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ANNEALING OF HEAVY ION RADIATION DAMAGE IN MUSCOVITE MICA AND CONCEPT OF SINGLE ACTIVATION ENERGY

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Annealing behaviour of heavy ion radiation damage in muscovite is studied at different temperatures. The activation energies E_a for annealing of heavy ion tracks of different energies, viz. ^{93}Nb (18.0 MeV n^{-1}), ^{208}Pb (17.0 MeV n^{-1}), ^{238}U (10.0 MeV n^{-1}) and ^{252}Cf (fission fragments), are found to be the same (~0.97 eV). The concept of a single activation energy as an intrinsic property of the detector seems to be fully justified.

INTRODUCTION

At an early stage in the development of fission-track dating, Fleischer *et al.*[1] showed that, of various environmental parameters which could possibly affect the long-term stability of fission tracks, temperature is by far the most dominant factor. Since then a considerable number of laboratory annealing studies have been made of the stability of fission tracks in a variety of minerals and glasses.[2-6] A number of models[7-11] have been proposed to explain the annealing mechanism as a function of both annealing time and temperature. Previous fission track annealing studies have described the reduction in fission-track density in terms of a series of fanning lines on an Arrhenius plot. This has been interpreted in terms of a range of activation energies corresponding to different degrees of annealing. Mark *et al.*[12] proposed that the annealing of fission tracks in apatite can be explained by a summation series of exponential decay functions. They observed different activation energies corresponding to different ranges of temperature. However, they also argue that a single activation energy is sufficient for the quantitative description of the annealing process at sufficiently high temperatures. Dartyge *et al.*[8] suggested that radiation damage in a given solid state nuclear track detector (SSNTD) consists of both the point and extended defects and hence there are two different activation energies for annealing of the two types of defects. Gold *et al.*[9] developed a general reaction rate theory for the annealing process in SSNTDs. The limitations of these models are discussed elsewhere.[10]

Modgil and Virk[10] postulated a three-step annealing model which explains the annealing behaviour of radiation damage in bulk materials. The authors favoured the concept of a single activation energy of track annealing and proposed an empirical formula:

$$V_a = At^{-n} e^{-E_a/kT}, \tag{1}$$

where V_a is the annealing rate, i.e., the rate of change of track length 'l' given by dl/dt; A is the proportionality constant; k is the Boltzmann constant; T and t the annealing temperature and annealing time respectively; E_a the activation energy of annealing and n is the exponent of annealing time, t. According to the proposed model it is the annealing rate V_a and not the activation energy which varies with temperature and time. Recently, Green *et al.*[11] have also formulated the concept of single activation energy based on the results of annealing experiments on apatite.

The present study was undertaken to test the application of our model to the annealing of radiation damage produced by heavy ions in muscovite detector.

EXPERIMENTAL PROCEDURE

Different sets of samples were prepared from muscovite detector collected from Nansa mine, Rajasthan, India. These sets were exposed to ^{93}Nb (18.0 MeV n^{-1}),

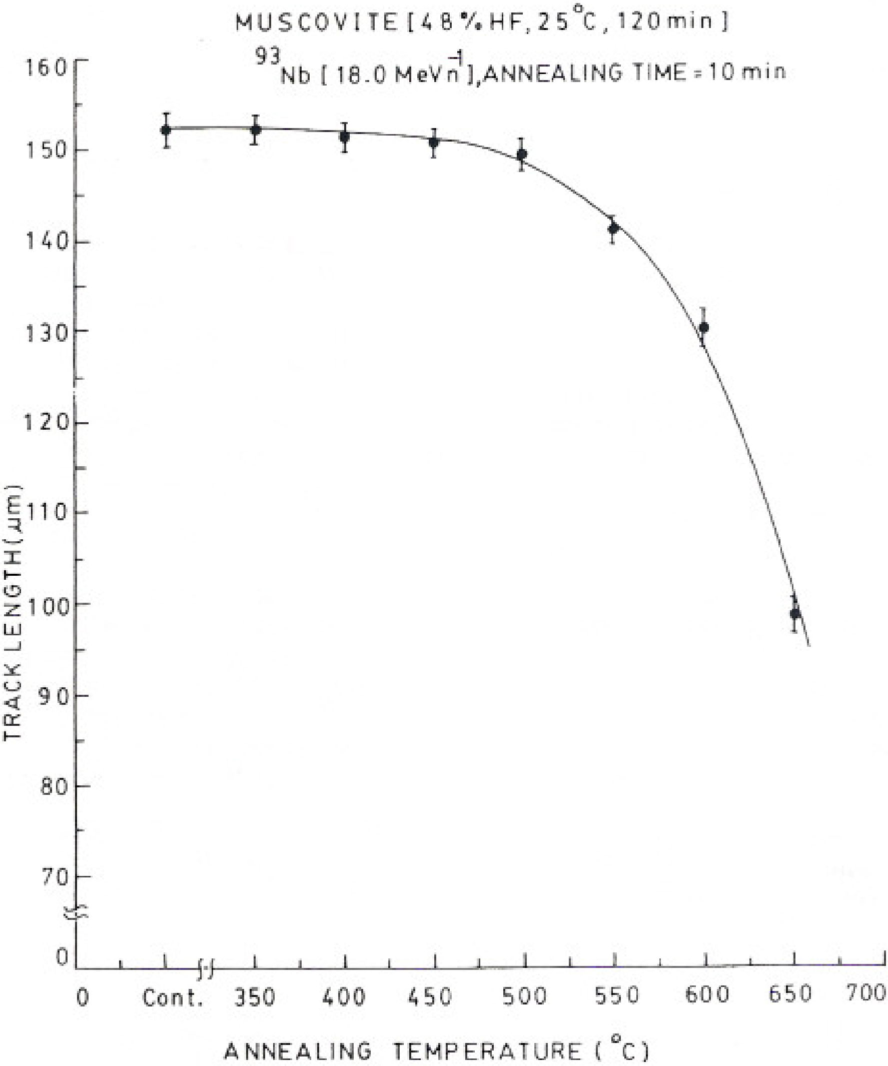

FIGURE 1 The variation of mean length of ^{93}Nb ion tracks with annealing temperature in muscovite.

^{208}Pb (17.0 MeV n^{-1}), and ^{238}U (10.0 MeV n^{-1}) ion beams obtained from the UNILAC accelerator at GSI, Darmstadt, West Germany. The incidence angle of beams with respect to the detector surfaces was fixed at 15°. A few samples were also irradiated with fission fragments from ^{252}Cf source at 15° angle of incidence. The irradiated samples were heated in a muffle furnace at temperatures ranging from 350 to 700°C. The annealed and unannealed reference samples were then etched with 48% HF at 25°C. Track lengths were measured with a Carl Zeiss binocular microscope (Figure 1). A plot of ln V_a vs. $1/T$ (Figure 2) shows an exponential dependence of V_a on the annealing temperature for muscovite, following Eq. (1).

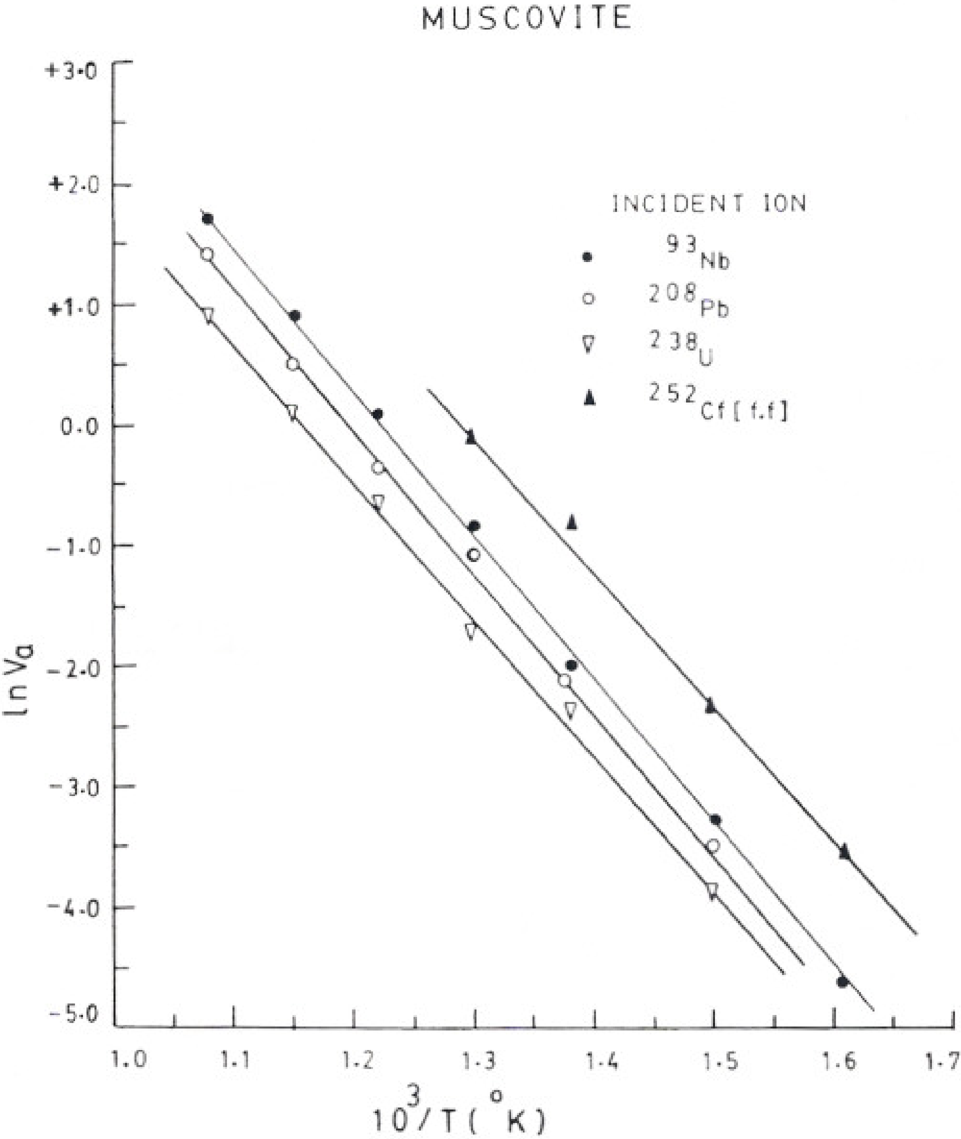

FIGURE 2 Plot of ln V_a vs. $1/T$ for ^{93}Nb, ^{208}Pb, ^{238}U and fission fragment tracks in muscovite.

RESULTS AND DISCUSSION

The experimental data on annealing of heavy ion tracks in muscovite fully satisfies the empirical relation proposed by Modgil and Virk.[10] The values of activation energies as deduced from the respective plots of ln V_a vs. $1/T$ are given in Table 1.

TABLE 1
The values of activation energy in muscovite using different ion beams

Incident ion	Activation energy E_a(eV)
^{93}Nb (18.0 MeV n^{-1})	0.98
^{208}Pb (17.0 MeV n^{-1})	0.98
^{238}U (10.0 MeV n^{-1})	0.97
Fission fragments (^{252}Cf)	0.96

It is interesting to note that all categories of heavy ions, even of different beam energies, yield almost identical values of the activation energy of annealing. This shows that the minimum energy required to start the annealing process in muscovite is independent of the nature and energy of the track-forming ion. This further supports the proposed model that the activation energy of annealing of radiation damage is a characteristic property of the detector material.

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