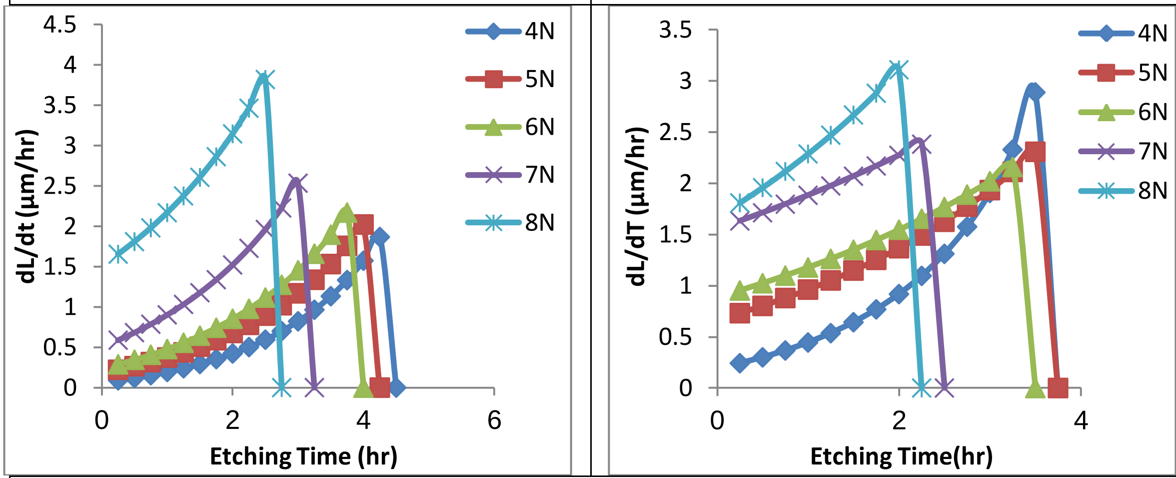

Fig (4) show the length growth rate as a function of etching time for CR-39 detectors were etched in NaOH and KOH for different normality.

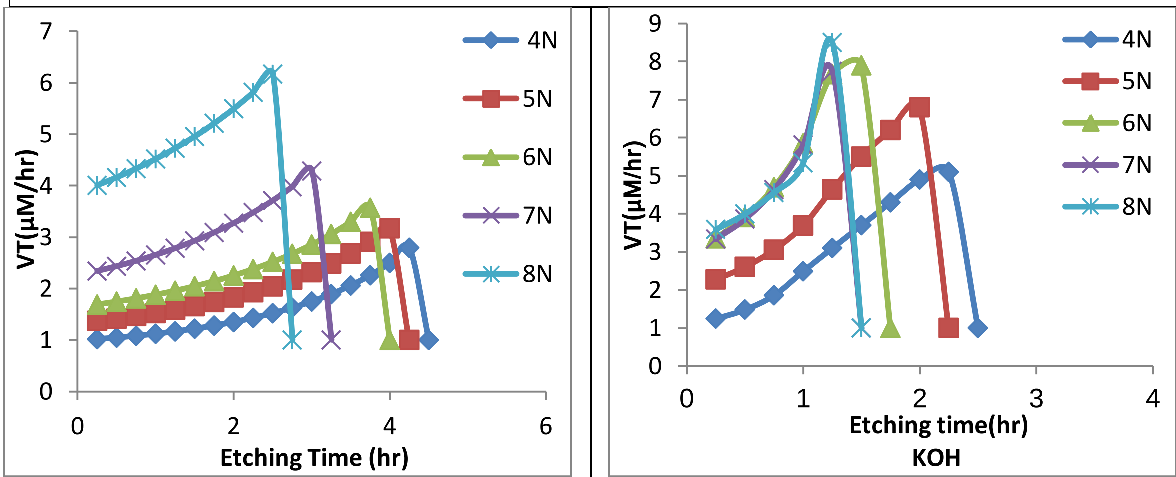

Fig (5) the track etch rate V_T with etching time for CR-39 detectors were etched in NaOH and KOH different normality

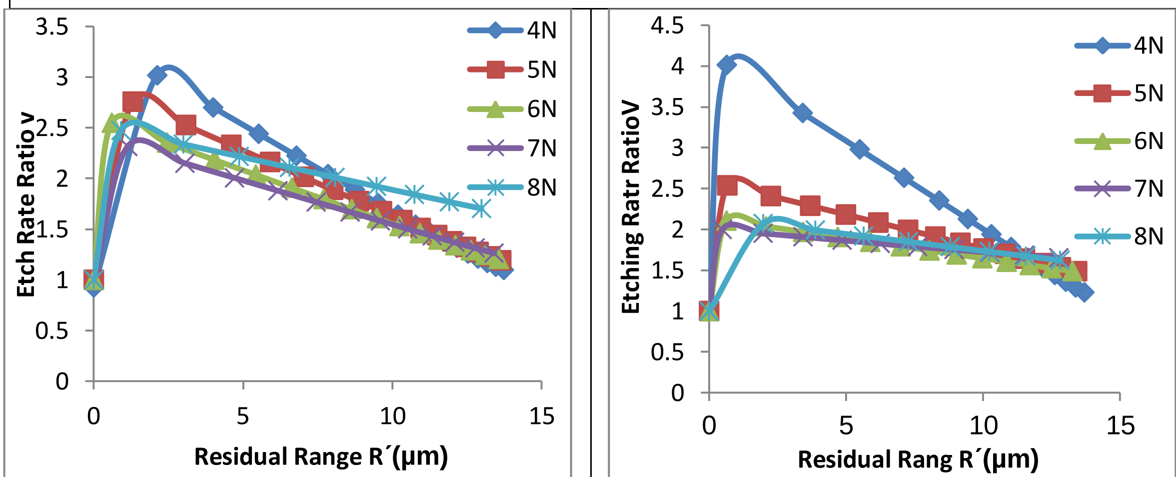

Fig (6) the track etch ratio V with Residual Range R' for CR-39 detectors were etched in NaOH and KOH different normality

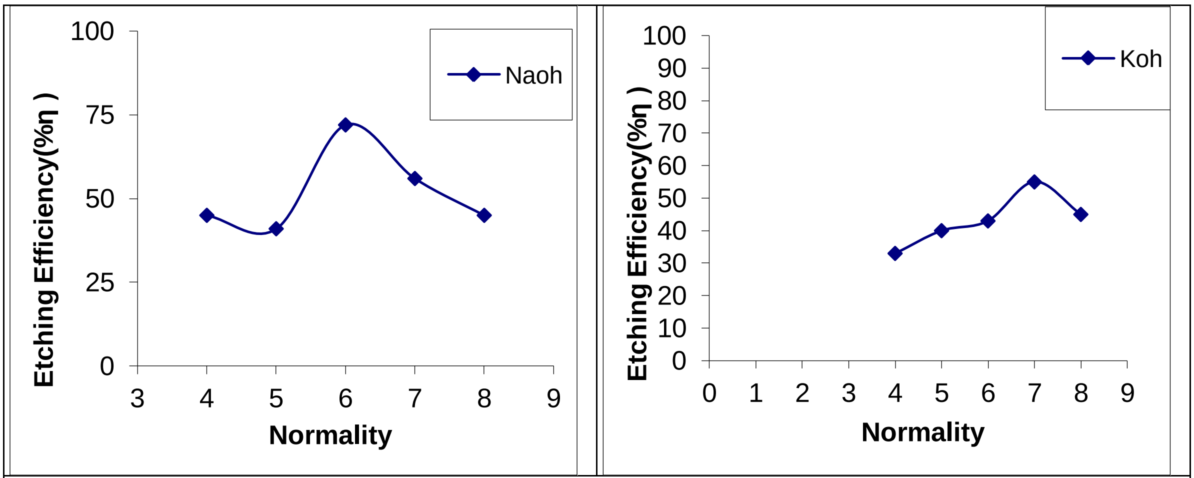

Fig (7) the efficiency ηfor CR-39 detectors were etched in NaOH and KOH at different normality

Table (1) shows the bulk etch rate V_B and efficiency η for CR-39 as a function of morality of NaOH and KOH solution and the percents different between them.

Normality	V_B Naoh	V_B KoH	$\Delta V_B\%$	η% Naoh	KoH η%
4	0.927	0.95	0.0248	45	33
5	1.1	1.5	0.266	41	40
6	1.4	1.95	0.39	72	43
7	1.86	2.5	0.344	65	55
8	2.38	2.9	0.218	45	45

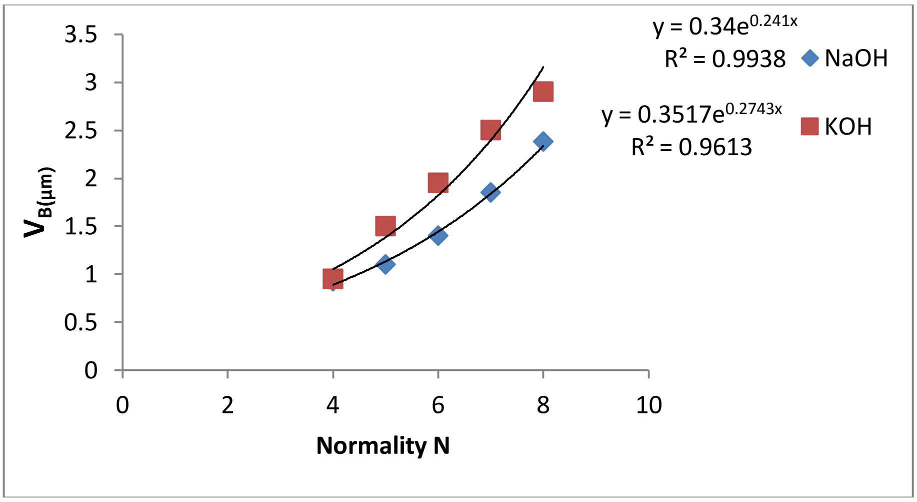

Fig (8) the relation between V_B as afunction of normality N for CR-39 detector were etched in NaOH and KOH.

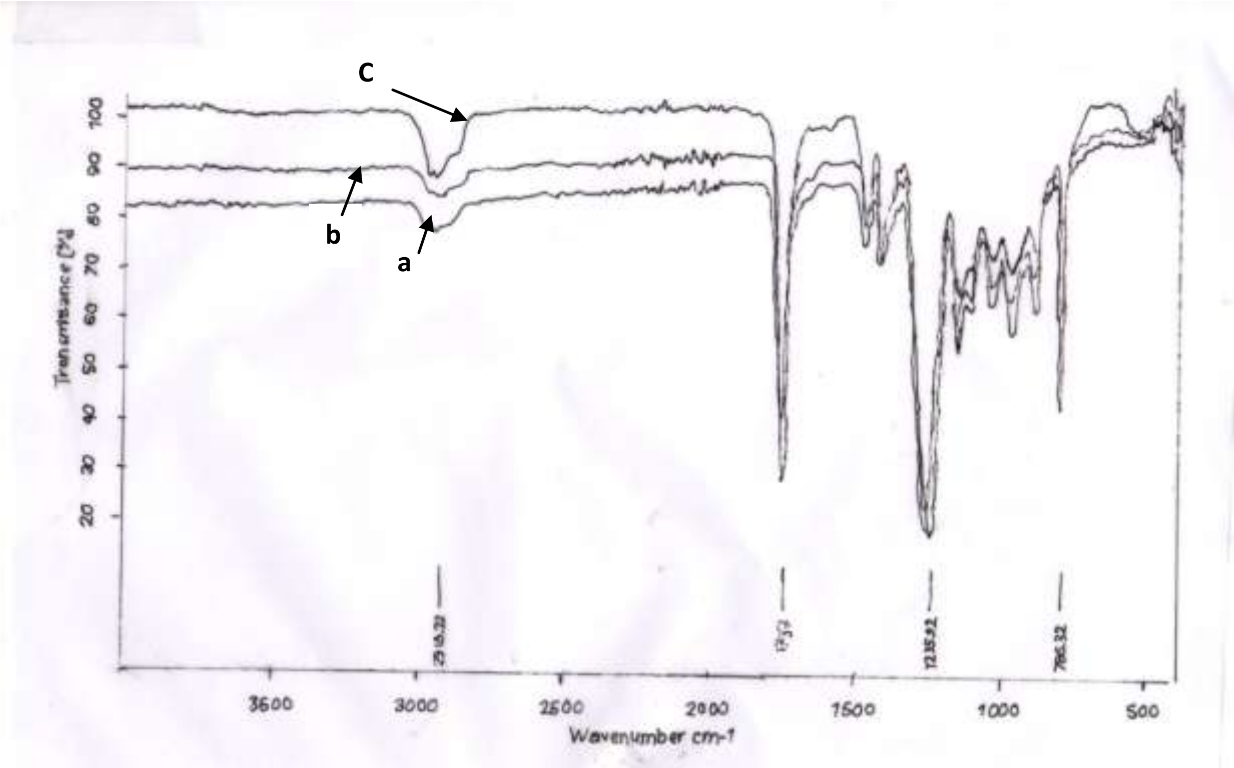

Fig (9) FTIR Spectroscopy spectra for CR-39 detector, (a) un-etched CR-39 detector, (b) CR-39 etching in NaOH/H_2O for 6hr in 6N normality at 70°C (c)) CR-39 etching in NaOH/H_2O for 12 hr in 6N normality at 70°C.

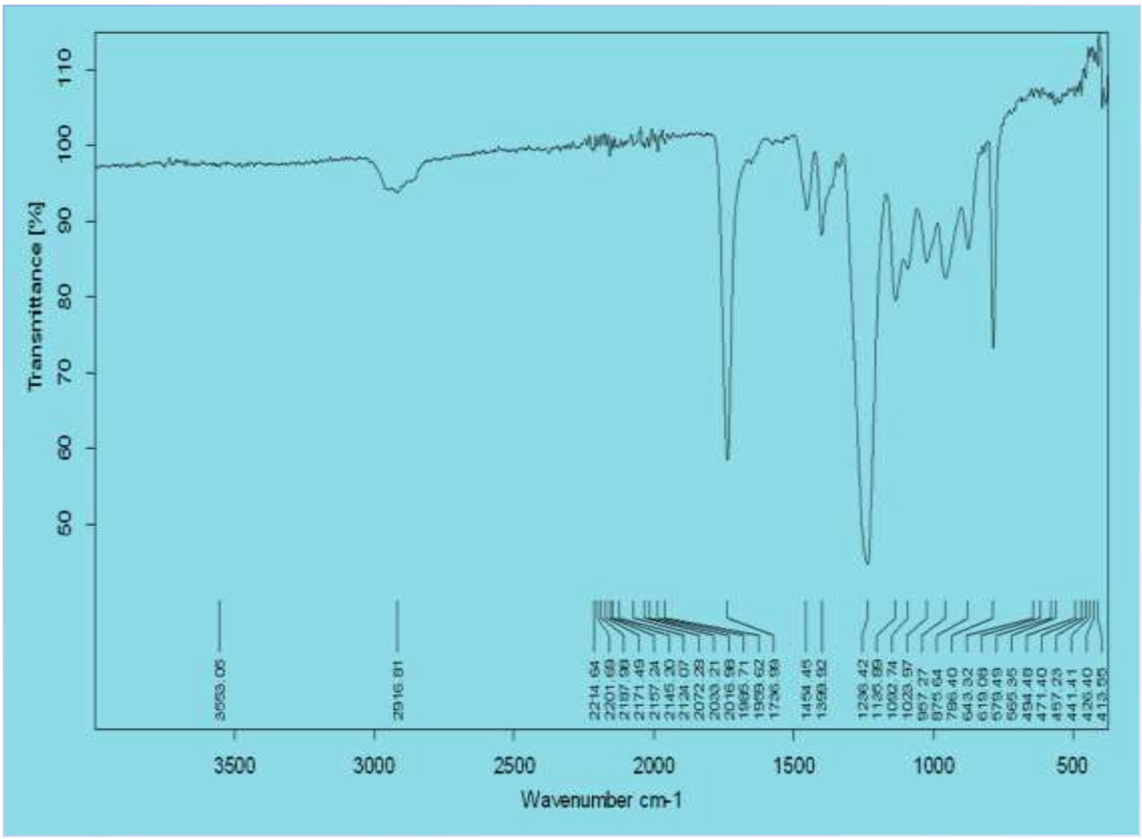

Fig (9) FTIR Spectroscopy spectra for un-etched CR-39 detector

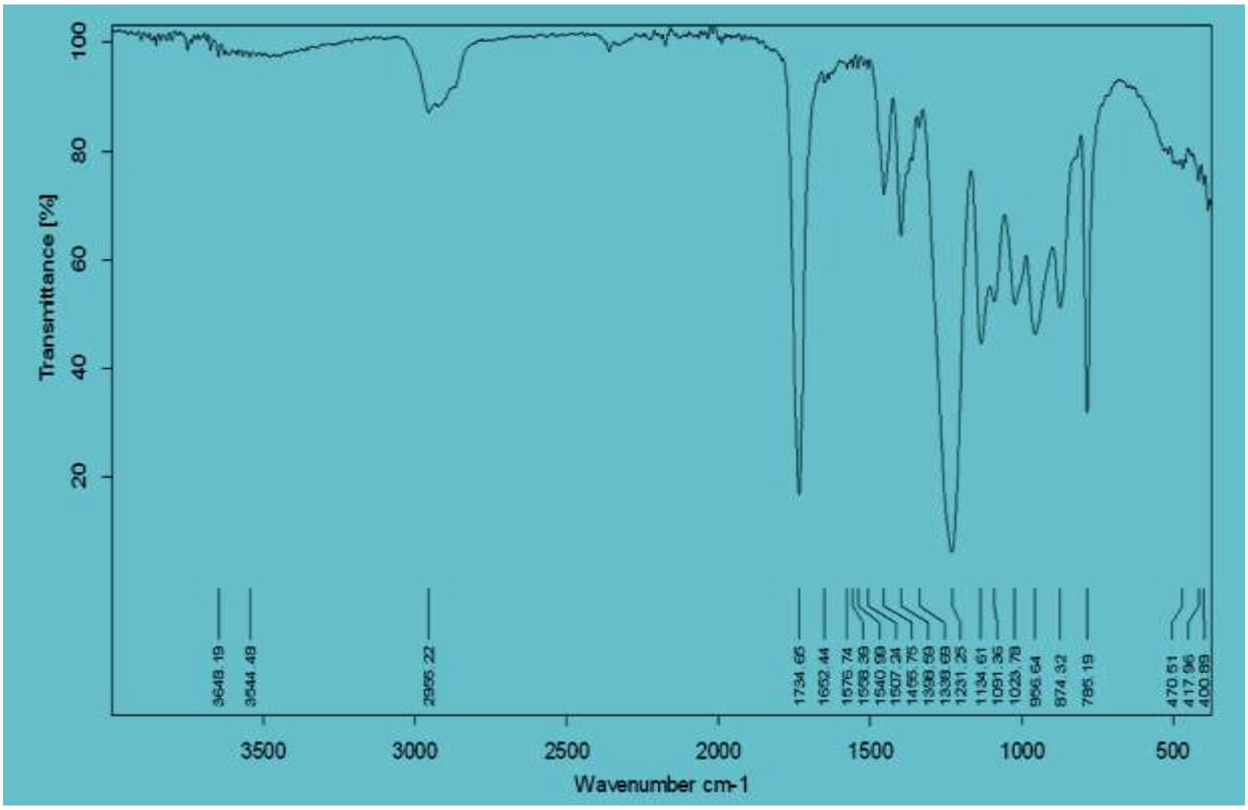

Fig (9) FTIR Spectroscopy spectra for CR-39 detector etched for 12h