Effect of Fluid and Oxide on Electrical Conductivity of Rock

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SUMMARY

Electrical conductivity measurements of rhyolitic and basaltic rocks were conducted under high temperature conditions. From the specific data, we observed minor electrical conductivity variation around the glass transition temperature. To interpret the measured conductivity data, we applied a neural network computation to the prediction of the electrical conductivity of rock. We also studied on the conduction mechanism within the tock utilizing a cell-type lattice constitutive model.

Keywords: Electrical conductivity, fluid, oxide, glass transition temperature

INTRODUCTION

We have been studying the physical properties of rock and mineral to interpret the subsurface structure of the Earth. In particular, electrical conductivity is an important physical parameter to study the conductivity structure in the Earth. We performed electrical conductivity measurements of rhyolite glasses and basaltic glasses across the glass transition temperature. Our experimental data show that, in an Arrhenius plot, the conductivity of rhyolite has an inflection point. The inflection points correlate with the glass transition temperature, and are compared with results of previous experiments.

We also conducted theoretical study for rock by using the Neural Network Analysis and random network model.

In this workshop, we introduce experimental and theoretical approaches to investigate the effect of oxide and fluid on electrical conductivity of rock

Method

We synthesized rhyolite and basaltic glasses using the piston cylinder apparatus. Glass samples were synthesized at 1GPa. Electrical conductivity measurements were conducted using DIA-type cubic anvil press. In our experiments, the sample assembly was designed to have high insulation resistance. The cell assembly mainly consists of pyrophyllite, ZrO_2, Al_2O_3 and MgO to keep high insulation as shown in Figure 1. Before starting conductivity measurement, the assembly was pre-heated below 500-600 K to exclude the contained water and moisture. The glass sample was surrounded by single crystal material. To avoid chemical reaction between sample and surrounded material, we conducted preparatory experiments and carefully inspected reactivity using the SEM.

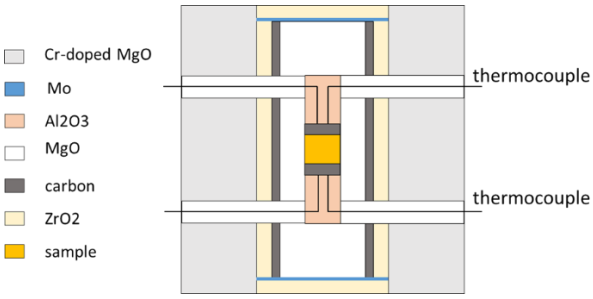

Figure 1. Schematic cross-section of assembly used for electrical conductivity measurements. To maintain high insulation, the cell assembly mainly consists of pyrophyllite, ZrO_2, and MgO. Two pairs of $W_{97}Re_3$–$W_{75}Re_{25}$ thermocouples were used to accurately measure temperature. The reaction between the sample and capsule was examined in advance.

We also applied a neural network computation to the prediction of the electrical conductivity of volcanic rock. Neural network calculations precisely reproduced the experimental data for the electrical conductivity of rock.

In addition, we developed a cell-type lattice constitutive model and used a random number generation scheme to construct natural mineral distribution patterns of rock. Using this model, we studied on the connectivity of neighboring cells.

Results

After conducting pre-heating to purge contained water and moisture around the assembly, stable conductivity data were obtained. Between 500 and 1600 K, the conductivity of rhyolite seemed to stabilize and show linear trend as expected from Arrhenius equation. We succeeded in electrical conductivity measurement to have stable and reversible values up to 1600 K. The conductivity linearly increased with increasing temperature. Using the linear trend of Arrhenius law, the activation energy of the sample was estimated. From the specific data, we observed minor electrical conductivity variation around the glass transition temperature as shown in Figure 2.

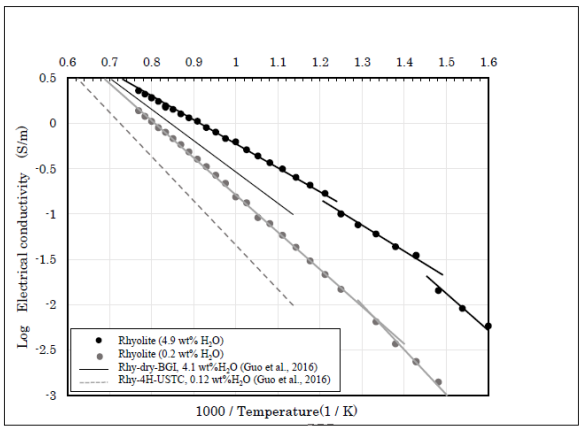

Figure 2. Electrical conductivity of rhyolite glasses. A minor conductivity change can be seen for the rhyolite glasses with 0.2 and 4.9 wt% H_2O and showed two different gradients of the Arrhenius lines.

In the low-temperature range, the conductivity of the rhyolitic samples showed a linear trend, as expected from the Arrhenius equation. In the high-temperature region, we did not observe a clear linearity in conductivity up to 1500 K in either the dry or wet rhyolitic sample; however, we observed minor changes in electrical conductivity around their glass transition temperatures. Our data show that the Arrhenius behavior of rhyolite with 0.2 wt% H_2O has an inflection point around 760 K. The activation energy of rhyolitic glass with 4.9 wt% H_2O varies and the gradient of conductivity changes between 685 and 825 K.

A new method for estimating the electrical conductivity of rock through neural network calculations is utilized. A layer type neural network, which includes an input layer, a middle layer and an output layer, is used in the present work, as shown in Figure 3.

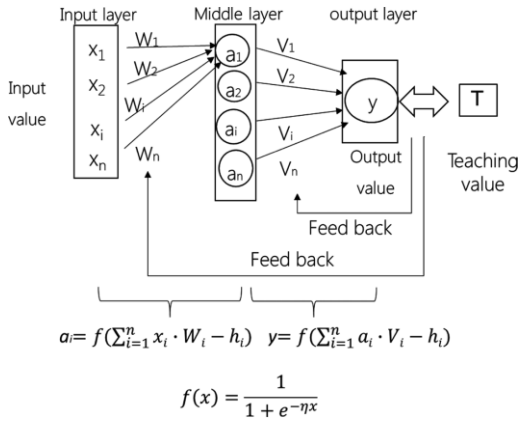

Figure 3. Schematic diagram of layered neural network used in neural network computation.

Conclusions

We conducted electrical conductivity measurements of rhyolitic and basaltic glasses as a function of temperature. We observed minor changes in electrical conductivity around their glass transition temperatures. Our experimental results can constrain the degree of welding of clastic and hydrous rock. The neural network calculations precisely reproduced the experimental data for the electrical conductivity of rock. The neural network was capable of accurately estimating the electrical conductivity of various types of chemical composition of rock.

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References

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