THIN-LAYER ETCHING AND TRACK PARAMETER MEASURING TECHNIQUE FOR HEAVY AND SUPER-HEAVY GALACTIC COSMIC RAY NUCLEUS FLUX REGISTERED IN PALLASITE OLIVINE CRYSTALS

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Introduction

In frame of OLIMPIA project [1] there was studied a charge spectrum of high energy galactic cosmic ray (GCR) nuclei registered in iron-nickel matrix of Marjalahti and Eagle Station pallasite olivine crystals [2]. The nucleus deceleration traces are registered in olivine crystals as chemically etched tracks. The nucleus charges are identified on the current experiment stage by two parameters: a measured segment of track-etch length (L) and corresponding track-etch rate (V_{tr}). In the presented paper the results of experimental analysis of identified charge values (Z) in dependence of quantities L and V_{tr} for different track segments are discussed.

Method

In the procedure of the super-high nucleus track geometrical parameter measuring in 1-2mm olivine crystals it is very important to fix accurately coordinates of the initial and finite points of track-etch length. The precise measurements of L were held on completely automated complex PAVICOM [3].

In first approximation geometrical shape of chemically etched track of a heavy charged particle looks like a “syringe” consisting of two main segments: cylindrical or base one with diameter D_{base} slightly varying along the segment length and needle or cone one with diameter d_{cone} decreasing from value $d_{cone,RR}$ corresponding to the nucleus residual range (RR) to ~ 0 in the initial point of track etched zone (see fig.1).

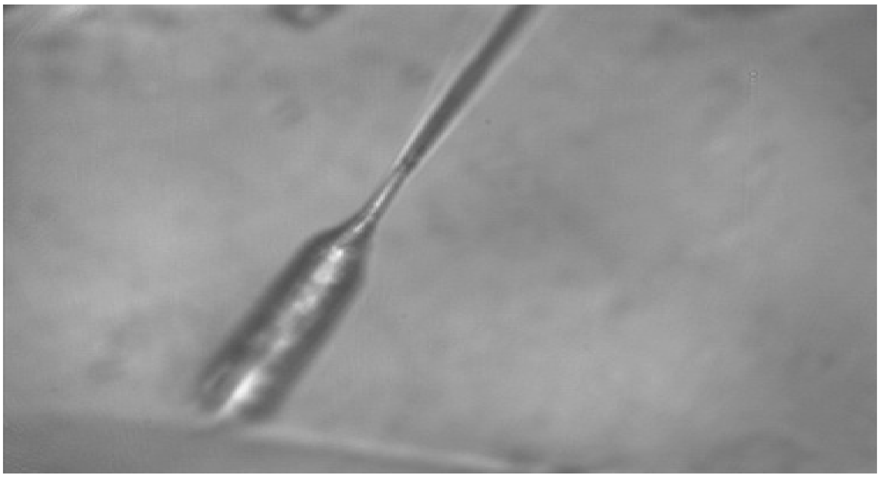

Fig.1. Track of high-energy galactic cosmic ray nucleus registered in the Marjalahti pallasite olivine crystal after 48 hour etching in WN solution.
Photo size ~ (150 × 300) μm.

Chemical etching of olivine crystals packed in epoxy resin tablet was held in modernized WN solution with addition of NaOH up to pH = 8.6 ± 0.1 in hermetically closed steal vessel with interior teflon tumbler under temperature 110 ± 1 ºC. The etching time intervals were chosen according to total time for VH nuclei (23 < Z < 28) full track length (RR_{base} = 15μm) etching (t ~ 4 hours) and to time for VVH nuclei (30 < Z < 40) track length (RR_{base}= 50 – 70 μm) etching (t ~ 8 hours). Consequently, minimum etching time required for detecting on the crystal surface tracks with R ≥ 100 μm corresponding to nuclei with Z ≥ 50 is t ~ 10-12 hours. Our investigations included three consecutive stages of etching: I – 12 hours, II – 12 hours and III – 24 hours, what means general etching time for the stages I – 12 hours, II – 24 hours and III – 48 hours. Simultaneously on every etching stage the following consecutive actions are fulfilled: (1) chemical etching of the newly polished surface; (2) removing of 8 ± 2 μm layer with high density of short-path tracks of GCL VH nuclei; (3) scanning and measuring of geometric parameters of long-path tracks. Then according to the detected track lengths a layer of definite thickness is removed from the etching surface by method of plane-parallel grinding. The following dependences for the removed layer thickness h were experimentally discovered: a) while the h value increases from ~20 to ~50mkm essentially decreases the registration efficiency η of tracks from nuclei with $30 \le Z \le 36$; b) at h = 50-100 μm η for tracks from nuclei with Z up to 40 decreases and several times increase errors of the track-etch lengths for nuclei with $Z \ge 50$.

The obtained data permitted to find the optimal conditions for step-by-step grinding, etching and track parameter determination. Measured differential volume density of the nucleus tracks gives the value of GCL heavy and super-heavy nuclei flux.

Results

Cosmic ray exposure time of the Marjalahti pallasite is ~ 175 million years. That is why in its olivine crystals the density of rear GCR nuclei with Z > 50 is rather high. There are about $10^3 - 10^4$ nuclear tracks with L > 100 μm per 1 cm^3 in olivine grains arranged ~ 6 cm deep from meteoroid pre-atmospheric surface. The high density allows to carry out statistically sufficient measurements of nuclear track characteristics by means of consecutive step-by-step chemical etching.

Results of experimentally measured track lengths L and calculated values of track-etch rates V_{TR} and nucleus charges Z of some characteristic events from 500 analyzed tracks are presented in table 1.

Table 1

Track-etch lengths L and track-etch rates V_{TR} of tracks registered in olivine crystals and consecutively etched for 12-48 hours

№	t_I = 12 hour			t_{II} = 12+12 hour			t_{III} = 12+12+24 hour		
	L	V_{TR}	Z	L	V_{TR}	Z	L	V_{TR}	Z
1	115.8	9.7	67	152.0	6.3	67	178.0	3.7	67
2	156.3	13	72	192.4	8.0	71	210.0	4.4	71
3	131.2	10.9	69	160.4	6.7	68	183.0	3.8	68
4	134.5	11.2	70	162.6	6.8	68	173.9	3.6	67
5	139.8	11.7	71	170.3	7.1	69	193.4	4.0	69
6	122.2	10.2	68	144.3	6.0	66	127.9	2.7	61
7	98.6	8.2	64	150.0	6.3	67	195.4	4.1	70
8	112.8	9.4	66	145.1	6.1	66	255.8	5.3	73
9	104.0	8.7	64	155.8	6.5	67	180.3	3.7	68
10	129.9	10.6	69	210.6	8.8	73	284.9	5.9	76
11	132.1	11	70	159.0	6.6	68	285.3	5.9	76
12	102.5	8.5	64	173.2	7.2	70	179.5	3.7	68

* Results for tracks with L ≥ 100 μm after 12 hour of etching are presented.

On the assumption of calibration experiments the results given in the table permitted to determine nucleus charges Z. One of advantages of the method is an opportunity of independent determination of Z on each short-time etching period. Some characteristic examples of step-by-step charge identification variations are presented in fig. 2.

The figure shows that all the measured tracks can be subdivided in at least four groups: (1) – Z value remains constant through all the etching process; (2) – Z varies within ±(2-3) charge units; (3) – Z increases by 5-7 charge units and (4) – Z variation changes from increase to decrease and vice versa. For the analyzed tracks the groups include 36%, 41%, 4% and 19% of events respectively.

Conclusions

Experimental investigations and data analysis of consecutive etching of long-path (L > 100 μm) nucleus tracks in Marjalahti pallasite olivine crystals showed that:

In process of GCR super-heavy nucleus charge identification on base of parameters L and V_{TR} of chemically etched tracks the following cases are observed: (1) practically constant nucleus charge value Z varying in limits not more than $\Delta Z = \pm 1$ charge units; (2) Z varies in limits of $\Delta Z = \pm$ (2-3) charge units; (3) Z increases by $\Delta Z = \pm$ (3-10) charge units and (4) Z increases-decreases (or vice versa) in limits of $\Delta Z = \pm$ (3-5) charge units.

The difference in character of the identified charge variations for tracks etched with different V_{TR} at constant time intervals must be explained by etching of different sections of detected track on corresponding etching stage. As the rate V_{TR} on etched track interval RR_{base} varies by an order of magnitude it brings to following variation of the identified Z value.

Taking into account all the above, investigation of GCR nuclear composition must include: (a) a consecutive determination of track parameters L and V_{TR} determined on each of 12 hour stage of etching; (b) as a final value of identified nucleus charge the maximum quantity Z_{max} through all the etching stages must be taken.

Further calibration experiments with accelerated nuclei for more detailed study of relationship between parameters L, V_{TR} and one more substantial geometrical parameter – diameter of etched channel of nuclei for different charges and energies – would allow to identify charges of GCR nuclei detected in meteorite olivine with more accuracy.

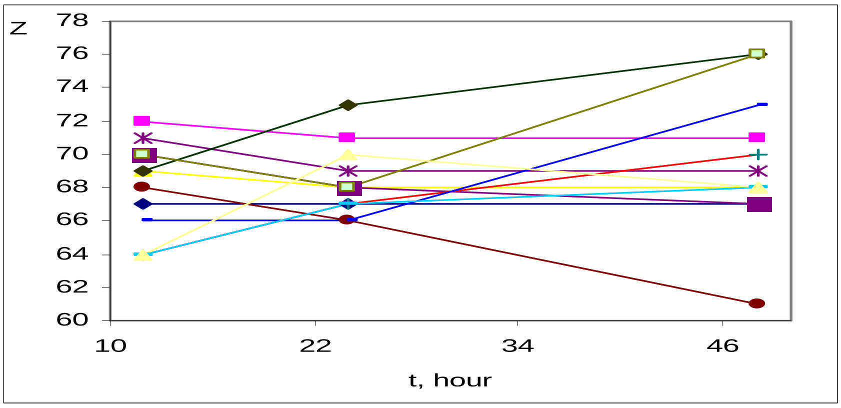

Fig.2. Variations of measured nucleus charges determined by track parameters L and V_{TR} obtained during consecutive 12-48 hour etching

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