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Seebeck Coefficient of Gabbro under Non-uniform Stress

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When a terminal of an air-dried igneous rock block is uniaxially loaded to form the non-uniform stress in the block at a room temperature, there appears the electromotive force that makes electric current flow from the stressed volume to the unstressed volume. Quartz-free gabbro tends to generate the stronger electromotive force than quartz-rich granite. Therefore, it is inconsistent to consider piezo-electric effect as the cause of this electromotive force. To explain this force, we have expected that positive charge carriers (holes) are generated in the stressed volume and flow into the unstressed volume. This will be the source of the electromotive force induced by non-uniform stress. However, we do not yet obtain reliable evidence for the activation/spread of positive holes. In this study, we measured thermoelectromotive force of air-dried gabbro blocks whose one terminal was uniaxially loaded/unloaded. We verified the activation/spread of positive holes from the increase/decrease of the Seebeck coefficient during loading/unloading. The hotter temperature was about 150 deg. C., the colder was about 30 deg. C., and the temperature difference was about 120 deg. C. The results indicated that the Seebeck coefficient of the gabbro without loading was about 0.8-1.2mV/K, meaning the majority of charge carriers are hole. On the other hand, the Seebeck coefficient of the volume under 60MPa of stress decreased to about 0.5-0.7mV/K, and that of the volume under stress free did not remarkably change. This meant that the concentration of holes increased in the stressed volume and such a change was little in the unstressed volume. In conclusion, it was clarified that holes were activated in the stressed volume and the distribution of the holes spreading reached only near around the stressed volume. As the source of the holes, we have focused on peroxy bonds, one of the most popular lattice defects in igneous rock-forming minerals, e.g., $O_3Si\text{-}OO\text{-}SiO_3$ in quartz. When this bond is deformed by mechanical force, an antibonding energy level of this bond shifts down into the Valence band and an electron can jump in this level from a neighbor oxygen site. As a result, a positive hole is activated in this neighbor site and an electron is trapped in the deformed peroxy bond. Once positive holes are activated, they can spread away through the Valence band. Provably, only a little part of the positive holes reached the unstressed edge. The slant in the distribution between these positive holes and the electrons trapped at the deformed peroxy bonds, i.e., the electric polarization in the stressed volume, is the source of the electromotive force induced by non-uniform loading.

Keywords: Igneous rock, Electromotive force, Seebeck coefficient, Lattice defect, Positive hole