ON THE PROBLEM OF THE GALACTIC COSMIC RAY NUCLEI CHARGE IDENTIFICATION IN OLIVINE CRYSTALS FROM PALLASITES

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Introduction

Track method for the super-heavy ($Z > 30$) galactic cosmic ray (GCR) nuclei charge identification is based on experimental relation between the track-etch rate (V_{tr}) along the nucleus deceleration track and its residual range (RR) [1]. Study of the charge composition of GCR over the range $50 < Z < 92$ is one of the problems considered in frame of OLIMPIA project [2]. The publication briefly presents main principles of the approach worked out for GCR nucleus charge identification and some preliminary results of GCR composition determination.

Method for GCR nucleus charge identification

One of distinctions of the "syringe" geometrical shape of chemically etched tracks from high-energy ($E > 100$-200 MeV/nucleon) nucleus is the presence of at least four characteristic distinguished zones [3]. They are: I – a narrow cone zone (the "syringe" needle) formed from the energy $E_{cone,max}$ (corresponding to the maximum energy value in the energy specific loss region $(dE/dx) > (dE/dx)_{crit}$) to the energy $E_{cone,min}$; II – a zone of sharp transition from cone to base section of the track when on a rather short (about several microns) track length segment (interval $RR_{cone,min} - RR_{base,max}$ at nucleus energies $E_{cone,min} - E_{base,max}$) the track-etch rate sharply increases; III – a base track section looking like a hollow cylinder ("syringe" cylindrical segment) and IV – a zone symmetrical to zone II and looking like a short track section with a sharp transition from base zone to the track stop point. As the values of track-etch length and the described zone diameters quite differ it is reasonable to expect the corresponding variation of the track-etch rate along their lengths caused by efficiency of matter removal from the radiation disordered zone of olivine crystal lattice. Experiment measurements on completely automated complex PAVICOM [4] allowed to distinguish accurately the transition borders between each two zones of etched tracks and showed that relation between mean diameters of the main (D) and the cone (d) track zones for nuclei with $Z > 50$ equals $D/d = (3 \div 5)$.

Now only several experiments on determination of relationship between values of V_{tr} and RR are known for nuclei U ($E = 150$ MeV/nucleon) [5], Xe and Kr, including the data obtained in OLIMPIA project for the accelerated nuclei Kr, Xe, and U with energy $E = 11.4$ Mev/nucleon. On fig. 1 and in tab. 1 and 2 there are shown results of this experimental research giving V_{tr} and RR values for different high-energy nuclei. Moreover, in tab. 2 there are presented values of track-etch length L_{Vtr} for each nucleus at definite V_{tr}.

Table 1

Track-etch rate (Vtr) for accelerated Kr, Xe, U and Fe GCR nuclei from Marjalahti pallasite olivine crystals

Ion	E, MeV/nucleon	V_{TR} (μm/h) at RR (μm)				
		15 ± 5	25 ± 5	40 ± 10	60 ± 10	80 ± 10
Fe	>5	4 ± 2	~0.1	~0.05	–	–
Kr	10.2	10 ± 2	7 ± 2	2 ± 1	~0.1	–
Xe	11.4	14 ± 3	12 ± 3	11 ± 2	8 ± 2	≤1
U	11.4	27 ± 5	28 ± 5	26 ± 5	27 ± 5	26 ± 5

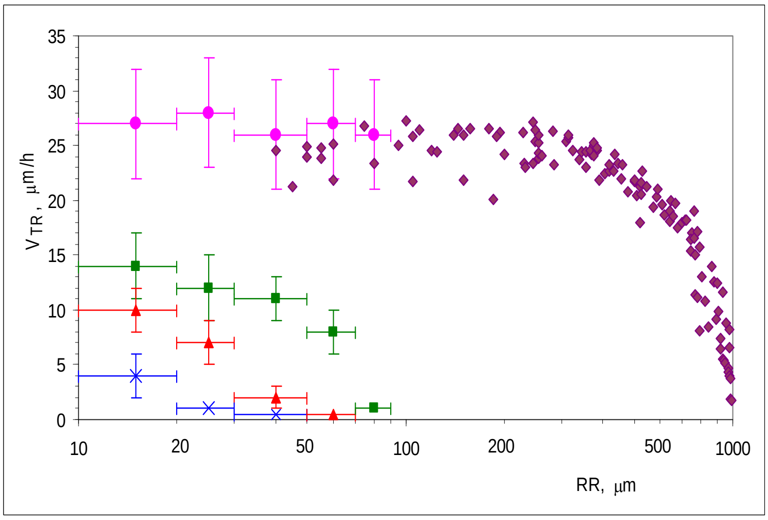

Fig.1. Track-etch rate (V_{TR}) as a function of residual range (RR) for the accelerated nuclei: Kr (36), Xe (54) and U (92). At RR > 100 µm – data from [5].
Points for Fe (26) are experimental data of GCR VVH-group measured for Marjalahti pallasite olivine crystals

Table 2

Residual range (RR) and track-etch length (L_{Vtr}) of high-energy GCR super-hheavy nuclei from Marjalahti pallasite olivine crystals at different track-etch rates

Nuclei (Z)	L_{TOT} (*) µm	L_{BASE} (**) µm	RR = $L_{V(TR)}$ (K_U=0.41) µm (***)				
			η =0.02	η = 0.12	η = 0.28	η = 0.68	η = 0.84
U (92)	14487	2897	1200	1000	900	700	500
Pb (82	7089	1418	607	490	441	343	249
Au (79)	6127	1225	502	420	380	296	212
W (74)	4295	859	352	300	270	210	150
Yb (70)	3154	631	259	218	197	153	110
Tb (65)	2322	464	190	160	144	112	80
Nd (60)	1794	359	148	124	112	87	63
Xe (54)	1211	242	99	83	76	59	42
Sn (50)	883	176	73	61	54	42	30
Ag (47)	685	137	57	47	42	33	24
Mo (42)	454	91	37	31	28	22	16
Kr (36)	261	52	22	18	16	13	9

(*) Calculated L_{TOT} – total track length for $(dE/dX)_{el}$ = 18 MeV/nucleon.
(**) Etched length of the track base section from relation L_{BASE}/ L_{TOT} = 1/5 for $(L_{BASE})_{Fe}$ = 15 µm and $(L_{TOT})_{Fe}$ = 77 µm.
(***) Track length (L_{Vtr} = RR) for different nuclei with $V_{tr} = 0.02 \times V_{tr,max}$ obtained from experimental data.

On base of the obtained data the value L_{Vtr} was plotted as a function of V_{tr}. The relation was used for GCR nucleus charge identification. These functions for nuclei with Z from 66 to 82 as example are presented on fig.2.

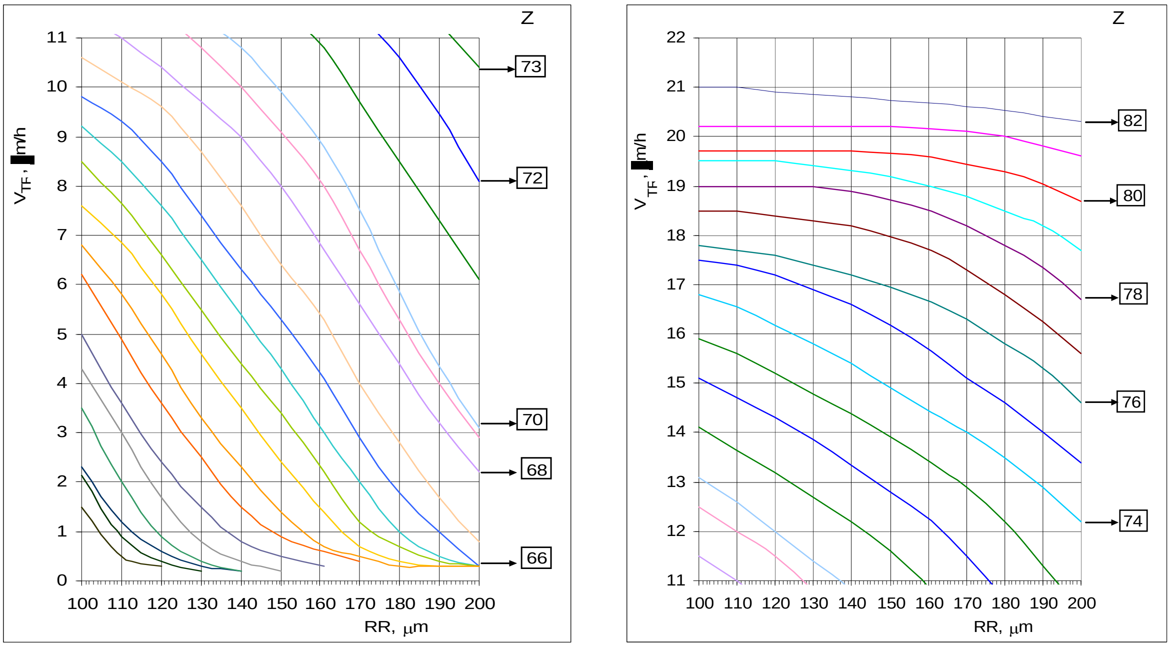

Fig.2. Track-etch rate (V_{TR}) as a function of residual range (RR) for the GCR nuclei of charge 66<Z<82 in the olivine crystals from the Marjalahti pallasite

Conclusions

The elaborated method for the GCL nucleus charge identification on the current stage is based on relation between the track-etch rate and measured etched track lengths. Some assumptions require further refinement and quantitative definition in calibration experiments with accelerated high-energy Pb-U nuclei. However, application of preliminary identification parameters allow to get the track charge distribution for about 1000 nuclei that were observed in 27 olivine crystals from Marjalahti pallasite.

The distribution shows satisfactory agreement with the other data obtained with a help of measuring equipment placed on cosmic stations [6].

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