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Simultaneous measurements of creep strength and electron conductivity of polycrystalline olivine

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It is important to know the value of activation energy with a small error range for creep of geomaterials when we apply an experimentally obtained flow law to the geological conditions. This study reports the result of uniaxial compression experiments of polycrystalline forsterite at atmospheric pressure and high temperature in order to analyze the change of flow stress and deformation mechanism with temperature. In addition, we also report the result of the measurements of electrical conductivity using an impedance technique. Creep rate is controlled by diffusion process of the slowest ionic species in the crystal whereas electrical conductivity is controlled by the process of the fastest one. We expect to understand the detail of diffusion mechanism, which controls the creep rate, with the help of electrical conductivity. Such studies will allow us to predict the rate controlling process of flow in the Earth interior.

The polycrystalline sample is composed of forsterite (Mg_2SiO_4) and enstataite ($MgSiO_3$), where their volume fractions are 90% and 10%, respectively. Instron-type testing machine equipped with tubular furnace was used for compression creep experiments. Prior to the compression experiment, grain size in the sample was saturated by heating at 1360^{o}C for 24 hours to inhibit grain growth during the experiment. We measured electrical conductivity over range of 1360 - 1200^{o}C at constant normal stresses of 10 and 20 MPa and under decreasing temperature with the rates of 0.11^{o}C/min, 0.03^{o}C/min and 0.02^{o}C/min at high, mid and low temperatures, respectively. Such slow cooling rates can provide enough strain of the sample at each temperature so that the relationship between the stress and strain rate at all temperatures is obtained. We also measured impedance of the sample at every 10^{o}C from 1360^{o}C to 1200^{o}C. This impedance is obtained from the relationship between voltage and current, which are measured when voltage of 2V was applied to electrodes of SiC. After the experiment, the sample microstructure was analyzed by scanning electron microscopy to know sample grain size. Viscosity - temperature relationship was analyzed by Arrhenius plots of stress divided by strain rate obtaining the activation energy of 706+-1kJ/mol. This result shows that the diffusion mechanism during this experiment did not change indicating that our obtained flow law can be applied to the Earth's interior where lower temperature condition than that in the experiments. The result of impedance measurement showed that electrical conductivity systematically decreased with decreasing temperature.

Keywords: olivine, creep, polycrystal, activation energy, electrical conductivity, impedance