AMORPHIZATION DEPTH OF ANORTHITE AND QUARTZ IN DEPENDENCE ON H^+ AND He^+ ION ENERGY AND IRRADIATION DOSE. E. N. Slyuta[1], S. N. Shilobreeva[1], L. L. Kashkarov[1], G. V. Kalinina[1], S. A. Voropaev[1]. [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 119991, Kosygin St. 19, Moscow, Russia. slyuta@mail.ru.

Introduction: There are two basic genesis of observed amorphous films on the surface of particles and minerals of lunar regolith. The former are films which were formed as a result of condensation of the evaporated lunar rocks during micrometeorite and meteorite impacts [1]. It is confirmed by the experimental and observed data [2]. But, apparently, the majority of amorphous films on the surface of regolith particles were formed as a result of an irradiation by solar wind ions (SW) [1, 3].

Technique and results: Distribution of SW ions in the Earth orbit is described by liquid model, in which speed of any ions same [4]. Energy is measured by units of Wp/nucleon, where Wp=0.3-3 KeV - a characteristic range of protons' energy. Kinetic energy of helium in 4 times is more than energy of protons. Therefore all calculations for protons were made for 1, 2 and 3 KeV, and for He^+ - for 4, 8 and 12 KeV accordingly. The observed saturated concentration of ^4He on the surface of lunar regolith grains corresponds to integrated stream of SW ions of ~7×10^{17} atom cm^{-2} [5]. Such dose of an irradiation corresponds to an exposition time of about 300 million years at modern intensity of SW stream.

Calculations with program SUSPRE [6] show that from 1 to 3 KeV the depth of protons' implantation into anorthite (Ca ($Al_2Si_2O_8$) increases three times irrespective of stream density while degree and depth of amorphization much more depends on stream density. If an irradiation dose is of 1×10^{15} atom cm^{-2} the implantation depth is more the amorphization depth, but if an irradiation dose is about of 1.6×10^{17} atom cm^{-2} the implantation is actually localized inside of already well developed amorphous film (Fig. 1). Unlike an irradiation by protons the thickness of an amorphous film which is formed during an irradiation by ions He^+ always coincides with the maximum depth of He^+ implantation. The implantation depth and the thickness of an amorphous film due to irradiation of helium ions is approximately twice more than is due to irradiation of protons (Fig. 2).

Implantation depth of protons into quartz (SiO_2) as well as in anorthite increases almost three times irrespective of irradiation dose in dependence on energy from 1 to 3 KeV. Destruction degree and amorphization depth of a quartz surface under the ionizing irradiation depends basically not on energy, but on irradiation dose. If irradiation dose is less 1×10^{16} atom cm^{-2} the depth of protons' implantation will considerably exceed the amorphization zone. But if the dose is exceeding of 1×10^{16} atom of cm^{-2}, the implantation of protons irrespective of energy is actually localized within of a formed amorphous film (Fig. 3). Full (100 %) amorphization (destruction) of a quartz surface develop at the dose exceeding 8×10^{16} atom of cm^{-2}, if irradiation dose is equal to 1.6×10^{17} atom of cm^{-2} the thickness of an amorphous film reaches 100 nanometers (Fig. 3). Unlike an irradiation by protons the depth of destruction of quartz structure and amorphization irrespective of energy and a dose always coincides with the maximum depth of implantation of ions He^+ (Fig. 4). Amorphization intensity is also basically defined by an irradiation dose (Fig. 4).

Summary: When irradiation dose by protons is enough high and close to integrated dose observed in lunar regolith (7×10^{17} atom cm^{-2}), all chemical and physical processes of space (geochemical) weathering of anorthite and quartz particles will occur in the radiation-induced amorphous film, without reaching crystal structure of a mineral. Unlike protons the maximum concentration of ions He^+ irrespective of a dose both in anorthite and in quartz will collect in a transitive zone between the radiation-induced amorphous phase and the crystal phase of a mineral.

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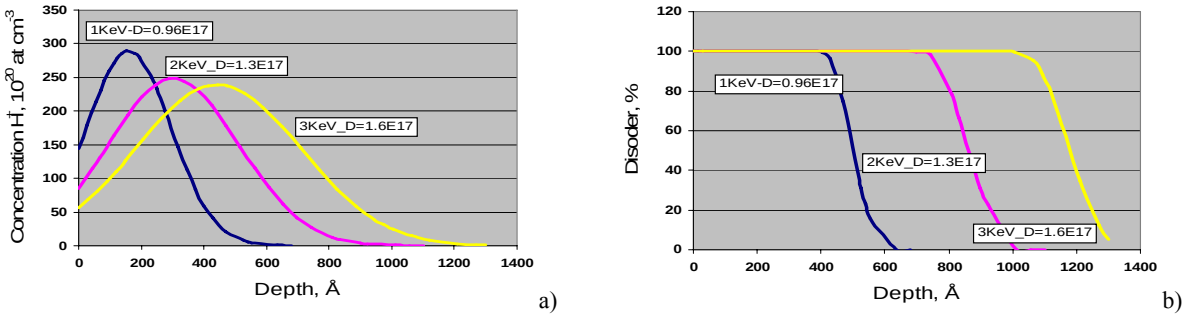
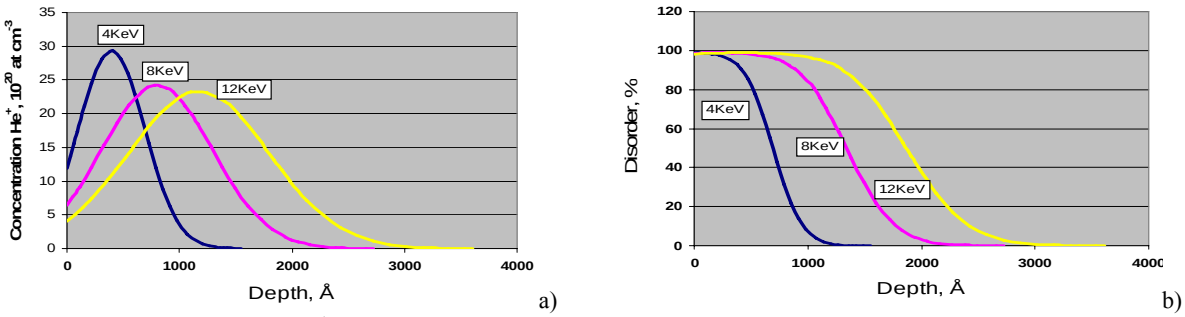


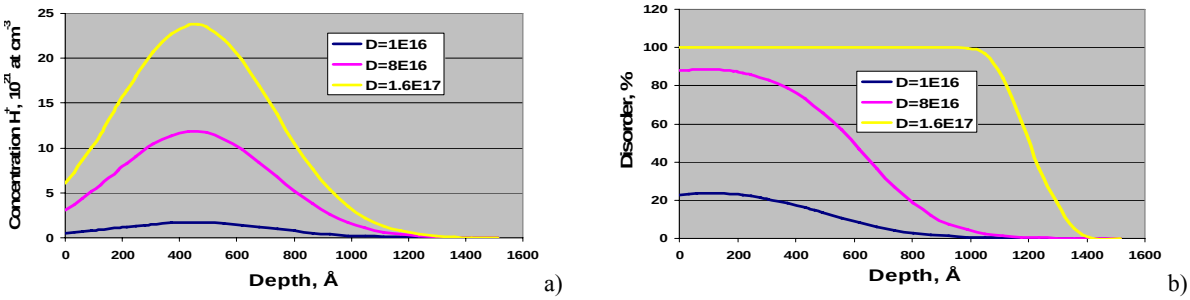
a) b)

Fig. 1. Protons' implantation depth and amorphization degree (disorder) in anorthite depending on protons' energy and a dose: a) distribution of concentration of the implanted protons; b) amorphization degree (disorder) of anorthite lattice. Energy and dose (D, at cm^{-2}) are specified at Fig.



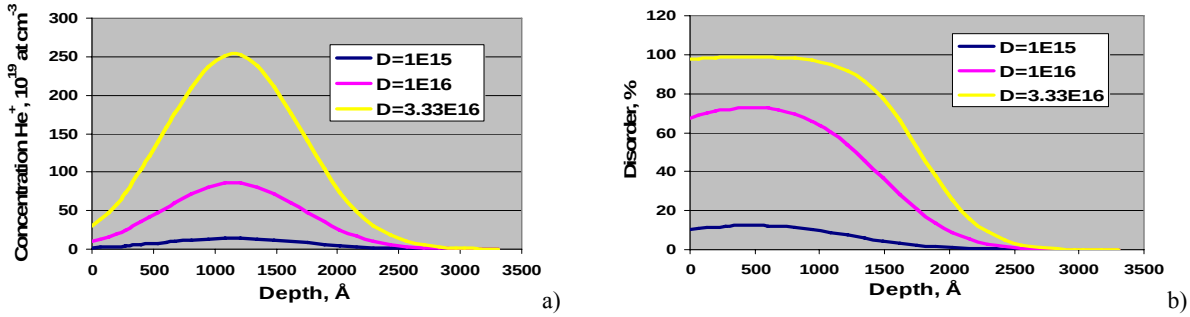
a) b)

Fig. 2. Implantation depth of He^+ and amorphization degree (disorder) in anorthite depending on ions energy and a dose for 4 KeV $D=2\times10^{16}$ atom cm^{-2}, for 8 KeV $D=2.8\times10^{16}$ atom cm^{-2}, for 12 KeV $D=3.5\times10^{16}$ atom cm^{-2}: a) distribution of concentration of the implanted helium; b) amorphization degree (disorder) of anorthite lattice. Kinetic energy of ions is specified at Fig.



a) b)

Fig. 3. Protons' implantation depth and amorphization degree (disorder) in quartz at constant energy of 3 KeV: a) distribution of concentration of the implanted protons; b) amorphization degree (disorder) of quartz lattice. Dose is specified at Fig.



a) b)

Fig. 4. Implantation depth of He^+ and amorphization degree (disorder) in quartz depending on dose at constant energy of 12 KeV: a) distribution of concentration of the implanted helium; b) amorphization degree (disorder) of quartz lattice. Dose (D, at cm^{-2}) is specified at Fig.