Permeability of Core-forming Melts: A Multidimensional Approach

H.C. WATSON[1], K.A. TODD[2], J. VAN DUESEN[1], K. SHI[1],
T. YU[3] AND Y. WANG[3]

[1]Department of Earth and Environmental Sciences, Rensselaer Polytechnic Intitute, Troy, NY, watsoh2@rpi.edu
[2]Department of Geology and Environmental Geosciences, Northern Illinois University, Dekalb, IL
[3]GSE-CARS, Advanced Photon Source, Argonne National Laboratory, Argonne, IL

It is well accepted that the Earth formed by the accretion and collision of small (10-100km) planetesimals. Isotopic evidence in meteorites suggests that the cores of these planetesimals formed within a relatively short time frame of a few million years. While a hot, deep magma ocean is a likely driving mechanism for core formation in large planetary bodies, it does not adequately explain differentiation and core formation in small planetesimals where wide-scale melting likely did not occur. In this case, efficient core formation requires that the metallic liquid is sufficiently well connected throughout a solid silicate matrix such that percolative flow is possible. At textural equilibrium, metallic melts are disconnected and unable to flow within an olivine matrix below a percolation threshold of 5-10 vol%. Shear deformation may act to increase connectedness of melt and permeability at or below this threshold, and thus may have contributed to rapid and efficient formation of planetesimal cores.

Experiments were performed to determine the effect of shear deformation on the distribution and permeability of core forming melts within a solid olivine matrix. Pre-synthesized samples of San Carlos olivine with 5-10 vol% FeS or FeSi were loaded into a rotational Drickamer apparatus at Sector 13 (GSE-CARS) at the Advanced Light Source. The samples were compressed to 2GPa, heated up to ~1200°C to melt the metallic phase, and then deformed by twisting the sample through several full turns. Three-dimensional images were collected *in-situ* using X-ray microtomography at regular intervals during the deformation to monitor the evolution of the microstructure and melt distribution. Fluid flow simulations using a lattice Boltzmann method were performed on the resulting digital volumes to calculate the permeability of the samples. The starting materials and post-run products were also examined by backscattered electron imaging to provide sub-micron resolution images. Although there is a clear evolution in the texture and distribution of melt in the deformed samples, the 3-dimensional flow simulations do not show a marked increase in permeability of samples bearing ~5 vol% melt. This is potentially a result of melt channels and networks created during deformation being too narrow to allow for efficient percolation.