

Formation conditions and chemical composition of early-condensed olivine in the solar system

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The conditions under which Mg-rich olivine formed in the solar system remain poorly constrained. The recent identification of metal-olivine inclusions (MOIs) in carbonaceous chondrites [1] provides a unique opportunity to investigate forsterite condensation. Our chemical and isotopic survey indicates gas-solid condensation, with Mg-rich olivines depleted in Ca, Al, and Ti. Combined with existing literature data, our findings support the condensation of both AOAs and MOIs under out-of-equilibrium conditions during transient, localized heating events in a thermally heterogeneous and dynamically evolving disk. A comparison with relict olivine grains in type I chondrules suggests that AOA-MOI association represent plausible type I chondrule precursors. These results challenge models proposing that Ca-Al-Ti-rich refractory forsterite predates chondrule formation. Instead, we argue that only Ca-Al-Ti-poor olivine retains information about the nature and conditions of early chondrule precursors.

[1] Ebel, D et al. (2025) MAPS 60, 757-777.