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TRACK ANNEALING STUDIES IN SOME MICACEOUS MINERALS

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ABSTRACT

The annealing model proposed by S.K. Modgil and H.S. Virk (1984) for inorganic solids is tested for some micaceous minerals being used as track detectors. The results of annealing experiments carried out in the temperature range of 200°-700°C, on chlorite, biotite, muscovite and phlogopite are employed and it is found that the relation $V_a = At^{-n} \exp(-E_a/kT)$ is the best fit to the experimental data. The activation energy, E_a, and the values of constants n and A for these minerals are determined. The activation energy varies from 0.63 to 0.96 eV. It has been observed that the activation energy is independent of temperature.

KEY WORDS

Annealing rate, activation energy, micaceous minerals.

INTRODUCTION

The annealing of radiation damage in solid state track detectors have wide applications in diverse fields (Storzer and Wagner, 1969., Singh and Virk,1977). Different interpretations have been given for track density retention in solid state track detectors (Gentner et. al., 1969., Fleischer and Hart, 1970). Recently, Modgil and Virk (1984) proposed a three step annealing model which explains the annealing behaviour of radiation damage in the bulk material. The authors introduced the concept of a single individual track annealing and have found a linearly decreasing relationship between annealing rate and heating time. According to the proposed model, it is the annealing rate, V_a, and not the activation energy which varies with the temperature and time. In the present study, annealing experiments are carried out in order to check the validity of new model for micaceous minerals.

EXPERIMENTAL PROCEDURE

a) V_a dependence on temperature: Annealing of fission fragment tracks was carried out by heating the irradiated chlorite samples in a Muffle furnace at the temperatures 200, 300, 350, 400, 450, 475 and 500°C for 10 mins. at each temperature, successively. These samples were etched simultaneously with 40%HF for 5 min at 25°C after thermal annealing. Track length, L, was measured at each temperature.

Track annealing rate, V_a, is calculated using the relation:

$$V_a = \frac{dL}{dt} \qquad \ldots \quad (1)$$

assuming that V_a remains constant over the first 10 min of heating. Plot of

$\ln V_a$ vs $\frac{1}{T}$ (Fig. 1) shows an exponential dependence of V_a on the annealing temperature for chlorite. The annealing experiments were repeated for biotite, muscovite, and phlogopite samples over the temperature range from 200 to 450, 200 to 500 and 450 to 700°C respectively, using intervals of 50°C and heating time 10 min for each sample. Similar plots are obtained for these minerals (Fig. 1).

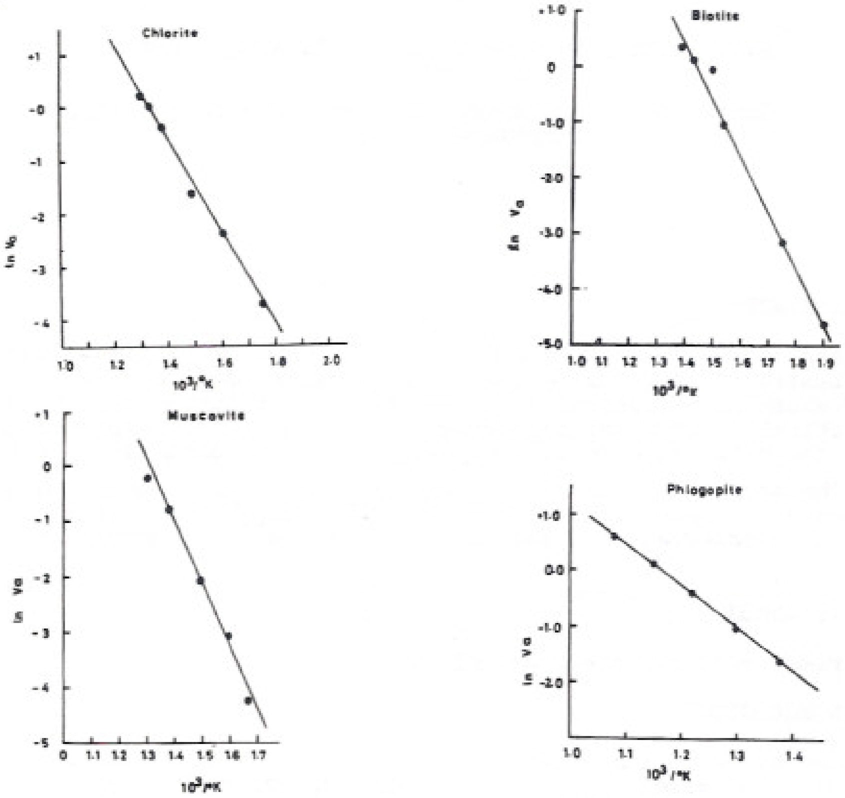

Fig. 1 Plots of $\ln V_a$ vs $\frac{1}{T}$ for chlorite, biotite, muscovite and phlogopite.

b) V_a dependence on annealing time: A few samples of chlorite, irradiated with Cf^{252} source, heated in a Muffle furnace at a temperature of 450°C for the intervals 10, 20, 30, 40, 50, 70, 90 and 120 min, successively. The annealing rate, V_a, is calculated for different durations of annealing.

The plot of $\log V_a$ vs $\log t$ is shown in Fig. 2. The annealing experiments are repeated for biotite, muscovite and phlogopite at temperatures of 425, 450 and 500°C respectively for the same heating intervals as for chlorite and similar plots are obtained (Fig. 2).

RESULTS AND DISCUSSIONS

We have used the following empirical relation:

$$V_a = At^{-n}e^{-Ea/kT} \quad \ldots \quad (2)$$

as a best fit to the experimental data. Where k is the Boltzman constant, T, the absolute temperature, A, the proportionality constant and n, the exponent of the annealing time, t. The values of A, n and Ea are calculated for these detectors from their respective plots and are summarized in Table 1.

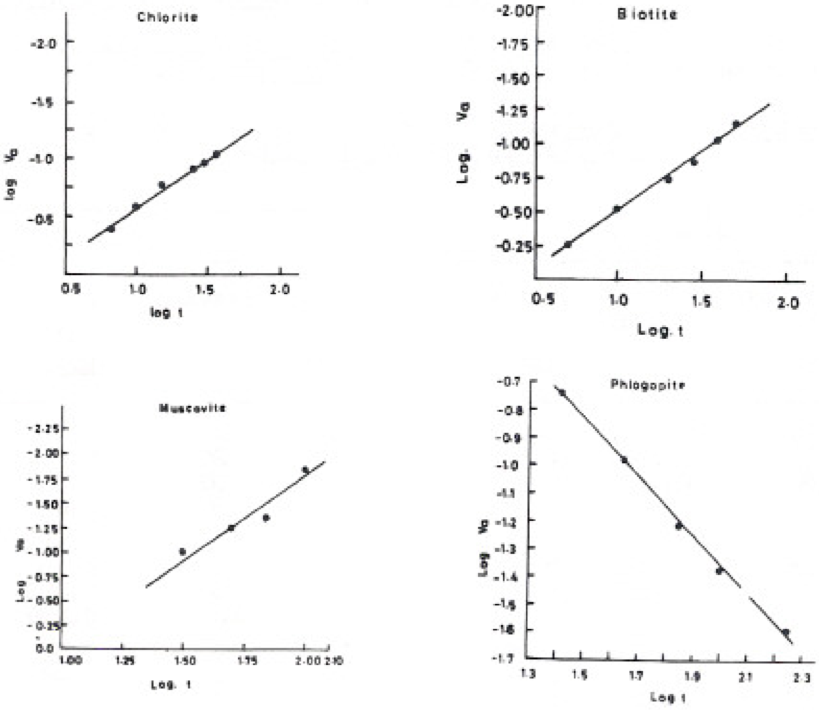

Fig. 2 Plots of log V_a vs log t for chlorite, biotite, muscovite and phlogopite.

TABLE 1 Activation energy for annealing, n-value and A-value for micaceous minerals

Mineral	Etchant	Activation energy of annealing(eV)	n-value	A-value (μm/min.)
Muscovite	HF	0.96	1.60	9.25×10^{7}
Chlorite	HF	0.78	0.84	1.31×10^{6}
Biotite	HF	0.82	0.91	9.78×10^{6}
Phlogopite	HF	0.63	1.00	5.35×10^{4}

The track annealing rate, V_a, is calculated for chlorite, biotite, muscovite and phlogopite using eq.(2) at different temperatures and heating times (Tables 2a, b). It is evident that the computed values of V_a for different detectors are in close agreement with the values obtained from the experimental data. Thus the proposed formula holds good for micaceous minerals also, and is capable of measuring annealing rate at a particular temperature and duration of annealing.

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TABLE 2a Annealing rate as a function of temperature and time in micaceous minerals

Muscovite				Chlorite			
Temp. (°C)	Heating time (min)	Annealing rate V_a(µm/min) Exp.	Cal.	Temp. (°C)	Heating time (min)	Annealing rate V_a(µm/min.) Exp.	Cal.
425	10	0.22	0.27	375	10	0.12	0.16
	30	0.04	0.05		20	0.086	0.09
	60	0.017	0.02		30	0.069	0.06
					60	0.032	0.036
375	10	0.07	0.08	425	10	0.41	0.44
	15	0.043	0.04		30	0.16	0.18
	20	0.017	0.014		60	0.092	0.098
					100	0.059	0.064
475	10	0.83	0.79	475	20	0.51	0.59
	20	0.28	0.26		30	0.48	0.41
	30	0.12	0.14		60	0.29	0.23
					100	0.12	0.15

TABLE 2b Annealing rate as a function of temperature and time in micaceous minerals

Biotite				Phlogopite			
Temp. (°C)	Heating time (min)	Annealing rate V_a(µm/min.) Exp.	Cal.	Temp. (°C)	Heating time (min)	Annealing rate V_a(µm/min.) Exp.	Cal.
375	10	0.47	0.50	500	25	0.188	0.185
	20	0.23	0.27		45	0.104	0.102
	30	0.21	0.19		70	0.059	0.065
	60	0.079	0.098		100	0.043	0.045
400	10	0.87	0.87		135	0.034	0.034
	20	0.41	0.47		180	0.027	0.026
	60	0.21	0.17				
	100	0.10	0.11				
450	30	0.97	0.85				
	60	0.41	0.45				
	75	0.29	0.37				
	100	0.24	0.28				