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Direct determination of bulk etching rate for LR-115-II solid state nuclear track detectors

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Abstract. The thickness of the removed layer of the LR-115-II solid state nuclear track detector during etching is measured directly with a rather precise instrument. Dependence of bulk etching rate on temperature of the etching solution is investigated. It has been found that the bulk etching rate is 3.2 μm/h at 60°C in 2.5 N NaOH of water solution. It is also found that the track density in detectors exposed to soil samples increases linearly with the removed layer.

Keywords. Bulk etching rate; LR-115-II; sensitivity.

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1. Introduction

Many authors had established that the thickness of the removed layer during etching of the solid state nuclear detector is one of the main factors influencing the track parameters or shape characteristics [1–3]. Other factors, which determine the track parameters and shape, are incident angle characteristics, energy, charge and impact angle.

The removed layer of LR-115-II is also a decisive factor which influences the detector performance relevant for particle detection of particularly α-particles. The thickness of the removed layer is very important when this detector is used for radon measurements and α autoradiography.

Bulk removing rate is the objective of this work. We use a nonstrippable LR-115-II detector, which consists of 12 μm cellulose nitrate on a substrate of 100 polyester, manufactured by Kodak pathe France.

2. Experimental

Different values for the bulk etching rate of LR-115-II detector are available in literature [4,5]. Various methods [6–8] were used to determine the etching rate. Some

Table 1. The bulk etching rate at different temperatures.

Temperature (°C)	Bulk etching rate (μm)
50	1.80
60	3.20
70	8.51

methods [9] use the mass difference before and after etching, and some other methods are based on measurement of the diameter of track opening after the irradiation by heavy ions. All these methods are indirect, involving large uncertainty. We have a novel image analyzer system with a movable stage in three dimensions and it has a vertical digital indicator to display the relative height to a preset upper threshold position. The image analysis system consists of Leica DMRE optical microscope connected to a personal computer. To measure the bulk etching rate we use only the optical microscope. The movable stage is shifted up and down in the vertical direction in steps of 0.7, 1 and 1.5 μm height. The stage is shifted in the present work with the shortest possible shift (0.7 μm). During measurement we focused on the upper surface of the detector before etching and we have set this position as the upper threshold or the height zero then after etching for a given time we refocused on the upper surface of the detector. The height relative to the upper threshold is displayed on the microscope monitor as shown in figures 1 and 2. The difference between the two focus positions represents the thickness removed from the detector surface during this time.

To determine the etching rate we used three groups of detectors each consisting of three pieces. Each group is etched in 10% NaOH solution for different time periods in water bath at different temperatures such as 50, 60 and 70°C. The temperature

Figure 1. The focusing position on the upper surface of the unetched detector set as upper threshold.

Figure 2. The focusing position on the upper surface of an etched LR-115-II detector in 2.5 NaOH for 120 min at 60°C.

is kept constant with an accuracy of 1°C, then the detectors are removed from the solution and washed in distilled water. Each detector is observed under the microscope, the height of the focus position is recorded and the thickness of the removed layer is determined as described above, and the etching process is continued again. This process is repeated for each temperature until the sensitive layer of the detector is completely removed. From figure 3 we can see that the sensitive layer is completely removed after 85, 225 and 400 min at etching temperatures 70, 60 and 50°C, respectively. Figure 3 also shows that the etching rate is strongly dependent on the temperature. From these results the bulk etching rate at each temperature is illustrated in table 1. The most frequently used etching condition is 60°C, 120 min and 2.5 N of NaOH, where, the mean bulk removal rate is 3.20 μm.

3. Repercussion of α autoradiography

Many authors [10,11] investigated the sensitivity of LR-115-II detector on the thickness of the removed layer and it was established that the thickness of the removed layer is a deceive parameter but the characteristics of the dependence at different temperatures were not studied properly. In order to study these characteristics, a set of 15 detectors were placed in a well-closed container which contains a garnet sample. Physically this sample is in powder form with the grains diameter 1–2 μm and the detectors were in close contact with the samples. The detectors are divided into three sets etched in 2.5 N NaOH at three different etching temperatures, namely, 50, 60 and 70°C at different time durations. The detectors are then washed in distilled water and scanned using image analyzer, and the data obtained is represented in figure 3. As expected, the track density increases as etching time is increased (i.e. the thickness of the removed layer) but the characteristics of increasing differs for different temperatures. This is quite obvious in figure 4 where

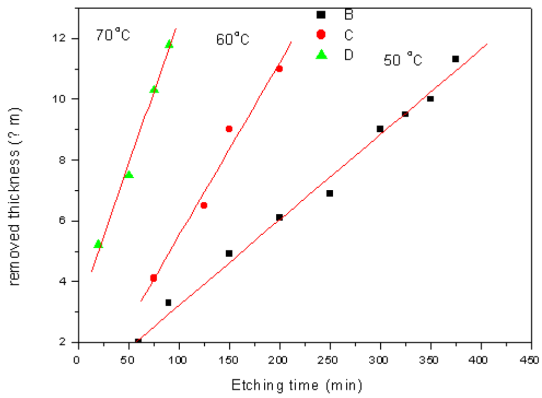

Figure 3. The thickness of the removed layer as a function of etching time at different etching temperatures.

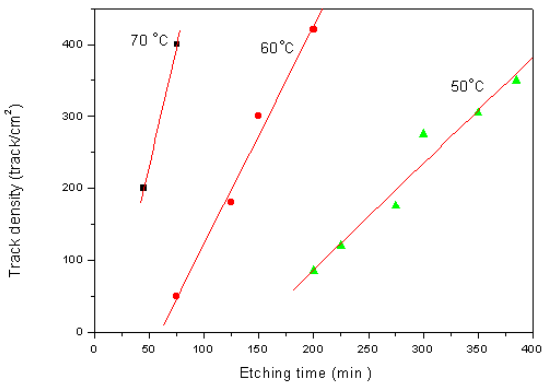

Figure 4. Track density as a function of etching time at different etching temperatures.

the slopes of the three lines are different. That means that (V_T) depends on the temperature, if not the three lines would be parallel (i.e. would have the same slope) with increasing temperature.

4. Limit of energy sensitivity

Many authors had studied the energy limits for α-particles detection theoretically and experimentally [12]. In our laboratory we are going to use LR-115-II in different applications and so it is important for us to know the energy limit for α-particles sensitivity according to our laboratory conditions, to verify the energy limit of LR-115 sensitivity to produce an etched though. We irradiated a group of detectors by

Table 2. The minimum and maximum energy which produce open holes in LR-115-II from literature.

Literature	(E_α)(max) (MeV)	(E_α)(min) (MeV)	Registration mode
Frank and Benton [13]	3.5–4.25	1.8	Generally for CN
Nakahara *et al* [14]	4		photographic 160 min, 60°C 10% NaOH, LR-115
Durrani and Bull [9]	≤4	–	Microscope 60 min, 60°C, 10% NaOH
Costa-Reberio and Lodao [15]	≤4.3	–	Projector 95 min, 60°C, 6.25 N NaOH LR-115, 10 μm
Abu Jarad and Fermalin [16]	1.9–2.5	0.5	Projector 120 min, stirring 60°C, 6.25 N NaOH, LR-115
Supruny and Turek [17]	4.1±0.2	–	Microscope 2–10 h, 40°C, 2.5 NaOH, LR-115
Jonsson [1]	5.13	1.7±0.2	Holes visible in microscope 120 min, 59°C, 10% NaOH, LR-115
Present investigation	5.13	1.65	Visible in image analyzer 120 min, 59°C, 10% NaOH, LR-115

α-particles of different energies at normal direction using ^{241}Am point source using a varying distance collimator. The different energies used were 0.613, 1.65, 2.41, 3.024, 3.73, 3.88, 3.95, 4.19, 4.20, 4.40, 4.68, 4.76, 4.94, 5.13 and 5.30 MeV. Then the detectors were etched in 2.5 N NaOH for 120 min at 60°C and then washed using distilled water and viewed using Lieca image analyzer. We observed an etched breakthrough in the energy range from 1.6 MeV to 5.1 MeV. The results of this investigation and others from literature are listed in table 2.

5. Conclusion

A direct method to determine the bulk etching rate using a modern image analyzer has the facility of displaying the height position relative to a pre-focusing position by focusing on a nonetched detector. For the most frequently etching conditions for LR-115-II, 2.5 N NaOH at 60°C, we have found that the etching rate is 3.2 μm/h. The thickness of the removed layer is an important factor in all applications of α-particles detections where the track density increases linearly with the removed thickness.

The energy window for α-particles that could be detected by LR-115-II is 1.58–5.13 MeV for vertically incident beam α-particles according to our laboratory conditions. More theoretical investigation is needed to verify these experimental results.

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