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The formation of pallasite meteorites. A combined experimental and numerical study

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Pallasites are stony-iron meteorites made of olivine, FeNi, FeS +/- pyroxene and other ancillary phases. The olivine is present as well-rounded grains or highly angular fragments, and occasionally both types (mixed-type pallasites). It has been suggested that mixing of Fe-Ni-S and olivine was caused by a non-destructive collision among planetesimals. Yet, this hypothesis needs to be tested and hitherto no attempt to reproduce the simultaneous presence of olivine, solid Fe(Ni) and molten FeS has been done.
In this study we performed experiments with olivine plus partially molten Fe(Ni)-S, a composition most similar to those of pallasite meteorites. The main goal was to define the grain growth rate of olivine surrounded by a matrix of Fe(Ni) and FeS melt. Additionally, a 2D finite-difference numerical model was used to define a realistic scenario (e.g., time of impact, depth of intrusion of the Fe-Ni-S) for the formation of rounded- and mixed-type pallasites for the first time.
Olivine grain growth rate in partially molten Fe-S follows: d ˆn – d0 ˆn = 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 ˆn s ˆ-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 grain growth than in the case of olivine surrounded by FeS melt (i.e. n = 2.42), but significantly faster than for olivine+FeNi or olivine+Ni (n > 4 or 5). We concluded that the grain growth rate limiting factor is the coarsening of solid Fe(Ni), which competes with olivine grain growth. This result is in good agreement with previous studies. What is more, we observed that the presence of FeS melt in contact with Fe(Ni) catalyzes the ripening of the latter, providing a strong explanation for a value of n < 4. The overarching conclusion of this study is that all main phases known to be present during annealing of a given silicate mineral must be reproduced experimentally in order to accurately define its growth rate, with simplified systems not suited for the scope.