Search for the tracks of galactic cosmic nuclei with $Z \geq 110$ in meteorite olivines

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The results of investigations of nuclear tracks from galactic cosmic rays in meteorite olivine crystals are presented. Among the identified tracks of nuclei with $Z \geq 60$, about 150 tracks are associated with the nuclei of the uranium group; the 365-μm-long track probably belongs to a nucleus with $Z \geq 110$.

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The search for superheavy nuclei ($Z \geqslant 110$) in galactic cosmic rays started with the investigation of nuclear tracks in thick layers of nuclear emulsion exposed in sounding balloons in the upper layers of the atmosphere.[1] Multiplate detectors made from polymer materials combined with Cerenkov detectors were also used in the subsequent investigations. Twenty-three tracks of a nucleus with $86 \leqslant Z \leqslant 100$ and no tracks of a nucleus with $Z \geqslant 110$ were identified in all the investigations.[2,3] An analysis of these results[4] shows that the nuclear tracks in the region $86 \leqslant Z \leqslant 100$ are more difficult to identify than it was assumed. Preliminary results have been obtained in Ariel-VI and HEAO-C experiments in the region of nuclear charges $86 \leqslant Z \leqslant 100$. An effective search for superheavy nuclei requires the use of a technique with a higher sensitivity, which requires the development of orbital-station track or electron detectors with an area of ~ 100 m^2 and an exposure time of at least a year. The ability of silicate meteorite (olivine, pyroxene) crystals to record and store for a long time ($> 10^8$ years) the tracks of nuclei with $Z \geqslant 20$ (Ref. 6) opens new possibilities for the search of superheavy elements in galactic cosmic rays. A simple estimate shows that 10^2–10^3 tracks of nuclei with $Z \geqslant 90$ can be recorded in 10^8 years per cm^3 of such crystals situated at a depth of $\leqslant 5$ cm from the preatmospheric surface of a meteorite and up to 10^4 tracks can be recorded in crystals from the surface regions of a meteorite ($\leqslant 1$-cm depth).

In the beginning of these investigations in 1974–1979, the track densities of a metal group were measured in olivine crystals from 20 pallasite-type and medosiderite-type meteorites. To search for the tracks of superheavy nuclei, we have selected olivines from the Mar'yalakhti, Eagle Station and Lipovskiĭ Khutor meteorites, in which we discovered the regions that are situated at a depth of 2–6 cm from the preatmospheric surface of the meteorites. Experiments were performed involving the calibration of olivine crystals by ions ranging from Ti to Xe, which were accelerated in accelerators, identification of nuclear tracks, their discrimination from the etch figures of the capillary inclusions and dislocations,[7,8] and the development of methods of identification of nuclear tracks with a total etchable length.[9]

An analysis of the separation of the lengths of tracks obtained in the scanning of

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~700 mm^3 of olivines from the Mar'yalakhti meteorite[10] was performed on the basis of the data for the etchable lengths of nuclear tracks used in the Katz and Kobetich model[11] and on the basis of the calibration by accelerated heavy ions; more than 5500 tracks were associated with the region $Z \geqslant 50$. The values for the abundance of nuclei with $Z \geqslant 50$ in galactic cosmic rays,[10] which were obtained on the basis of the given distribution, are in satisfactory agreement with the results of the experiments on recording of cosmic-ray nuclei and with the data for the abundance of elements in the solar system.[12] To increase the sensitivity of the search for tracks of superheavy nuclei significantly, we used a method of artifically annealing the nuclear tracks (the crystals with tracks were placed in a medium whose temperature was elevated for a certain period of time) in order to increase the recording threshold of tracks in the crystals. The behavior of nuclear tracks during annealing was investigated using the tracks of accelerated heavy Fe, Cr, Ge, Kr, and Xe ions.[13] According to the results of these experiments, a large number (~6 cm^3) of olivine crystals from the Mar'yalakhti meteorite was annealed at $T=430°$C for 32 hours; the etchable length of the tracks of accelerated Xe nuclei ($E=8.3$ MeV/nucleon) was equal to (26 ± 2.5) μm. The etchable track lengths of nuclei in olivine crystals must be equal to ~350-400 μm for $Z \geqslant 110$, ~180-240 μm for nuclei of the U group, and ~140 -180 μm for those of the Pt and Pb groups. A group of tracks with lengths of 180 to 240 μm, which are related to the tracks of the uranium group, can be separated out in the distribution of the etchable lengths of nuclear tracks (Fig. 1). It should be noted that the procedure used to identify the tracks in crystals--annealing, lasing--is highly efficient for tracks of lengths > 100 μm and much less efficient for 20 to 50-μm-long tracks, which explains the decrease in the number of < 100-μm-long tracks from nuclei with $Z<70$. The only track with an etchable length of 365 μm can be the track of a nucleus with $Z \geqslant 110$. We should note that the orientation measurements of this track in the crystal showed that it does not coincide with the main crystallographic directions. This enabled us to rule out the channeling effect as well as the growth defects of the structure as being responsible for formation of this track. The abundance of nuclei with $Z \geqslant 110$ relative to that of the uranium nuclei $P_{Z \geqslant 110}/P_U = (1-3) \times 10^{-3}$ is consistent with the abundances of the superheavy nuclei $10^{-1} \leqslant P_{Z \geqslant 110} : P_U \leqslant 10^{-4}$.[14]

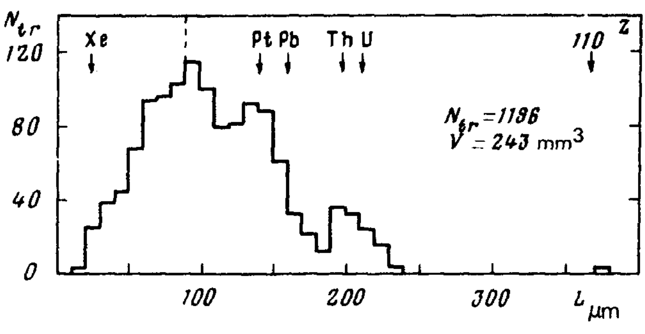

FIG. 1. Distribution of track lengths measured in annealed olivine crystals from Mar'yalakhti and Eagle Station meteorites. The maximum exposure efficiency was obtained for ≥ 100-μm-long tracks.

The annealing procedure for processing these crystals corresponds to elimination of the undeveloped tracks with specific losses of 2.4×10^{10} erg/cm, which corresponds to the ionization produced by multiply charged, hypothetical Dirac monopoles with a magnetic charge $n = 5$. An absence of extended etch figures in the olivines examined by us, which are characterized by a constant etching rate along the track, enabled us to determine the upper limit for the abundance of multiply charged monopoles ($n \geqslant 6$) at the level of $\leqslant 6 \times 10^{-20}$ $I/\text{cm}^2 \cdot \text{sec} \cdot \text{sr}$ in outer space.

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