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Dihedral angles and element partitioning between metallic liquids and perovskite at lower mantle conditions

C. Liebske (1), M.W. Schmidt (1), W.van Westrenen (2)

(1) Institute for Mineralogy and Petrology, ETH Zuerich, 8092 Zuerich, Switzerland, (Christian.Liebske@erdw.ethz.ch); (2) Faculty of Earth and Life Sciences, Vrije Universiteit, 1081 HV Amsterdam, The Netherlands

The formation of the Earth's core may have involved porous flow of metallic liquids through a solid silicate matrix. Whether such a mechanism is likely depends on the interfacial energies between liquids and silicates, which can be expressed in terms of the dihedral angle that forms at the junction of e.g. two adjacent mineral grains and metallic liquid. At low dihedral angles ($<60^\circ$) the liquid can form an interconnected network and may allow percolative core-formation, while at higher values ($>60^\circ$), at sufficiently low melt fractions, some liquid would be stranded in the silicate matrix, resulting in an inefficient core-formation. A number of studies investigated textural equilibrium between metallic liquids and upper mantle minerals and found dihedral angles too high for percolative core-formation. However, according to Earth accretion models, most likely, the planet became largely molten and core-forming liquids probably never passed through a solid upper mantle. If such a magma ocean extended well into the lower mantle, as geochemical evidence suggests, then investigation of textural and chemical equilibrium between metallic liquids and silicate perovskite, as the most dominant lower mantle phase, will be more appropriate to draw conclusions about possible mechanisms of core-formation.

In this study, we investigate dihedral angles and element partitioning between metallic liquids and a perovskitic matrix. Experiments are performed in a spherically constrained multianvil apparatus, using 14 mm sintered diamond cubes as second stage anvils. Pressure cells consist of Cr_2O_3-doped MgO octahedra with 7 mm edge length. Sintered diamond cubes have corner truncations of 2 mm. This experimental setup allows pressures of at least 36 GPa to be reached. Such pressures are required to investigate textural and chemical equilibrium between metallic liquids and silicate perovskite as a function of pressure, which potentially allows results to be extrapolated to higher pressures.

Preliminary results from an experiment performed at 31 GPa and 1500˚C show that the dihedral angle between a $Fe_{69}Ni_9S_{22}$ (at%) liquid and a typical lower mantle silicate perovskite composition (based on a peridotitic bulk mantle) is $\sim$83˚. The observed value is too high to allow core-formation by percolation of metallic liquids through a solidified, perovskite-dominated lower mantle in the early Earth. We will present data on dihedral angles as a function of pressure and composition of perovskite and liquids and we will investigate the partitioning of oxygen and silicon and moderately siderophile elements between these phases. The results will be discussed in the context of core-formation processes and geochemical signatures of the present-day mantle.