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Olivine plus partially molten iron-sulfide: The best proxy for the genesis of fragmented-, rounded-, and mixed-type-olivine pallasites

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The origin of pallasite meteorites, composed of olivine, FeNi, FeS +/- pyroxene, where olivine could be present as well-rounded grains or highly angular fragments, and occasionally both of them in close proximity (mixed-type pallasites) is still unclear. Most recent studies indicated mixing of Fe-Ni-S from an impactor's core with the silicate mantle of a planetesimal target body as the most likely mechanism for their formation. Yet, only end-member type experimental works (i.e. olivine+FeNi, olivine+Ni, olivine+molten FeS) were used to address the formation of equilibrium-like texture of rounded olivine-bearing pallasites and the origin of mixed-type samples remained unclear.

This novel investigation employs annealing experiments with olivine plus partially molten Fe(Ni)-S of a composition similar to those of average pallasite to define the grain growth rate of olivine. The resulting phase assemblage at experimental conditions consists of olivine + solid Fe(Ni) + FeS melt, which corresponds is identical to that present during natural pallasites formation. The grain growth rate was computed after digital image analysis of BSE images. Additionally a 2D finite-difference numerical model was employed to identify the best conditions (e.g., time of impact, depth of intrusion of the Fe-Ni-S) for the genesis of rounded olivine pallasites and to define a realistic scenario for the formation of mixed-type pallasites for the first time.

The results of annealing experiments indicate olivine grain growth rate in partially molten Fe-S as follows: d^n – d0^n = k0 exp(-Ea/RT) t, where, d is the grain size at time t, d0 is the starting grain size, n = 3.70 (61) the growth exponent, k0 = 3.20 μm^n s^-1 a characteristic constant, Ea = 101 (78) kJ/mol the activation energy for a specific growth process, R the gas constant, and T the absolute temperature. This is a substantially slower growth than in the case of olivine surrounded by FeS melt (i.e. n = 2.42). Yet, it is significantly faster than grain growth in olivine+FeNi or olivine+Ni experiments (n > 4 or 5) suggesting a key role of the type of matrix on the coarsening rate of olivine + non-silicate material at conditions relevant for the interior of planetesimals.