The 456th Geodynamics Seminar

From modeling defects to the rheology of the Earth's interior

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Abstract

The nature of defects and plastic deformation mechanisms involved in the Earth's mineral constituents determine their rheology and have as such profound implications on the dynamics and evolution of our planet. A prominent example is solid-state mantle convection that occurs through the motion of crystal defects. So far, the behaviour of crystal defects under high pressure and temperature conditions in minerals of the Earth's interior remains barely understood.

Since the pressure and temperature conditions of the Earth's transition zone became accessible to plastic deformation experiments, it is possible to compare and combine results from experiments with those of theoretical studies. This is important since the transition zone may play a crucial role constraining the style, vigour and scale of global mantle convection through the fate of subducting slabs or rising mantle plumes. Together with evidence of seismic anisotropy of the upper mantle, it is generally accepted that dislocation creep is one of the most efficient ways to produce plastic strain in olivine. In the present study, a theroretical mineral physics approach is used to investigate and address the effective creep process(es) in both high pressure polymorphs of olivine: wadsleyite and ringwoodite. Starting at the atomic scale, we have been using a multi-scale approach to model thermally activated glide of dislocations (line defects) as they exist in wadsleyite and ringwoodite. The intrinsic properties of dislocation core structures are modeled through *ab initio* calculations to take carefully into account the effect of pressure on atomic bonding. Plastic deformation is finally described by dislocation dynamics based on the former results of glide and experimental data for climb. After validating the theoretical results with experiments, we show the inefficiency of dislocation glide as a strain producing mechanism in wadsleyite and ringwoodite under natural conditions in contrast to olivine in the Earth's upper mantle. The results show the importance of point-defect mediated diffusion and the potential existence of an efficient deformation mechanism operating in the high-pressure silicates of the transition zone: pure climb creep. The latter would imply the mantle transition zone to be rheologically distinct from the upper mantle.

The latter study, among others, proposes that point defect diffusion may control plastic deformation of deep Earth minerals and hence the viscosity structure of the Earth's interior. Motivated by the latter, I have been starting to study vacancy diffusion in the high pressure polymorphs of Fe at inner core conditions by *ab initio* calculations. Preliminary results show that high pressure changes the atomic bonding which leads to (very) low intrinsic vacancy concentrations. Extrinsic diffusion mechanisms are required that allow for vacancy diffusion to occur.

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