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EFFECT OF ETCHANT CONCENTRATION AND TEMPERATURE ON BULK ETCH RATE FOR SOLID STATE TRACK DETECTORS

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ABSTRACT

The dependence of the bulk etch rate on etchant concentration and temperature for solid state track detectors viz. sodalime glass, tektite, obsidian, lexan and CR-39 plastic is studied. It is found that the bulk etch rate for these detectors is described by the relation $V_B = \alpha C^n e^{-E_b/KT}$. The values of the exponent n and the parameter α for the detectors are calculated. The activation energy of etching for Lexan and CR-39 is 0.73 eV whereas its value for obsidian, sodalime and tektite is found to be 0.26, 0.33 and 0.42 eV respectively.

KEYWORDS

Solid state track detector; bulk etch rate; track etch rate; etchant concentration; activation energy; optimum etching.

INTRODUCTION

The etching of charged particle tracks is one of the most important phenomenon in particle detection by solid state track detectors (SSTDs). During the process of chemical etching, the etch rates - bulk etch rate, V_B and track etch rate, V_T, play a significant role in the development of latent tracks (Price and Walker, 1962; Fleischer and Price, 1964a; Khan and Durrani, 1972a; Somogyi and Szelay, 1973; Dwivedi and Mukherji, 1979). The knowledge of etch rates is highly useful as it considerably affects the etching efficiency $\eta = 1 - V_B/V_T$ of the detectors. The etch rates depend upon the following three factors: (i) temperature of the etchant (ii) concentration of the etchant and (iii) time of etching.

Etching is a diffusion process and hence temperature dependent. A simple exponential dependence of V_B on temperature T is given by the relation (Enge and co-workers, 1974; Sharma and co-workers, 1979);

$$V_B = Ae^{-E_b/KT} \tag{1}$$

where A is constant, E_b the activation energy for bulk etching and K, the Boltzman constant. Though this relation is being used frequently yet it does not include explicitly the effect of etchant concentration on the bulk etch rate. Thus the relation was modified by introducing one more parameter, concentration of the etchant, and is given by

$$V_B = \alpha C^n e^{-E_b/KT} \tag{2}$$

where C is the etchant concentration in normal and α is a proportionality constant. This relation has been found to hold good for CR-39 plastic detector (Somogyi and Hunyadi, 1979). The present study aims to generalise the effect of etchant concentration and temperature on V_B for different categories of

SSTDs.

EFFECT OF ETCHANT PARAMETERS

(a) Concentration. The dependence of V_B on concentration is studied for sodalime glass in our laboratory and for tektite, obsidian, Lexan and CR-39 plastics, the data published by other authors is used (Blanford and co-workers, 1970; Khan and Durrani, 1972; Najjar and co-workers, 1975; Enge and co-workers, 1975; Gruhn and co-workers, 1979). The plot of log V_B vs log C, for the detectors under reference, show the linear dependence of V_B on etchant concentration (Fig. 1). The value for the exponent n is calculated from the respective plots. Somogyi and Hunyadi (1979) obtained a V_B dependence on the 3/2 power of NaOH normality for CR-39, whereas we have found the exponent value 1.8. It is observed that the n-values are different for NaOH and KOH for the same plastic (Table - 1) from which we may conclude that KOH is more efficient etchant for plastic detectors.

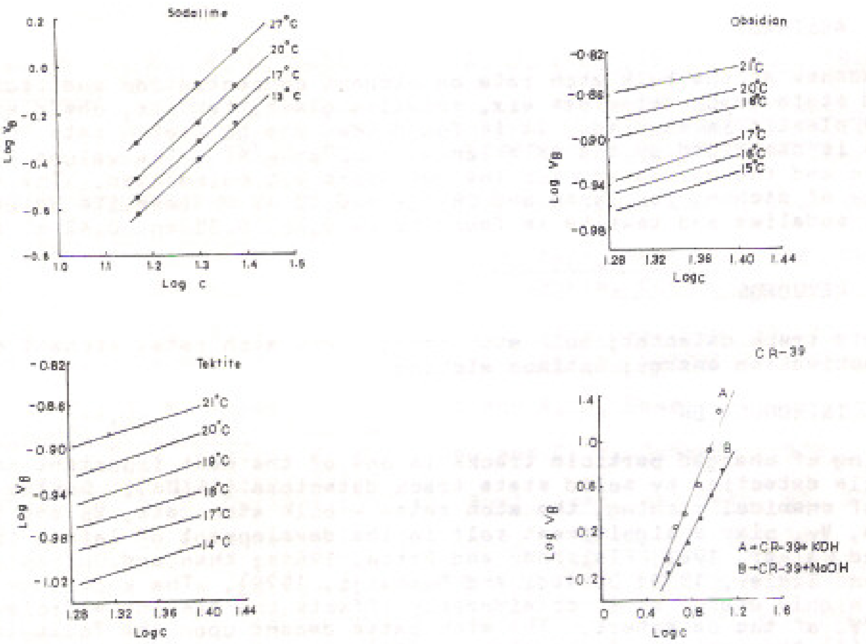

Fig. 1 Plots of log V_B vs log C at different etchant temperatures for sodalime, obsidian, tektite and CR-39.

TABLE 1 Activation energy, n-value and α-values for different detectors

Detector	Etchant	Activation energy (eV)	n value	α -value (μm/min.)
Sodalime	HF	0.33	1.80	1.177×10^{3}
Obsidian	HF	0.27	0.34	1.72×10^{3}
Tektite	HF	0.42	0.32	7.01×10^{5}
Lexan	NaOH	0.74	2.33	1.69×10^{9}
	KOH	0.73	2.46	2.55×10^{9}
CR-39	NaOH	0.73	1.80	2.86×10^{9}
	KOH	0.73	2.30	2.35×10^{9}

It is evident from n-value for glasses that the bulk etch rate in the soda-lime glass is nearly six times as compared to the rates in tektites and obsidian at the same etchant concentration and in agreement with the previous experimental results (Fleischer and Price, 1963; Fleischer and Price, 1964b; Fleischer and Price, 1964c). The experimental as well as calculated V_B using relation (2) for the detectors at different etchant concentration and temperatures are found to agree well.

The values for the proportionality constant α are determined. It is found that α -values lie between 1.69×10^9 and 2.86×10^9 μm/min for the plastic detectors. Somogyi and Hunyadi (1979) obtained an α -value $(8.2 \pm .04)10^{11}$ μm/h for CR-39 plastic detector. For glasses, α values are found to be 1.18×10^3, 1.72×10^3 and 7×10^5 μm/min in case of sodalime, obsidian and tektite respectively.

(b) Temperature. Log V_B vs 1/T plots (Fig. 2) give straight lines showing exponential dependence of V_B on temperature. The activation energy for the bulk etching of SSTDs is calculated from the respective plots. Activation energy for sodalime, tektite and obsidian glasses is found to be 0.33, 0.42 and 0.27 eV respectively. In case of Lexan and CR-39, the activation energy for bulk etching is calculated to be 0.73 eV for both the etchants, NaOH and KOH as reported by other authors (Enge and co-workers, 1974; Dwivedi and Mukherji, 1979; Najjar and co-workers, 1979). However, Somogyi and Hunyadi (1979) reported E_b value 0.88 eV for CR-39.

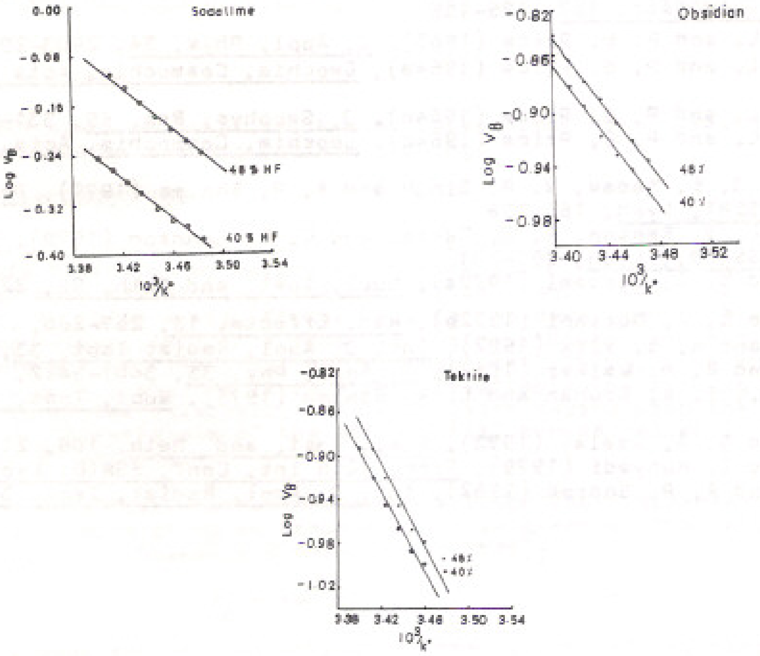

Fig. 2 Plots of log V_B vs 1/T at different etchant concentrations for sodalime, obsidian and tektite.

The parallelism of the plots, log V_B vs 1/T, at different etchant concentrations clearly indicates that activation energy is independent of the etchant parameters and hence a constant for the bulk material, a result in contradiction with that of Singh and Sharma (1982).

CONCLUSION

The present investigation proves that the bulk etch rate, V_B is a linearly increasing function of etchant concentration. It is found that V_B increases at a faster rate in sodalime glass as compared to tektites and obsidian for the same etchant concentration. However, in case of Lexan and CR-39 plastic detectors, V_B increases at the same rate with etchant concentration.

From this study, we may conclude that the activation energy of bulk etching is independent of the nature of etchant and its parameters like concentration and temperature. It is a characteristic of the bulk material and must remain constant.

The relation (2), in general, can describe explicitly the role of etchant concentration and its temperature for bulk etch rate of SSTDs, which may prove useful for obtaining optimum etching conditions for different SSTDs.

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