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ETCHING STUDIES OF FISSION DAMAGE IN QUARTZ

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ABSTRACT

Etching characteristics of fission fragment tracks in quartz have been studied using NaOH as the track etchant. The track etching efficiency of 87.9% has been observed corresponding to the etching temperature of 150°C. The activation energies for bulk and track etching have been found to be 0.43 eV and 0.22 eV respectively.

KEYWORDS

Etching; quartz; fission tracks; etch rate; activation energy.

INTRODUCTION

Etching studies of fission fragment tracks in quartz have been carried out in order to use it as Solid State Nuclear Track Detector. It has been observed that hydrofluoric acid (HF) is incapable to reveal the tracks satisfactorily on all the planes of the mineral (Nand Lal, Bal and Nagpaul, 1981). In the present investigations a more suitable track etchant viz. 65% NaOH has been employed for evaluating varicus etching parameters for quartz mineral. The samples were collected from the Dungarpur, Ajmer and Bhilwara districts of Rajasthan state (India).

EXPERIMENTAL TECHNIQUE

The quartz samples were fixed on glass slides, ground with emery powders of mesh size varying from 100 to 600 μm and were polished with cerium oxide powder. Final lap of polishing was given with 1 μm diamond paste on chamois leather. Polished samples were irradiated with fission fragments source (Cf^{252}) for 5 minutesin '2π' geometry and were etched with 65% NaOH using the reflux condenser assembly and a constant temperature bath. The track length and track diameter measurements in the Dungarpur samples were made at the etching temperatures of 150°C, 170°C, and 190°C for various intervals of time. For measurements, specific tracks were selected and marked. The bulk etch rate, V_G, was calculated from the slope of the curve, etching time versus track diameter.

The track etch rate V_T was calculated on the assumption that V_T remains constant for very small etching times, during which a small segment of particle trajectory is etched out (Fleischer, Price and Walker, 1975). The relation between the track etch rate (V_T) and the track length (L) for an etching time (t) is given by

$$L = \int_0^t V_T \, dt \qquad (1)$$

$$\text{or} \qquad V_T = \frac{\Delta L}{\Delta t} \tag{2}$$

The etching efficiency (η) was calculated from the relation

$$\eta = 1 - \frac{V_G}{V_T} \tag{3}$$

A few samples of quartz were prepared and etched in NaOH (65 %) at 170°C for three hours for counting fossil track density. Similar samples were irradiated with a dose of 10^{16}(nvt) thermal neutrons from CIRUS reactor of BARC, Trombay. The irradiated samples were etched under identical conditions as for fossil tracks and induced track density was determined by substraction method. Fission track age is estimated using the age equation (Virk and Koul, 1974):

$$T = 6.57 \times 10^9 \ln(1+9.25 \times 10^{-18} \times \frac{\rho_s}{\rho_i} \times \phi) \tag{4}$$

Where ρ_s and ρ_i are the fossil and induced track densities and ϕ is the total integral thermal neutron dose.

Uranium content in the samples was calculated using the relation (Nagpaul, 1974; Virk and Koul, 1975):

$$C_U = \frac{2m\rho_i}{R\phi INd} \quad \text{gm/gm} \tag{5}$$

$$C_U = 0.12 \times 10^2 \frac{\rho_i}{\phi} \quad \text{gm/gm} \tag{6}$$

Where the symbols have their usual meanings.

RESULTS AND DISCUSSION

The plot of track length and track diameter versus etching time is given in Figs. 1 and 2. The plot of bulk etch rate, V_G and track etch rate, V_T versus

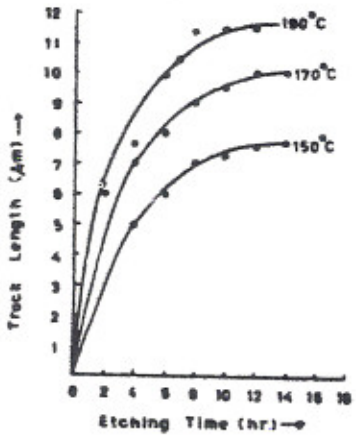

Fig. 1. The variation of track length with track etch time.

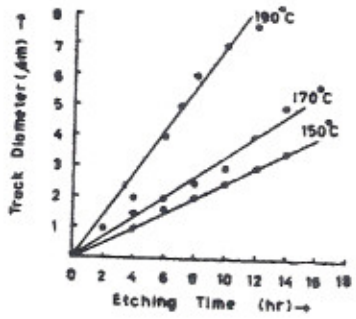

Fig.2. The variation of track diameter with track etch time.

etching temperature are shown in Figs. 3 and 4 respectively. It has been found that for the same concentration of the etchant (65%) NaOH both the bulk etch (V_G) and track etch (V_T) rates increase with etching temperature (Table-1).

TABLE 1. Variation of V_G, V_T and η with Temperature.

S.No.	Temperature (°C)	V_G (μm/hr)	V_T (μm/hr)	$\frac{V_G}{V_T}$	η (%)
1	150	0.125	1.031	0.021	87.9
2	170	0.170	1.380	0.123	87.7
3	190	0.350	1.670	0.209	79.1

However, the track etch efficiency (η) has been found to decrease with etching temperature. From Figs. 3 and 4 it is evident that the variation of V_G and V_T is exponential and may be expressed as

$$V = Ae^{-E/KT} \qquad (7)$$

Where V, is the etching rate; K, Boltzman constant; T, Temperature (°K); and E, activation energy.

The values of activation energies for bulk etching E_G and track etching E_T have been calculated from the slope of the curves (Figs. 3, 4). The activation energies for bulk etching and track etching have been found to be 0.43eV and 0.22eV respectively.

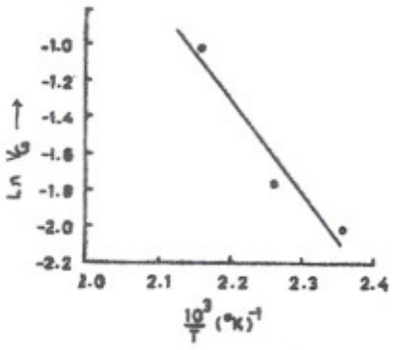

Fig.3.Plot of $\ln V_G$ vs $\frac{10^3}{T}$ (°K)$^{-1}$

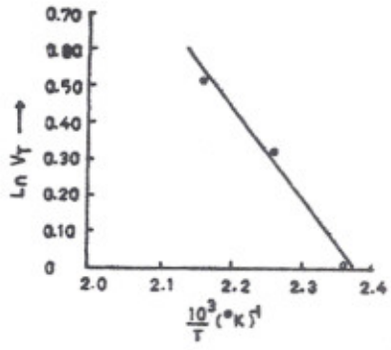

Fig.4. Plot of $\ln V_T$ vs $\frac{10^3}{T}$ (°K)$^{-1}$

Etching efficiency of 87.9 % is attained by using 65 % NaOH which is better than 72.4 % using HF (40 %) as etchant as reported earlier (Shi Lun Guo and coworkers, 1981). The fission track ages determined by using eqn.(4) for quartz (Tab.2)appear to be quite low as compered to f.t. ages of other minerals from the same

belt determined by other authors (Singh and Virk, 1978; Holmes, 1955). This disagreement may be due to the low value of uranium and its heterogeneous distribution in quartz (Dran and coworkers, 1976).

TABLE 2. Uranium Content and F.T. Ages in Quartz

Sample Location	Fossil Track density (ρ_s) $10^4 T/cm^2$	Induced Track density (ρ_i) $10^4 T/cm^2$	$\frac{\rho_s}{\rho_i}$	Age T(m.y)	Uranium content 10^{-10} gm/gm
Dungarpur	7.96	6.72	1.18	685	0.81 ± 0.05
Ajmer	1.84	3.76	0.49	289	0.45 ± 0.05
Bhilwara	0.40	4.72	0.08	48	0.57 ± 0.07

Total thermal neutron doze = 10^{16}(nvt)

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