Large-strain deformation experiments under deep mantle conditions using a rotational Drickamer apparatus (RDA)

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Rheological properties and deformation microstructures (lattice-preferred orientation, grain-size evolution) in deep mantle minerals are critical to our understanding of global dynamics but quantitative deformation experiments at high-temperatures were limited to ∼0.3 GPa. To extend this pressure at least by a factor of 50 (i.e., 15 GPa), we have spent last ∼10 years to develop new techniques of high-pressure deformation ([*Karato and Rubie*, 1997; *Xu et al.*, 2005; *Yamazaki and Karato*, 2001]). A rotational Drickamer apparatus (RDA) is a result of this effort by which quantitative deformation experiments have been performed to ∼15 GPa and ∼1800 K to shear strains to ∼2 ([*Xu et al.*, 2005; *Yamazaki and Karato*, 2001]).

The apparatus is composed of a pair of opposed anvils (with a gasket) inserted in a cylinder. A thin sample is inserted in a sample space together with heater and other materials. After pressurization and annealing (to eliminate unwanted defects), a sample is sheared by rotating one of the anvils. Both stress and strain are monitored by synchrotron X-ray: stress from X-ray diffraction and strain by X-ray imaging using the technique developed by Don Weidner and his colleagues. We have made a number of modifications to adopt synchrotron techniques with RDA. Important modifications include the process of making a disk heater and X-ray transparent electrodes. As opposed to D-DIA where deformation experiments are conducted by the radial motion of anvils ([*Wang et al.*, 2003]), anvils in a RDA are supported in a similar way as static experiments. Consequently, deformation experiments can be performed at much higher (∼50%) pressures in RDA than in D-DIA if anvils with same material are used as demonstrated by the data ([*Xu et al.*, 2005]). In addition, the maximum strain achieved is much larger for RDA than for D-DIA that has two important consequences: (1) Microstructural development such as lattice-preferred orientation can be studied only at larges strains, and (2) steady-state rheological properties can only be determined when a sample shows steady-state rheology that is achieved (according to our results) only after several 10s%.

The RDA has been used to deform wadsleyite and olivine (in addition to Fe and (Mg,Fe)O). We have shown that a constant strain-rate experiment can be performed to P∼15 GPa and T∼1800 K, and the first stress-strain curves for wadsleyite and olivine were obtained under these conditions (for olivine to ∼11 GPa) ([*Nishihara et al.*, 2005]). We found: (1) there is a significant transient period (up to ∼20-40% strain) after which nearly steady-state deformation is achieved (this implies that results from low strain experiments significantly underestimate the steady-state strength), and (2) wadsleyite is somewhat stronger than olivine (a factor of 2-3) under the conditions so far explored.

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