Detection threshold of a SSNTD

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Introduction

Detection threshold of a solid state nuclear track detector (SSNTD) is the minimum value of (Z/β), where Ze is the charge and β (=v/c) the reduced velocity of a particle incident on the detector, for which a 'permanent' damage trail is produced by the projectile along its direction of motion. The damage trail can be 'developed' and made visible under a microscope by a suitable chemical reagent.

Motivation

For inorganic nuclear track detectors like mica, the 'ion explosion spike' model of Price and Fleischer [1] explains the main features of the tracks. In particular, they have established the role of tensile strength or Young's modulus (Y) in resisting the appearance of a permanent damage trail following the passage of a charged particle through such an inorganic detector. Their model leads one to conclude that materials with low Y and high electrical resistivity (ρ_e) are most suited for track formation. Polymers have very low values of Y, and it has more or less the same value for all kinds of polymers; but they have widely different value of ρ_e and detection thresholds. It is apparent, therefore, that, at least for polymers, $(Z/\beta)_{th}$ is essentially a function of ρe.Indeed, contrary to expectations based on Price and Fleischer's work, the detection threshold actually increases with ρ_e for polymers. In this paper, we describe an attempt to explain this feature and make some predictions.

From the Table.1 [2] it is clear that, as far as polymers are concerned, $(Z/\beta)_{th}$ is sensitively dependent on κ and ρ_e ; it also depends, rather weakly, on s. It is well-known that κ and ρ_e are related with each other. So our aim is to construct a dimensionless quantity (since $(Z/\beta)_{th}$ is dimensionless) out of ρ_e and s, and may be a few other 'innocuous' variables.

Note that $(Z/\beta)_{th}$ should increase with thermal diffusivity h (since higher h would result in quicker 'fading' of a track, when the plastic film is dipped in an etchant solution at a relatively higher temperature) and decrease with diffusivity D of charge carriers (as removal of the electrons, produced during track formation, from the vicinity of the track would help in the preservation of the track). Moreover h and D have the same dimensions viz. $[L^2\ T^{-1}]$. Hence h/D is a dimensionless quantity.

Thus we may expect

$$(Z/\beta)_{th} \sim f(\frac{h}{D})$$

f(x) being a monotonically increasing function of x. Now, from Einstein's mobility equation:

$$\frac{D}{\mu} = \frac{kT}{e},$$

whereμ is the mobility of electrons and other symbols are customary. Again

$$h = \frac{k_t}{\rho_m s},$$

In the absence of any other guiding conditions, we may try to compare the number densities of electrons in different polymers by comparing their average first ionization potentials. This average, over a monomer comprising of H, C, N and O atoms, can be found by multiplying the ionization potential of each element by its stoichiometric weight in the monomer and then

Name	ρ_m	Y	s	k_t	$\kappa=\varepsilon/\varepsilon_0$	ρ_e	$(Z/\beta)_{th}$
CR-39	1.32	2.1	2.3	0.21	13-14	2×10^{8}	6
Cellulose Acetate	1.30	2.4-4.1	1.45 –1.51	0.167-0.335	3.5-7.5	13×10^{12}	40
Lexan	1.20	2.2	1.26	0.195	3	$1\text{x}10^{17}$	57
PET	1.38	2.8-3.1	1	0.15-0.24	2.2	5×10^{18}	140-190
Perspex	1.19	3.21	1.4 – 1.5	0.17-0.19	3	6×10^{15}	?

Table 1: properties of transparent dielectrics

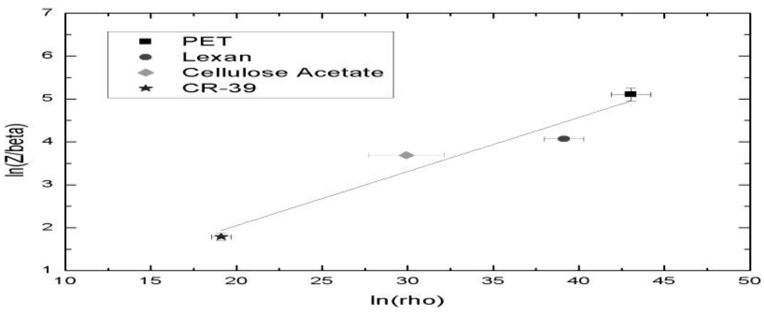

Fig. 1: A graph between $\ln(Z/\beta)_{th}$ vs. $\ln(\rho_e)$ for known plastics

taking the sum of these products over the elements. Consulting the values of the first ionization potentials of the elements, it is clear that the weighted average is around 13 eV for all the polymers.

Hence n appears to be nearly the same in all the plastics. Since ρ_m, s and k_t also vary only slightly from one plastic to another, we may conclude that $(Z/\beta)_{th} \sim F(\rho_e)$.

Conclusions

A simple guess would be $(Z/\beta)_{th} \sim (\rho_e)^q$

$\ln(Z/\beta)_{th} = q \ln(\rho_e) + c \pm q \ln 10$ (incorporating other factors). With the help of the graph, detection threshold $(Z/\beta)_{th}$ of perspex is predicted to be 78.

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