Pitfalls in etch pit calculation

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Introduction

An etch pit is formed inside a Nuclear Track Detector (NTD) on chemical etching of a latent track marking the passage of a charged particle through the detector medium. When a charged particle passes through such a material, it leaves behind a narrow trail of ions and broken bonds. On being treated by a suitable chemical reagent, the damaged portion is etched out at a much faster rate, called the track etch rate (V_t), compared to the rate of etching of the undamaged portion, called the bulk etch rate (V_b). When the size of the etch pit increases to ~ μm it becomes visible under an optical microscope.

Experimental method

Generally there are two common methods people use while measuring the charge response parameter (V_t/V_b). V_t can be measured by finding from the etch-pit the track length inside the detector and dividing that by the time of etching *'t'*. V_b can be ascertained by finding the change in the thickness of an unexposed detector sheet when subjected to chemical etching for a given length of time.

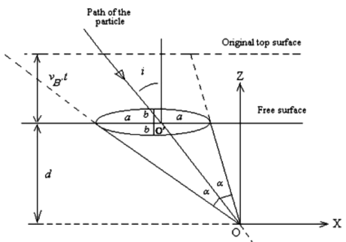

Fig. 1 Schematic diagram of an etch pit inside a detector.

Next V_t/V_b can be calculated using the formula:

$$p = \frac{V_t}{V_b} = \frac{OO'/t}{V_b} = \frac{d+V_b\times t}{V_b\times t\times cosi} \quad .....(1)$$

Alternatively (for a conical pit) [2,3]

$$i = cos^{-1}[\frac{1}{p}\frac{(1+E^2)}{(1-E^2)}] \quad .....(2)$$

$$p = \frac{V_t}{V_b} = \sqrt{1+\frac{4D^2}{(1-E^2)^2}} \quad .....(3)$$

where $D = \frac{a}{V_b\times t}$; $E = \frac{b}{V_b\times t}$

Observation

Using the first method we get the calibration curve displayed for a particular type of NTD, namely polyethylene terephthalate (PET). Here *dE/dx* values at the free surfaces are obtained from SRIM [4].

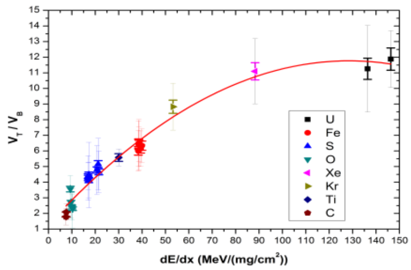

Fig .2 Calibration curve for PET using equation (1)

Ions	Energy of the incident ions (MeV)	Time[t] of etching (hr)	Major axis [2×a] (μm)	Minor axis [2×b] (μm)	$2\times V_b\times t$	V_t/V_b [From equation (1)]	V_t/V_b [From Equation (3)]
^{238}U	1724.5	2	7.89±0.06	7.54±0.07	2.1	11.89±0.7	1.63±0.08
	2641.8	1	3.90±0.06	3.71±0.07	2.1	11.3±0.7	1.55±0.07
^{56}Fe	129.8	3	7.71±0.06	6.82±0.04	6.3	6.4±0.03	28.8±4.1
	124	2	4.43±0.02	4.32±0.02	4.2	6.39±0.04	50.4±5.8
	113	3	6.97±0.06	6.12±0.06	6.3	6.13±0.04	43.9±6.3
	106.6	3	8.27±0.06	8.16±0.06	6.3	6.34±0.03	4.1±0.1
^{32}S	115.59	2	3.30±0.05	2.72±0.04	4.2	4.27±0.03	3.2±0.1
	113.03	1.83	2.15±0.05	1.78±0.05	3.84	4.46±0.06	1.77±0.04
	70.4	2	3.29±0.04	2.77±0.04	4.2	4.78±0.04	3.12±0.09
	67.37	1.83	3.23±0.03	3.12±0.02	3.84	5.16±0.04	5.4±1.7
^{16}O	22.4	3	2.9±0.1	2.8±0.1	6.3	2.3±0.1	1.55±0.07
	20.4	3	4.0±0.3	2.2±0.2	6.3	2.4±0.1	1.77±0.05
	18.3	3	2.8±1.1	2.7±1.1	6.3	2.7±0.1	1.50±0.06
	16.2	3	2.9±1.4	2.6±1.3	6.3	3.6±0.1	1.52±0.04
^{129}Xe	363.8	1	3.04±0.03	2.70±0.03	2.1	11.1±0.5	8.1±0.8
^{78}Kr	220	2	4.91±0.03	4.30±0.03	4.2	8.8±0.4	51.5±5.6
^{49}Ti	138.2	2	3.99±0.02	3.48±0.02	4.2	5.6±0.2	6.8±0.3
^{12}C	11	4	3.46±0.04	2.76±0.04	8.4	1.78±0.02	1.36±0.01

Table 1: Summary of the measured quantities in PET (Value = mean ± statistical error)

A summary of the measured quantities in PET is presented in the Table 1. Green /yellow /red colour signifies reliable /passable/ unacceptable value of V_t/V_b given by equation (3).

Conclusions

Although by using equation (3), one can easily get the value of 'p' at the surface by measuring the lengths of the major and the minor axis, we found that this formula can't be used blindly. For $p \geq 5$ we observe that $b>V_b\times t$ (so $E>1$); These etch pits cannot be conical in shape and the formula is not valid. Even for the other cases where $b \leq V_b\times t$, if the minor axis diameter is close to $2\times V_b\times t$, the value of 'E' becomes nearly equal to 1 and the denominator becomes almost equal to zero resulting in absurdly high values of V_t/V_b . The error (~ 1 μm) in the measurement of $2b$ in such cases make the value of $(1-E^2)$ and hence of V_t/V_b entirely unreliable.

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