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# Electrical conductivities of pyrope-almandine garnets up to 19 GPa and 1700 °C

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## ABSTRACT

Electrical conductivities of polycrystalline garnets ranging in chemical composition from almandine ($Fe_3Al_2Si_3O_{12}$) to pyrope ($Mg_3Al_2Si_3O_{12}$) were measured at 10 GPa and 19 GPa at temperatures ranging from 300 to 1700 °C using complex impedance spectroscopy in a multianvil device. Mössbauer spectroscopy of each sample was carried out both before and after the electrical measurements to characterize the oxidation state of Fe in the almandine bearing garnets. Similar to the behavior of other ferromagnesian silicates, the substitution of Fe for Mg along this compositional join dramatically increases electrical conductivity, but this compositional effect is reduced with increasing temperature. Conductivities increase with increasing total Fe content, as the average $Fe^{2+}$-$Fe^{3+}$ distance decreases. At 10 GPa, activation energies for conductivity vary smoothly with composition and increase rapidly toward the pyrope end-member composition, where it reaches a value of 2.5 eV. The results are consistent with an electrical conductivity mechanism involving small polaron mobility in the Fe-bearing garnets at 10 GPa. At 19 GPa, however, there is virtually no change in the activation energy as a function of Fe-Mg substitution for the pyrope-rich garnets. These higher pressure measurements reflect a mechanism involving oxygen related point defects, as conductivities increase with pressure at constant *T* for each garnet, and the effect of pressure is greater for the more Mg-rich garnets. The data also allow for a more quantitative evaluation of the effect of chemical composition, specifically Fe-Mg substitution, on the electrical conductivity profile of the mantle, using a recently developed laboratory-derived model. We apply the model using these data to a portion of the transition zone between 520 and 660 km, in which we vary the garnet composition from $Py_{100}$ to $Py_{85}Alm_{15}$. Although only a minor effect on bulk mantle conductivity results, we conclude that the overall garnet composition may, however, be important in characterizing the magnitude of any EC discontinuity with respect to the above-lying mantle.

**Keywords:** Electrical conductivity, pyrope-almandine, high pressure, cation substitution