Electical conductivity of polycrystalline olivine

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Small fractions of melt are present in many geodynamic environments in the crust and upper mantle. The occurrence of melt can result in drastic weakening with important consequences for tectonic processes such as spreading, rifting, subduction and formation of continental lithosphere. The influence of melt is controlled by melt fraction and distribution. However, a systematic understanding of the parameters that control melt distribution is lacking. The aim of this study is to develop improved models for melt distribution in mantle rocks and the effects of melt on rheology and other physical properties, using in-situ conductivity measurements.

With frequency dependent electrical conductivity experiments it is possible to measure quantitative transport properties of polycrystalline samples with melt present. We have decided to start with fine-grained forsterite (Mg_2SiO_4), the pure Mg-end-member of olivine, with a minor amount (5%) of enstatite ($MgSiO_3$) added. The first experiments on dry forsterite give us a reference to which the melt-impregnated samples can be compared. This is needed in order to be able to separate the signal of the dry material from the signal of the melt-phase. Three samples were used for the first experiments, one with a relatively high porosity (13%, sample Fo2), and two samples with a lower porosity (± 6.5 (Fo4) and 1.8% (Fo5)). The porosity is reduced by sintering the samples several hours at 1450 °C. The grain size of the samples increases during sintering, therefore the sample with the lowest porosity (Fo5) has the largest grain size and the sample with 13% porosity (Fo2) the smallest grain size (1 μm). At a certain temperature the sample with the highest porosity has the highest conductivity and visa versa. The mechanism for conduction is probably the generation of holes and cation vacancies by incorporation of oxygen into the lattice. The availability of oxygen is easiest for sample Fo2 due to the large pore space and the small grain size. This could explain the difference in conductivity between the three samples. At high temperatures the pore volume of sample Fo2 is reduced quickly and simultaneously also the conductivity. Sample Fo5 was heated to a maximum temperature of 1500°C. At this temperature a very small amount of material starts to melt which immediately leads to a strong increase in conductivity.

At the moment first measurements are performed on melt-infiltrated samples. The synthetic melt added to the samples consists of MgO, SiO_2 and Al_2O_3. Preliminary results show that below the melting temperature the conductivity of these samples is very similar to the dry samples. Above the melting temperature there is a strong increase in electrical conductivity compared to that of the dry samples.