Very high Ni olivine in a porphyritic cosmic spherule

M. S. Huber[1], S. Goderis[1,2], V. Debaille[1], and P. Claeys[1]. [1]Vrije Universiteit Brussel, Earth System Science, Dept. of Chemistry, BE-1050 Brussels, Belgium, matthew.huber@vub.ac.be, [2]Ghent University, Dept. of Analytical Chemistry, Krijgslaan 281 – S12, BE-9000 Gent, Belgium.

Cosmic spherules are dust particles of extraterrestrial origin that are melted during entry into Earth's atmosphere. The flux of such particles to Earth is approximately 40,000 tons per year [1]. Cosmic spherules typically have either glassy or quench textures. Over 1000 cosmic spherules and micrometeorites have been recovered from Widerøfjellet, Sør Rondane Mountains, Antarctica [2]. These cosmic spherules have a variety of textures and compositions.

A porphyritic cosmic spherule with an anomalous olivine has been found amongst the recovered cosmic spherules. The sample was embedded in epoxy and polished, with the resulting surface being mapped by electron microprobe and scanning electron microscope (SEM). The SEM images revealed a compositional zone in one of the large olivine crystals, which was revealed by electron microprobe to have 10.95 wt. % NiO, and a composition of $(Fe_{0.17}, Mg_{1.59}, Ni_{0.24})SiO_4$ (Figure 1). The surrounding olivine contains on average 2.6 wt. % NiO. The crystal structure was examined by Raman spectroscopy and determined to be consistent with olivine. High NiO abundances in olivine of cosmic spherules are sometimes associated with ablation spherules; however, the depletion of volatile elements suggests that this is not the case for this spherule [3].

To determine how such high percentages of NiO could be possible in a cosmic spherule, the MELTS program was used to model melting of precursors. Models used a range of 2000-1000 K to simulate total melting of chondritic precursors, with compositions taken from literature (i.e. [4]). High percentages of NiO were found to occur in olivine when melting an ordinary chondrite and allowing recrystallization in low redox conditions (Figure 2). The model also predicts low masses of crystallization of spinel (magnetite) prior to the crystallization of olivine, which is consistent with the petrographic observation of spinel crystals overgrown by olivine. The Ni-olivine zone is likely the result of changing crystallization conditions of the local melt. As can be seen in Figure 2, at the onset of crystallization of orthopyroxene, the Ni abundance of olivine temporarily increases. This is due to Mg preferentially entering orthopyroxene rather than olivine, resulting in Ni being more compatible with olivine for this period of crystallization.

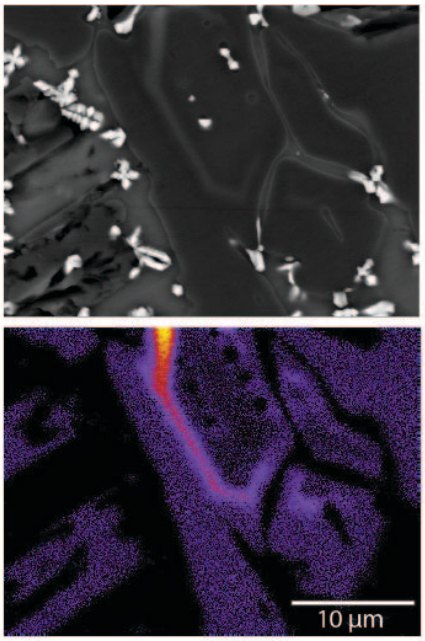

Figure 1: Top: SEM image of olivine in porphyritic cosmic spherule showing zone of high NiO. Bottom: Microprobe map of NiO in same sample. Yellow colors are highest abundance. The maximum measured NiO in this sample is 10.95 wt. % NiO.

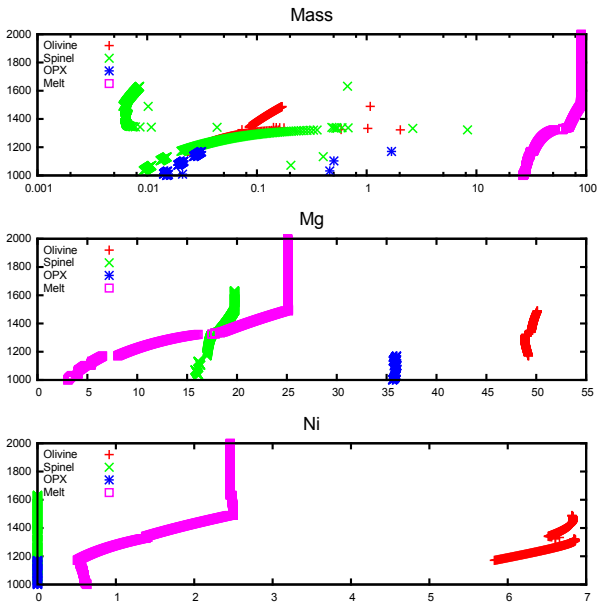

Figure 2 Results of MELTS model of melting ordinary chondrite. Top: Mass of crystallizing phases. Note logarithmic X scale. Middle: Abundance of Mg in each. Bottom: Abundance of Ni in each phase.

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