Experimental Investigation of the Effect of Shear on the Electrical Properties of Polycrystalline Olivine and the Role of Grain Boundaries

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Sheared rocks are thought to explain electrical anomalies in a deformed uppermost mantle as their high electrical conductivity and anisotropy reproduce electromagnetic data. Although it has been suggested that melt is required to reproduce asthenospheric electrical anisotropy, the electrical properties of the sheared polycrystalline matrix and its contribution to bulk electrical anisotropy at upper mantle conditions are not fully understood and require further investigation.

We present a systematic experimental investigation of the effect of shear deformation on the electrical conductivity of polycrystalline olivine (Fo_{90}). Starting samples were sheared at 1200°C and 0.3GPa in a gas-medium apparatus to a strain of up to 7.3. Electrical conductivity and anisotropy of the samples were measured at 3GPa over the temperature range ~700-1300°C in a multi-anvil apparatus using a two-electrode technique.

We observe that shear deformation increases electrical conductivity and that a significant anisotropy characterizes the conductivity of the shear samples: conductivity is highest in the direction of shear, with the sample deformed to the highest strain being the most conductive. Electrical anisotropy is higher at low temperature than at high temperature. For a similar shear strain, comparison with previous work on melt-bearing sheared samples shows that melt increases bulk conductivity but that melt-free samples deformed to high strain are more conductive than melt-bearing samples deformed to low strain. The role of grain boundaries on conduction mechanisms is investigated based on textural analyses and comparison with electrical data on olivine single crystals and undeformed polycrystalline olivine.

No simple model can explain jointly the electrical data and the samples' texture, as underlined by the lack of a clear correlation between grain size of sheared samples and conductivity. We propose that the measured electrical anisotropy could be due to (a) shape preferred orientation and/or (b) special, high-conductivity grain boundaries associated with the crystallographic preferred orientation. Our experimental data also suggest that the interpretation of electromagnetic data in the uppermost mantle requires considering the effect of rock deformation on the bulk electrical response, instead of attributing high electrical conductivities solely to rock chemistry (presence of hydrogen and/or melt).