Radiation Measurements 46 (2011) 722–725

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Technical report

Anisotropy of track revelation in epidote: Results of a step etching experiment with ^{86}Kr ion tracks

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A R T I C L E I N F O

Article history:
Received 29 October 2009
Received in revised form
29 April 2011
Accepted 7 June 2011

Keywords:
Epidote
Anisotropy
Step etching
Ion tracks

A B S T R A C T

Epidote etching anisotropy has been studied through step etching of ^{86}Kr (300 MeV) ion tracks. A slice of epidote natural monocrystal was taken from the (010) plane and then divided into five pieces. Each piece was then irradiated with ions whose incidence angles (zenith angles) were of 15°, 30°, 45°, 60° and 75° with respect to *y*-axis. The azimuthal angle of incidence of the ions was the same for the pieces 15°, 60°, 75° and 180° apart for the pieces 30° and 45°. Etching times were of 10, 20, 30, 40 and 50 min (HF 40%, 35 °C). The results show that etching velocities of ion tracks are higher in directions closer to the *y*-axis. The mean lengths of the ion tracks, regarding the angles, were of 23.14 ± 0.21 (15°); 19.89 ± 0.08 (30°); 19.39 ± 0.04 (45°) and 16.59 ± 0.10 μm (60°). Since no tracks were identified in the 75° aliquot it was assumed that the epidote has a critical angle, for recording of ion tracks with this mass/energy ratio, between 60° and 75°.

1. Introduction

Little is known about the epidote fission track etching anisotropy. In the literature only the work presented by Bal et al. (1982) dealt with the subject. The referred authors performed step etching of ^{238}U spontaneous fission tracks and of implanted ^{252}Cf fission tracks in different epidote faces ((010), (100), (001), ($\bar{1}$02)). The results indicate that the track etching is isotropic for tracks contained in the (100) and (010) planes, and strongly anisotropic for tracks contained in the (001) and ($\bar{1}$02) planes. In the present work an epidote face (010) was irradiated with ^{86}Kr ion tracks at different incidence angles. The ion tracks were then step etched and characteristics such as track length, etch pit size, and density were measured.

2. Experimental procedure and results

The epidote presents itself as a monoclinic crystal (Fig. 1). A natural epidote monocrystal from the Brejuí mine, Rio Grande do Norte State – Brazil, was sliced in the (010) plane and polished on both sides. Afterwards the sample was submitted to a temperature of 750 °C for 24 h in order to erase its fossil tracks. The epidote slice was then gently broken in 5 smaller pieces which, on their turn, were fixed on a glass support in order to preserve the same azimuthal angle of irradiation for all of them. The ion irradiation was performed at the Ionen-Strahl-Labor (ISL), Hahn-Meitner Institut (HMI), Berlin. The utilized ion was ^{86}Kr with energy of 300 MeV and ion nominal fluence of 3×10^5 ions cm^{-2}. This ion was chosen because it is representative of the light fragment peak of the fission mass distribution. The 300 MeV energy was the smallest available ion energy. To avoid straggling, and with it the lack of control about the angle with which the ions entered the mineral surface, energy moderators were not used. Even though the light fragment energy is around 100 MeV, the formed track can be interpreted as being composed of two parts: one of them due the ion energy deposition when its energy is above 100 MeV and another when it is below 100 MeV. In the latter one the Kr ion shall behave like a fission fragment. Incidence angles (zenith angles) were 15°, 30°, 45°, 60° and 75° with respect to the normal to the plane. Owing to a misplacement during ion irradiation the azimuthal angle of incidence of the ions was the same for the pieces 15°, 60°, 75° and 180° apart for the pieces 30° and 45°. This azimuthal difference can be seen by analysing the angles between the etch pits and track channels in Fig. 2.

The etching of the tracks was performed with HF 40%, 35 °C, being all the samples etched concomitantly. A step of 10 min was used for etching. Samples were etched until total etching time was 50 min Fig. 2 illustrates the track characteristics for 50 min etching time. No tracks were found in the 75° aliquot. For each etching time

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[1] In memoriam.

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doi:10.1016/j.radmeas.2011.06.021

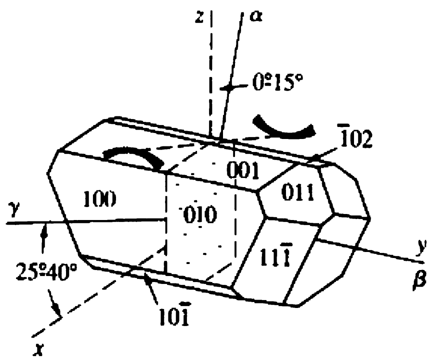

Fig. 1. Epidote crystallographic planes (Figure altered from Deer et al., 1986).

and incidence angle there were measured: the projected length of the tracks (p), the etch pit size (m) and the density of tracks (d). The projected length of the tracks (p) was defined as the distance between the end of the track inside the mineral and the farthest etch pit vertex (Fig. 2c). The etch pit size (m) was defined as the distance between its farthest vertices, since it presents itself as an irregular parallelogram (Fig. 2b). Due to the known energy and angle of incidence, 30 projected tracks were sufficient to characterize the parameters p and m. To characterize the density 50 fields were measured to each angle/etching time. The samples were measured with the aid of a Zeiss Axioplan 2 microscope, with nominal magnification of 1000×. The results can be seen in Table 1 and Figs. 3–6. Since the projected length of the tracks was influenced by the size of the etch pit (p definition), it was necessary to correct the projected length. The correction was made by taking the mean size of the etch pit and measuring the angle between the etch pit axis and the track length axis. This angle was determined by using a protractor and printed pictures of the tracks. The length of the projected tracks corrected for the etch pit influence was denominated (p_{corr}). The "real" length (l) of the ion tracks is given by projected length (p_{corr})/sin θ, where θ is the incidence angle of the ion. Also the density of tracks depends on the angle of irradiation since the flux of ions through the sample changes with the angle. The flux corrected density of tracks (ρ) is given by $d/\cos\theta$.

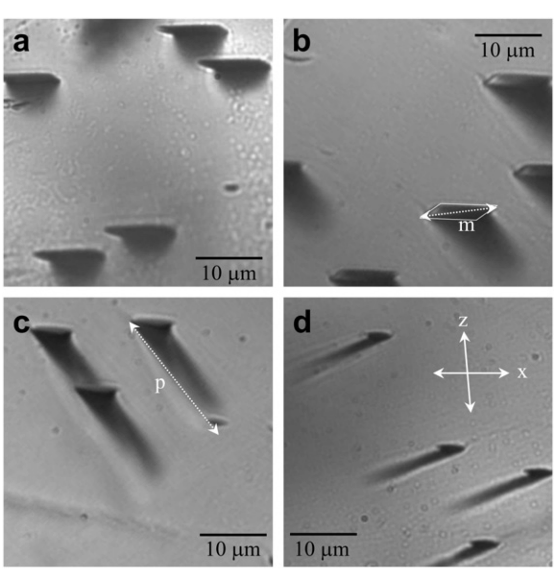

Fig. 2. ^{86}Kr (300 MeV) ion tracks for 50 min etching time. Incidence angles with respect to the y-axis (a) 15°, (b) 30°, (c) 45° and (d) 60°. p – projected length of the ion tracks; m – etch pit size. Crystallographic axes orientations are the same for (a–d).

Table 1
Experimental results. p – projected length of the ion tracks, p_{corr} – projected lengths corrected for etch pit (vide text), l – real length of the tracks, m – etch pit size, d – measured density of tracks, r – flux corrected density of tracks.

	10 min				20 min				30 min			
	15°	30°	45°	60°	15°	30°	45°	60°	15°	30°	45°	60°
p (μm) ± 1σ	5.24 ± 0.05	8.23 ± 0.11	10.27 ± 0.07	6.61 ± 0.29	5.95 ± 0.10	11.18 ± 0.10	13.92 ± 0.12	10.21 ± 0.03	5.95 ± 0.09	12.16 ± 0.09	15.24 ± 0.02	14.80 ± 0.11
p_{corr} (μm) ± 1σ	5.24 ± 0.05	7.46 ± 0.10	9.92 ± 0.07	6.61 ± 0.29	5.95 ± 0.10	9.84 ± 0.09	13.21 ± 0.11	9.55 ± 0.03	5.95 ± 0.09	10.12 ± 0.08	14.14 ± 0.02	13.87 ± 0.10
l (μm) ± 1σ	20.23 ± 0.19	14.92 ± 0.20	14.03 ± 0.10	7.63 ± 0.33	22.97 ± 0.39	19.68 ± 0.18	18.68 ± 0.16	11.03 ± 0.03	22.97 ± 0.35	20.24 ± 0.16	20.00 ± 0.03	16.02 ± 0.12
m (μm) ± 1σ	2.01 ± 0.02	1.89 ± 0.04	0.97 ± 0.02	–	4.16 ± 0.03	3.29 ± 0.04	2.00 ± 0.01	1.56 ± 0.02	6.62 ± 0.09	5.09 ± 0.01	3.15 ± 0.05	2.19 ± 0.05
d (tracks/field) ± 1σ	2.90 ± 0.22	3.40 ± 0.28	2.00 ± 0.21	0.40 ± 0.15	3.06 ± 0.28	3.44 ± 0.24	1.88 ± 0.16	1.52 ± 0.19	2.90 ± 0.23	3.36 ± 0.23	2.08 ± 0.19	1.62 ± 0.21
ρ (tracks/field) ± 1σ	2.99 ± 0.23	3.91 ± 0.32	2.83 ± 0.30	0.80 ± 0.30	3.15 ± 0.29	3.95 ± 0.28	2.66 ± 0.23	3.04 ± 0.38	2.99 ± 0.24	3.86 ± 0.26	2.94 ± 0.27	3.24 ± 0.42

	40 min				50 min			
	15°	30°	45°	60°	15°	30°	45°	60°
p (μm) ± 1σ	6.32 ± 0.08	12.61 ± 0.09	15.18 ± 0.06	15.92 ± 0.23	5.71 ± 0.11	13.22 ± 0.07	15.12 ± 0.06	16.71 ± 0.13
p_{corr} (μm) ± 1σ	6.32 ± 0.08	9.85 ± 0.07	13.63 ± 0.06	14.37 ± 0.21	5.71 ± 0.11	9.86 ± 0.05	13.35 ± 0.05	14.86 ± 0.12
l (μm) ± 1σ	24.40 ± 0.31	19.70 ± 0.14	19.28 ± 0.08	16.59 ± 0.24	22.05 ± 0.43	19.72 ± 0.10	18.88 ± 0.07	17.16 ± 0.14
m (μm) ± 1σ	8.92 ± 0.10	7.02 ± 0.05	4.51 ± 0.08	3.69 ± 0.06	11.07 ± 0.12	8.71 ± 0.08	5.20 ± 0.02	4.43 ± 0.07
d (tracks/field) ± 1σ	3.20 ± 0.22	3.40 ± 0.28	1.68 ± 0.20	1.58 ± 0.20	3.20 ± 0.24	3.26 ± 0.25	1.82 ± 0.18	1.66 ± 0.18
ρ (tracks/field) ± 1σ	3.30 ± 0.27	3.91 ± 0.32	2.38 ± 0.28	3.16 ± 0.40	3.30 ± 0.25	3.75 ± 0.29	2.57 ± 0.25	3.32 ± 0.36