POSSIBLE REDUCTION OF SLIGHTLY SIDEROPHILE ELEMENTS IN IMPACT PROCESS

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Introduction: V and Cr are lithophile elements. Nevertheless, the depletion of these elements in the crust by possible sink into the core infers their siderophile behavior during the Earth's accretion and provides classification of V and Cr as slightly siderophile elements. The problem of geochemical behavior of these elements is tightly connected with the definition of specific conditions during accretion which had induced metallization of elements. In a series of our former experimental works [1, 2] we have formulated an idea that the main reason of metallization of iron and other siderophile elements was their thermal reduction during impacts. Such a mechanism could provide reduction of elements in both impact melts and a vapor phase in every planetesimal impact during accretion. Here we present new experimental results which prove the possibility of impact-induced reduction of slightly siderophile elements during high-temperature impact related conditions. In a case that these reduced phases were accumulated in a core siliceous mantle of the Earth and Moon have to have depletion in these elements compared to the composition of source material.

Experimental technique: The experiments were carried out in a pulse-laser setup in the regime of a free generation of laser radiation [3]. The Nd glass laser had the following parameters: a wavelength of λ=1,06 μm, a pulse energy of ~600 J, a power density of radiation of ~10^6-10^7 W/cm^2, and a pulse time of ~10^{-3} s. Typical temperature under such condition were 3000-4000 K. Vaporization of samples was performed in helium at 1 atm. and room temperature. The laser beam was focused to a diameter of ~3 mm. It melted and vaporized a few tens of milligrams of a sample. A metal screen was installed in the spreading path of the vapor at a distance ~7cm from the sample. Glass tiny spherical particles (1-20 μm in diameter), which were frown out from the melted sample by expanding vapor, were found on the film of the condensate.

Starting samples in this set of experiments were prepared as pressed tablets of carefully mixed powders of peridotite with V_2O_3 and Cr_2O_3 oxides. The compositions of starting samples were (mol %): 1) Si 11.6; Fe 5.8; Mg 9.3; Ca 3.9; V 10.8; O 58.6; 2) Si 14.4; Fe 3.8; Mg 16.0; Ca 1.9; Cr 5.4; O 58.5. It was important that all elements in starting samples were in oxidized state.

Chemical analyses of glass spherules were made using PHI 660 Scanning AUGER Microprobe. Chemical analyses of the condensates were made with by XPS technique.

Results: a) Condensates. Analyses of the condensates have shown that together with metallic component of iron there are sufficient proportions of metallic V and Cr. The mean compositions of condensates were: (sample 1) Si 19.1; Fe^{+2} 3.1; Fe^0 1.9; Mg 11.8; Ca 1.5; V^{+4} 0.7; V^{+3} 3.1; V^0 0.7; O 58.2; and (sample 2) Si 18.4; Fe^{+2} 3.2; Fe^0 1.6; Mg 10.4; Ca 1.8; Cr^{+3} 4.5; Cr^0 1.2; O 59.0.

The average degree of reduction of iron in the condensate was ~35%, and for chromium and vanadium that was ~20% and ~15% respectively.

b) Spherules. Analyses of spherules shows a vide diversity of their compositions, what is indicative of individual thermal history of melted droplets. Auger analyses show a pronounced deficit of oxygen in droplets. The quantity of oxygen was depleted compared to its starting value 10 to 20% in average. To estimate the degree of reduction of samples we have calculated the reduction index (RI), which was the subtraction from unity of a ratio of measured concentration of oxygen in droplets to that in starting sample. RI shows the proportion of oxygen, which is lacking for the total oxidation of elements in a spherule. This index is varying between 25 and 70% for sample 1 and between 13 and 50 for sample 2 (Fig. 1 and 2). Such high deficit of oxygen is the result of the presence of elements in metallic state in the melt. Taking into account analyses of condensed films, we consider that metallic component is mainly presented by iron, with some quantity of chromium and vanadium. Analytic evaluation of the state of silicon and magnesium in some spherules has shown that up to 15% of silicon and up to 15% of magnesium also can be present as Si^0 and Mg^0.

Conclusions: Experimental results prove the efficient thermally-induced reduction of iron and slightly siderophile elements (Cr and V) during high-temperature impact-related heating of silicates. It could be an efficient mechanism for metallization of siderophile and slightly siderophile elements during a period of impact accretion of the Earth and the Moon. Metallic components of slightly siderophile elements could be partially removed from the mantle material by their dissolution in metallic iron phase and consequent sank into the forming core providing a certain depletion of these elements.

References: [1] Gerasimov M.V. et al. Reduction of W, Mn, and Fe during high-temperature vaporization // LPS XXXV, 2004, #1491 (CD-ROM) [2] Dikov Yu.P. et al. Siderophile behavior of P in impact processes // LPS XXXVI, 2005, #1125 (CD-ROM) [3] Gerasimov M.V. et al. Physics and chemistry of impacts // In: Laboratory Astrophysics and Space Research. 1999. P.279-329. Kluwer Academic Publishers.

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Fig. 1

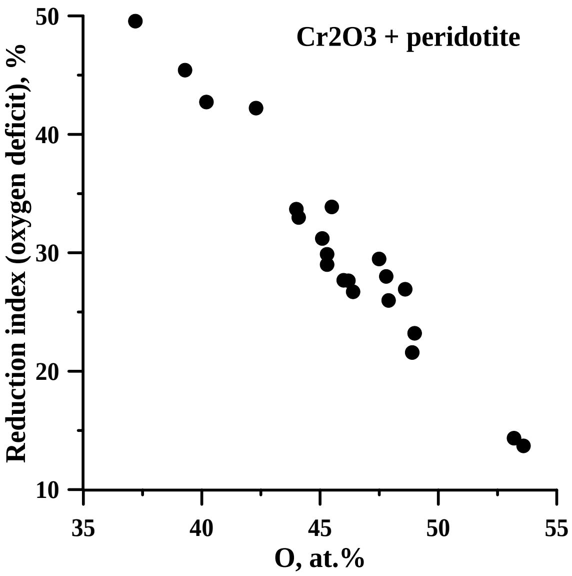

Fig. 2