Cr-Ca SYMPLECTITE LAMELLAE IN AN OLIVINE GRAIN FROM THE LUNA-24 REGOLITH.

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Introduction: Cr-Ca symplectites in olivine are known as spinel-pyroxene vermicular intergrowths usually observed as irregular shaped blebs along grain boundaries [1-3] or rarely as oriented needles [1, 2, 4] in olivine grains from terrestrial [3, 4] as well as lunar rocks [1, 2]. The origin of the Cr-Ca symplectites is debated yet [1-4] and suggested to be resulted from either exsolution process during cooling of Al- and Cr-rich olivine [4], or combination of processes including either diffusion, discontinuous precipitation, and metamorphism [3], or a breakdown of garnet [2], or crystallization of a trapped late-stage melt [1, 2], or diffusion of Ca, Al and Cr out of olivine [2] and a reaction between olivine and plagioclase [1, 2]. The Cr-Ca symplectites in terrestrial and lunar olivines are very similar in their morphology, texture and phase composition in spite of Cr content in lunar and terrestrial olivines as well as the *f*(O2) conditions on the Moon and on the Earth are different [5]. Here we describe lamellae of Cr-Ca symplectites in an olivine grain from a Luna-24 regolith sample firstly reported as Cr-Ca lamellar inclusions by [6]. The olivine grain was investigated by EMPA and ASEM.

Results: Cr,Ca-rich lamellae of 1-3 mkm in width cross the olivine grain parallel to the (100) crystallographic plane (Fig. 1). BSE image show that lamellae have a vermicular texture that is typical for symplectites (Fig. 2). White and grey worm-like bands are in about 1:1 volume ratio and alternated approximately normal to the lamellae/olivine host interface. The adjacent host olivine matrix has a chemical composition of $Mg_{1..53}Fe_{0.47}SiO_4$. The lamellae are too thin to be analyzed precisely by traditional EMPA and ASEM methods. Just the same, our measurements demonstrate that (i) Ca/Cr atomic ratio is about 1.2 in the lamellae (Fig. 3); (ii) Mg/Fe atomic ratio is 3.25 in the olivine host and decreases in the lamellae being in relation to both the Mg substitution for Ca + Cr in lamellae and the Fe extraction due to $Fe + 2Cr^{2+} = \nu Fe + 2Cr^{3+}$ oxidation reaction; (iii) O/Si atomic ratio is <4 in the lamellae; (iv) A(tot)/Si ratio is less than 2 in the lamellae (where A(tot) is a total number of octahedral cations, A(tot) = Mg + Fe + Ca + Cr + Al). Thus, the chemical composition of the lamellae can be considered as Ca,Cr-olivine with a some deviation from the olivine stoichiometry (Fig. 4). The deviation from olivine stoichiometry is considered as a summary effect due to the presence of two kinds of point defects in the host olivine prior to the lamellae formation: (i) *v*Fe associated with Cr^{3+}, (ii) *v*O and *v*Mg in a ratio 1:1 associated with either a deficite of MgO, or controversaly with a $MgSiO_3$ excess. The lamellae are considered as a product of simultaneous segregation of the point defects and Ca, Cr, and Al, which was followed by a cellular precipitation process inside the lamellae. Cellular intergrowths in terrestrial symplectites were described in [3]. The chemical composition of the lamellae from the Luna 24 olivine grain is calculated from the EMPA and ASEM data by extraction of the matrix contribution to analyses and found to vary between $FeCr_2Ca_{2.8}Mg_{2..2}Si_{4.4}O_{16.8}$ and $FeCr_2Ca_2Mg_{3.3}Si_{5.3}O_{19.8}$ that corresponds to a mixture of several phases, such as $FeCr_2O_4$ spinel, $CaMgSi_2O_6$ diopside, as well as $MgSiO_3$ orthopyroxene and Ca_2SiO_4 larnite, both in minor amount. Amount of $MgSiO_3$ corresponds to the deficit of MgO in the lamellae, whereas amount of Ca_2SiO_4 corresponds to atomic excess of Ca relative to Cr^{3+} in the analyses. The EMPA and ASEM data show a heterogeneous distribution of orthopyroxene and larnite within lamellae and the Sp:Di mol. ratio as 1:2. We can not preclude the presence of olivine within the lamellae too.

Conclusion: The EMPA and ASEM data led us to the suggestion that the lamellae have been formed due to a solid-state exsolution reaction by moving of point defects + Ca, Cr, and Al from the host olivine interior with a segregation of them into the lamellae. Subsequent very low cooling was a reason for discontinuis decomposition and Sp-Cpx-Opx symplectite formation within the lamellae. However, some questions arise: what was a driving force for the exsolution; what was the agent responsible for the oxidation; how to explain the orthopyroxene occurrence in the lamellae; why point defects and Ca, Cr, and Al segregated to form a lamellae instead of to form a more obvious segregation along structure imperfections and grain boundaries. A study to elucidate these questions is in a progress.

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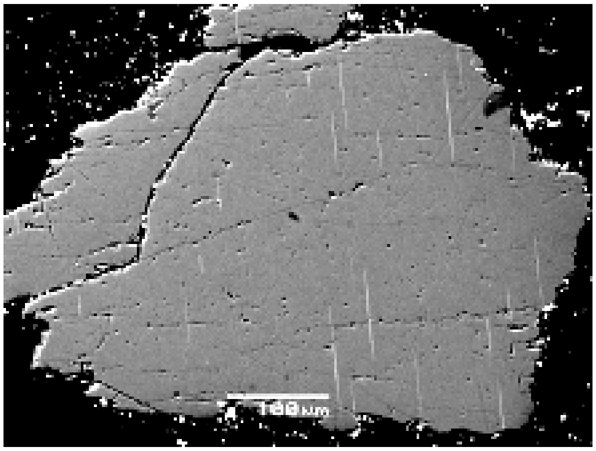

Fig. 1. BSE image of the olivine grain contained Cr-Ca lamellae.

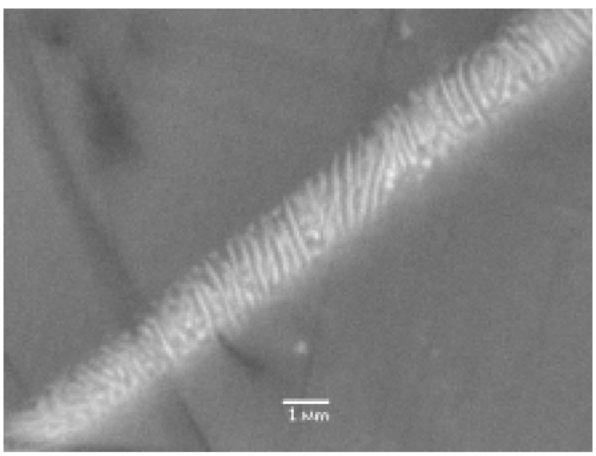

Fig. 2. BSE image of the symplectite-bearing lamellae.

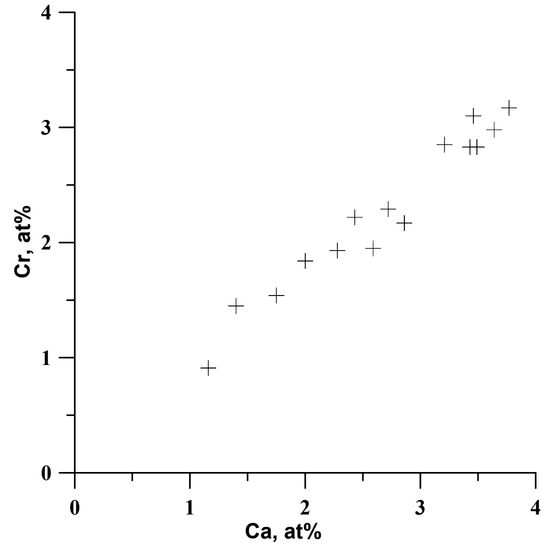

Fig. 3. Ca versus Cr for a mixture of the lamellae + adjacent host olivine.

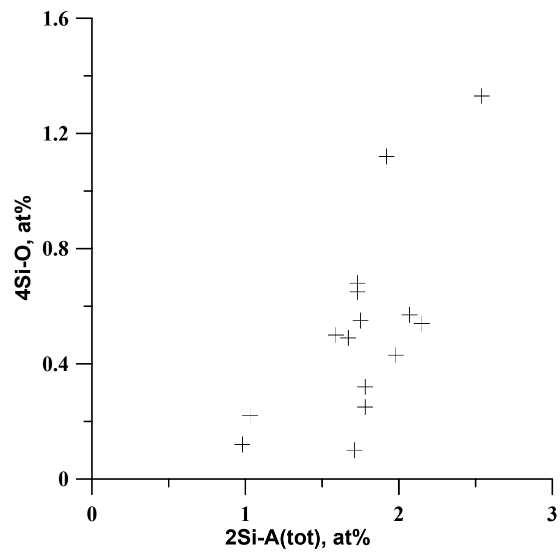

Fig. 4. [2Si – A(tot)] versus [4Si – O] for a mixture of the lamellae + adjacent host olivine. A(tot) =(Mg + Fe +Ca +Cr), at.%.