

THE BEHAVIOR OF Ni IN SILICATE MELTS DURING IMPACT-SIMULATED HIGH TEMPERATURE HEATING. Yu.P.Dikov¹, M.V.Gerasimov², O.I.Yakovlev³, F.Wlotzka⁴, J.Huth⁴. ¹Institute of Ore Deposits, Petrography, Mineralogy and Geochemistry, RAS, Moscow 109017, Staromonetny per., 35, dikov@igem.ru, ²Space Research Institute, RAS, Moscow 117997, Profsoyuznaya st., 84/32, mgerasim@mx.iki.rssi.ru, ³Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow 117975, GSP-1, Kosygin st., 19, yakovlev@geokhi.ru, ⁴Max-Plank-Institut für Chemie, Abteilung Kosmochemie, Mainz, Germany.

Introduction: Investigation of siderophile elements (SE) composition in impactites from terrestrial and planetary impact craters is an important key for understanding of the presence of an impactor material. Any enrichment of SE in impactites compared to SE concentration in target rocks is usually considered as a result of contamination by chondritic projectile material. This approach is supported by the fact that many SE (particularly highly siderophile elements) are refractory elements and the resulting change in their concentration is expected only due to simple mixing of colliding materials. Nevertheless, there are mechanisms which provide sufficiently high mobility of highly refractory elements during an impact. Earlier we reported about an efficient reduction of iron in silicate melts at impact related high-temperature conditions with subsequent removal of metallic iron particles into the vapor outflow [1,2]. The formation and efficient loss of metallic iron particles is a possible mechanism which provides scavenging SE from silicate melts. Experiments with Pt-rich target have shown that Pt tended to form separated phases and be removed from silicate melts [2]. So, the behavior of SE during an impact needs further experimental investigation to give true evaluation of SE budget in different impactites.

One of the aims of the present experiment was to investigate the behavior of Ni at impact-related high-temperature conditions.

Experimental technique: Our experiments were performed using a laser pulse (LP) technique [3]. Composition of the vapor cloud was investigated by analysis of the composition and structure of the condensed film, which was precipitated on a Cu-foil at ~8 cm from the place of vaporization of the sample. Glass spherules with diameters ranging from around one to several tens of microns were found on the surface of the condensed film. Chemical analysis of spherules was performed using FESEM/EDS microprobe analysis. We used a layer-by-layer etching of the film by Ar ions to study the composition of the condensed film through its thickness. Chemical analysis within layers was performed using X-ray photo-electron spectroscopy (XPS) technique.

Samples: We used minerals garnierite (SiO₂ – 33,00, NiO – 44.50, MgO – 4.52, CaO – 0.33, Fe₂O₃ – 1.08, Al₂O₃ – 0.62, H₂O – 16.42 wt.%) and kerolite (SiO₂ – 53,44, NiO – 11.32, MgO – 22.59, Fe₂O₃ – 0.24, Al₂O₃ – 0.05, H₂O – 12.58 wt.%) as starting samples in this set of experiments. The selection of samples was guided by the necessity to have sufficiently high concentration of Ni for analysis by XPS and EDS technique. Concentration of iron in both minerals was reasonably less than that of Ni to provide the behavior of Ni independent of Fe.

Experimental results: Chemical compositions of starting samples and of two types of experimentally obtained high-temperature products - condensates and melted spherules - differs noticeably indicating rather high degree of selective volatility of main elements. Fig. 1 shows the main trends in differentiation of Si,

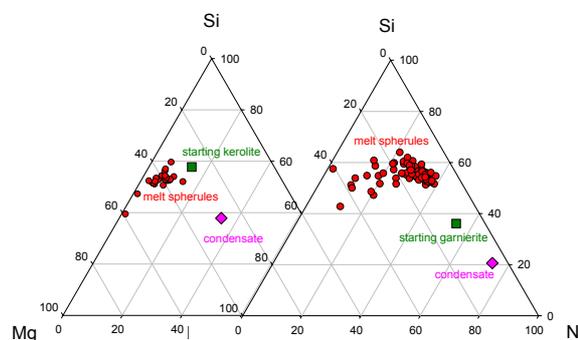


Fig. 1. Composition (in mol %) of starting kerolite (left plot) and garnierite (right plot) and of their experimentally produced condensate and melt spherules.

Mg, and Ni during high-temperature heating of kerolite and garnierite. Compared to starting samples condensates are depleted in Mg and Si but noticeably enriched in Ni. Melt spherules have opposite trend and are forming a sequence of compositions, which depend on the degree of high-temperature exposure, which define the degree of completeness of volatilization. Fig. 1 shows that spherules continue the loss of Ni with higher degree of volatilization which is also accompanied by the depletion of Si. As a result, Mg-rich glasses are produced.

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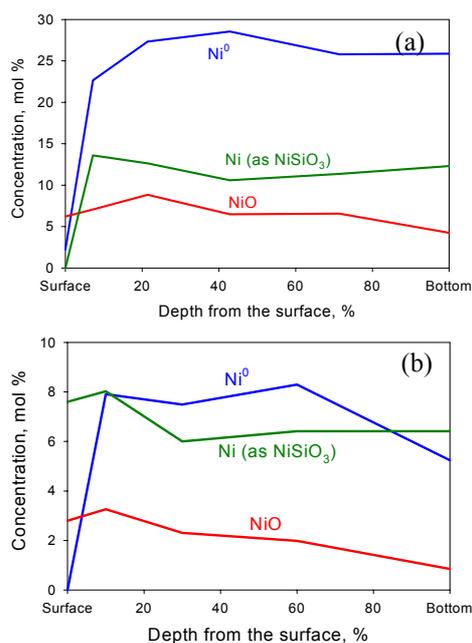


Fig. 2. Depth-profiles of concentrations (mol %) of Ni components through the thickness of condensed films in experiments with (a) garnierite and (b) kerolite.

XPS analysis of Ni in the condensates shows its bonding in three main components: (1) metallic; (2) oxide; and (3) silicate (NiSiO₃) type. Fig. 2 shows the depth-profiles of these components through the thickness of the condensed film in experiment with garnierite. Reduced metallic nickel is the major component in the condensates. Metallic nickel amounts to about 60% of total Ni in garnierite condensate and up to ~45% in case of kerolite. Nickel bound in NiSiO₃ clusters represents about one fourth of total Ni in garnierite condensate and about the same as metallic component in case of kerolite. Nickel as oxide amounts up to 15% and 11% in condensates from garnierite and kerolite, respectively. The concentration of components is almost constant through the thickness of the film with noticeable depletion of Ni⁰ in the surface layers, which are forming at decreasing temperature of vaporization.

Iron and silicon also have noticeable reduction in the condensates. Fig. 3 shows the depth-profiles of iron and silicon components in the condensed film from experiment with garnierite. Iron is mainly represented by oxide component which is about 62% of total iron. About one fourth of iron is bound in FeSiO₃ type clusters and about 13% is present as metallic iron. Silicon is mainly bound in silicon-oxygen tetrahedrons but about 16% of silicon is reduced and present as NiSi component.

Discussion and conclusions. Experiments with both garnierite and kerolite shows an efficient volatilization of nickel into the vapor phase. The enrichment

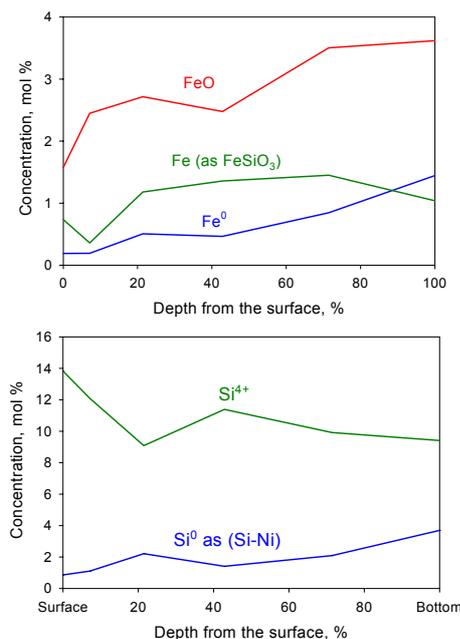


Fig. 3. Depth-profiles of concentrations (mol %) of Fe (upper plot) and Si (lower plot) components through the thickness of condensed film from experiment with garnierite.

of condensates in nickel compared to the starting samples was about 2.2 and 2.8 times for garnierite and kerolite, respectively. Residual melt has the same average depletion in nickel. The presence of large quantities of reduced Ni⁰ in the forming condensate supports an idea that the behavior of Ni is similar to that earlier (e.g. [1,2]) suggested for iron. The formation of pure Ni particles is probably low at natural concentrations of Ni and it must mainly be accumulated in metallic iron particles. Nevertheless, the separation of siderophiles into metallic aggregates is a general effect of their high-temperature behavior.

A certain portion of nickel was condensed as oxide or being bound to NiSiO₃ cluster. Such clusters have only low range ordering and do not form perfect phases. Nevertheless, the formation of such clusters indicate the possibility of metal/silicate partitioning of Ni during an impact-induced high-temperature processing.

The high-temperature behavior of Ni does not contradict to the observed Ni budget of lunar regolith fine fraction and impact glasses and must be accounted for in evaluation of the role of impact processing.

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References: [1] Dikov Yu.P. et al. (2001) LPSC 32th, abstr. #1559 CD-ROM. [2] O.I.Yakovlev, et al. (2002) LPSC 33th, abstr. #1271, CD-ROM [3] Gerasimov M.V. et al. (1999) Physics and Chemistry of Impacts. In: *Laboratory Astrophysics and Space Research*, P. Ehrenfreund et al. (eds.), KAP, 279-329.