Rheology of $CaGeO_3$ (perovskite)±MgO: Implications for multiphase flow in the lower mantle

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With a thickness of well over 2000 km, the lower mantle is the largest rocky layer in Earth and plays a critical role in controlling dynamics of deep earth. Mineralogical mantle models suggest that the lower mantle is dominated by (Mg,Fe)SiO_3 bridgmanite (SiBr) and (Mg,Fe)O ferropariclase (Fp). In addition to rheological properties of these individual minerals, knowledge of stress/strain partitioning among the phases and texture evolution during deformation is critical in understanding dynamic processes of the deep Earth. Currently, there is a lack of experimental studies on lower mantle rheological properties, because of the difficulties in conducting quantitative experimental studies under lower mantle pressure and temperature conditions. Here we examine rheological properties of a two-phase polycrystalline assembladge consisting of $CaGeO_3$ perovskite (GePv) and MgO, deformed in the D-DIA with strain rates of ~1 - 3×10^(-5) s^(-1) at high pressures and temperatures (up to 10 GPa and 1200 K, respectively), with bulk axial strains up to ~40%. Stresses within individual phases are measured directly using in-situ monochromatic x-ray diffraction. GePv is found to have a strength 3 - 4 times that of MgO, a ratio similar to that between SiBr and Fp. Thus strain is expected to partition primarily into MgO. Elasto-ViscoPlastic Self-Consistent modeling (EVPSC) is used to reproduce experimentally measured lattice strain and texture of the two phase aggregate. Recovered samples are examined using electron back scattered diffraction (EBSD) and scanning electron microscopy (SEM), to extract final microstructural information. These results are compared with deformation of single-phase $CaGeO_3$ perovskite polycrystals. Active slip systems of the two phases, partitioning of stress and strain in the composite aggregate, and textural development will be discussed, with potential implications to the lower mantle. We find that texture development, which depends primarily on the level of shear strain, has a fundamental influence on the bulk rheology of multi-phase assemblages. A texture-induced rheological transition is likely to occur in certain regions of the lower mantle, profoundly affecting convection patterns in the Earth.

Keywords: multi-phase rheology, lower mantle, convection, mantle dynamics