RESEARCH OF GAS BUBBLES FORMATION PROCESS IN CRYSTALS OF THE LUNAR SOIL SILICATE MINERALS

Kashkarov L.L., Assonov S.S., Ivliev A.I., Kalinina G.V.
ugeochem@geochem.home.chg.ru

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Introduction

The lunar soil matter in a surface regolith layer is constantly irradiated by nuclei of cosmic radiation: low-energy (E_{KIN}~1 кeV/nucl) ions of a solar wind (SW); VH-nuclei of solar cosmic ray (SCR), E_{KIN} ~(1-100) MeV/nucl, and galactic cosmic ray (GCR), E_{KIN}>100 MeV/nucl. As a result, the specific effects are storaged in silicate crystals consisting meteoritic and lunar objects that gives possibility to search their radiation history. [1]. One of the most interesting effects connected to SW ions, are the gas micro-bubbles, which were found in highly irradiated silicate grains of lunar regolith [2]. Subsequent research [3,4] have resulted in the assumption, that micro-bubbles, containing very high gas concentration (due to implanted He-ions of SW) could be generated in the exposed crystals during their further essential heating

Complex study of a radiation-thermal history of the lunar regolith crystals, carried out by us recently years with help of thermoluminescence and nuclear track methods [5-7], also have shown, that gas micro-bubbles, could be formed as a result of heating up to (500-600) ^{o}C at shock-thermal events, mainly caused by the micro-meteoritic bombardment of matter on the lunar surface.

In the given work the results of an experimental research of gas micro-bubbles formation process in individual lunar Ol crystals are presented.

Researched samples

For study 30 Ol crystals of (120-200) μm size fraction, selected from ~200 crystals of sample 1603 of the Luna 16 column soil, were taken. Each of the selected crystals was characterized by high track-density (ρ) of SCR VH-nuclei. As a result of such selection, the crystals were taken only, in which gradient of track-density is observed. Parameters of a gradient: maximal $\rho \geq 10^{8}$ cм$^{-2}$, and more than 2-multiple reduction of ρ on depth about 70 μm. It indicate an irradiation of the given crystals on the regolith surface at thickness of a shielding matter layer not higher than ~10^{-3} g cm^{-2}.

Technique of measurement

For supervision and measurement of the gas bubble parameters (sizes, surface density, morphology) was used electronic scanning microscope (ESM) of type JEOL with magnification up to ~50000x. Each of the Ol crystals smously crushed on 4-5 fragments serving in the further experiences with heating as individual objects. Each of such fragments was located in a separate quartz ampoule, which after that was vacuumed and vacuum-sealed. Prepared by this manner four sets (till 10 fragments in everyone) were exposed to heating in tubular heater at temperature 500, 600, 700, and 800 ^{o}C during 10 and/or 60 min. After heating the fragments of microcrystals were taken in ESM with the purpose of revealing and measurement of gas bubbles parameters.

Results and discussions

From 30 of investigated Ol crystals, concerning on the VH-track characteristics as micro-objects, irradiated by the high doze $\Sigma \geq 10^{18}$ cm^{-2} of SW He-ions, only in four crystals after heating at 600 ^{o}C during 60 min., or at 700 ^{o}C during 10 min. were found the new-formed of gas bubbles. Surface density of gas bubbles for these crystals lies in limits ~$(10^{9}\div10^{11})$ cm^{-2}, that corresponds to values of bubbles-density, observed by us for some Ol, Pl and Px crystals of a Luna 16 column, not heated in laboratory conditions [5]. The relative number of such crystals is lower than ~10%, that specifies complexity of formation process of gas bubbles in natural conditions, in particular - in the top layer of the lunar regolith. The sizes of gas bubbles, observed on a Ol surface as spherical up to ellipsoidal of the form, varies over a wide range - from ~10 nm up to ~100 nm.

Carried out by us earlier with the help 1 МэВ high-voltage electronic microscope research of morphology and the structure of micro-crystals of a lunar soil have shown, that on a surface of highly irradiated crystals it was observed an amorphous layer. The thickness of this layer, as a rule, does not exceed ~100 nm, that corresponds to a surface material depth of a complete absorption of the SW He-ions.

Based on the given results, the process of gas bubbles formation in thin-surface zone of silicate crystals can be submitted as follows. In crystals irradiated with SW He-ions with a total doze $\Sigma \geq 10^{18}$ cm^{-2}, is formed amorphous layer. In a case rather short-term (less than hour) heating up to temperature T~(600-700)^{o}C in this layer due to diffusion and migration processes He atoms effectively concentrate in gas micro-bubbles. Initial sizes of these started micro-bubbles do not exceed the first of ~nm. Further (or longer on time) the heating results that the sizes of micro-bubbles are increased up to ~100 nm, and on a surface of a crystal there are some cases of open (dissection) bubbles.

Note, the thermoluminescence research for individual lunar crystals [6], has shown the presence of the shock-thermal influence traces in some of the crystals under investigation. It confirms our assumption of micrometeoric bombardment on a lunar surface, as the most probable local sources of heating of the individual crystals.

Conclusions

The carried out experimental researches of the gas bubbles formation process in the lunar Ol crystals have shown, that:

1. Micro-bubbles are observed only in crystals with gradient of track-density at its maximal value on a crystal surface $\rho \geq 10^{8}$ cm^{-2}, that corresponds to the integral doze of He ions of SW Σ~(10^{17}-10^{18}) cm^{-2};
2. The formation of initial gas micro-bubbles occurs at heating of highly irradiated crystals up to T=(600-700)^{o}C during ≤1 hour;
3. The most probable mechanism of the gas bubbles formation are diffusion and migration of the implanted SW He ions. As result atoms of He are concentrated in gas bubbles by the sizes ~nm. As the surface layer of crystals, irradiated with SW ions with a doze $\Sigma \geq 10^{18}$ cm^{-2}, is in amorphous condition, it promotes formation of spherical bubbles by the size up to several hundreds nm.
4. A source of the local heating of the lunar regolith matter is repeated impact events, occurred under bombardment of the lunar surface by the micrometeorites. As a result of such practically of "dot" process of heating the relative number of the Ol crystals, having micro-bubbles, is low and accounted for smaller than~10%.
5. Extrapolation of the received results on shorter (~сек) the time intervals are given of temperature of gas bubbles formation T~1000^{o}C. But it is needed to note, that the so short-time process of the gas bubbles formation must to be examined experimentally.

References

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