

A TRANSMISSION ELECTRON MICROSCOPY STUDY OF THE OLIVINE CORONAS IN THE VACA MUERTA MESOSIDERITE

S-L Hwang¹, M. Saavedra², P. Shen³, M.E. Varela², H-T Chu⁴ and TF Yui⁵

1-Department of Materials Science and Engineering, National Dong Hwa University, Hualien, Taiwan, ROC; 2-ICATE-CONICET, San Juan, Argentina; 3-Department of Materials and Optoelectronic Science, National Sun Yat-sen University, Kaohsiung, Taiwan, ROC; 4-Central Geological Survey, PO Box 968, Taipei, Taiwan, ROC; 5-Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, ROC.

Introduction: Mesosiderites are breccias usually composed of approximately equal amounts of Fe-Ni metal and silicates. The latter contains mineral and lithic clasts in a fine-grained matrix [e.g., 1-3]. Based on silicate textures, mesosiderites are subdivided into four subtypes (1 to 4), which are considered to reflect an increasing degree in metamorphism [4]. Coronas in olivine, a mineral always present in scarce amounts (~2 vol%), are considered the result of thermal metamorphism formed by the reaction of olivine with a mesosiderite-like matrix assemblage [4-7]. Coronas consist mainly of orthopyroxene with abundant chromite and merrillite and minor plagioclase, clinopyroxene and ilmenite [5]. Although the coronas are texturally similar, they can be divided in different mineralogical distinct zones with variable development even within the same mesosiderite. Here, a transmission electron microscopy (TEM) coupled with energy dispersive X-ray (EDX) analysis was performed to shed light on the main process under which the Vaca Muerta coronas were formed.

Results and Discussion: The studied samples of the Vaca Muerta (VM) mesosiderite (VM-DR; VM-O; VM-K, from ICATE collection) have one or two relatively large olivine grains ($\text{Fa}_{35.6-39.6}$) with microscopically visible coronas. They are characterized by a symplectite texture made up by one or two layered necklaces of chromite/ilmenite vermicular grains. Some pyroxenes related to the corona exhibit exsolution lamellae. The estimated equilibrium temperatures between both phases (applying QUILF 6.42, [8]) is within the range of 1054 ± 28 to $900 \pm 50^\circ\text{C}$. As for the coexisting chromite-olivine in the coronas, the lower temperatures ($\sim 850^\circ\text{C}$) obtained applying the spinel-olivine geothermometer [9], signals that the exchange of Mg and Fe between both phases continued during cooling to lower temperatures.

A TEM bright field images (BFIs) montage associated with SAED pattern of focused-ion beam (FIB) sections across the corona, shows that the lamellar symplectite consists mainly of topotaxial chromite plates in a matrix of enstatite which is non-epitaxially adjoined with the olivine porphyroblasts. The later are almost free of defects. The topotaxial twin variants of chromite plates follow the primary crystallographic orientation relation (COR-I): $[001]_{\text{en}} // \langle 112 \rangle_{\text{chr}}$; $(100)_{\text{en}} // \{111\}_{\text{chr}}$; $(010)_{\text{en}} // \{110\}_{\text{chr}}$. There is a secondary COR-II following also $(100)_{\text{en}} // \{111\}_{\text{chr}}$ but with $[010]_{\text{en}} // \langle 112 \rangle_{\text{chr}}$ pointing towards a Brownian rotational reorientation. Occasionally, there is almost epitaxy chromite plate in enstatite matrix being ~15 degree off the optimum COR by twisting $\{111\}_{\text{chr}}$ or the parallel $(100)_{\text{en}}$ to become noncoherent and hence an arbitrary $\{111\}_{\text{chr}} / (hkl)_{\text{en}}$ interface with $\langle 011 \rangle_{\text{chr}} \sim // [02\bar{1}]_{\text{en}}$. These features indicate that thermal metamorphism was not sufficiently long and/or did not reach temperatures high enough for an effective Brownian rotation of the confined particles.

The concentration profiles of siderophile elements (Fe, Cr, Mn) in olivine turned out to be monotonous with an abrupt change across the olivine/enstatite interface according to point-count TEM-EDX analysis. This indicates that olivine alteration is about directional diffusion-controlled $\text{Liq} + \text{Ol} \rightarrow \text{En} + \text{Chr}$ reaction, as shown by [7] for the Emery and Morristown olivine coronas, rather than a solid-state interdiffusion-controlled process.

References: [1] Floran (1978) Proceedings of the Lunar and Planetary Science Conference, 9th, 1053-1081; [2] Hewins (1983) Proceedings of the Lunar and Planetary Science Conference, 14th, B257-B266.; [3] Mittlefehldt et al., (1998) In Planetary Materials (Editor Papike J. J.), pp 4-1 to 4-195; [4] Powell (1971) Geochimica et Cosmochimica Acta, 35, 5-34; [5] Nehru et al., (1980) Geochimica et Cosmochimica Acta, 44, 1103-1118; [6] Ruzicka et al. (1994) Geochimica et Cosmochimica Acta, 58, 2725-2741; [7] Ruzicka (1998) American Journal of Science, 298, 1-29; [8] Andersen et al., (1993) Computers and Geosciences, 19, 1333-1350; [9] Evans and Frost (1975) Geochimica et Cosmochimica Acta, 39, 959-972.