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Rectifying sulfide minerals and application of geoelectric phenomena

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Various geoelectric phenomena, such as self-potential anomalies and electromagnetic radiation induced by volcanic eruptions and earthquakes have been known. Although various models have been proposed as a mechanism of electromagnetic phenomena, its origin is not fully understood. Recent research proposes that semiconductor minerals are involved in electromagnetic phenomena (e.g. Sobolev et al., 1982). For example, negative self-potential anomaly is observed in the upper ore body, and the radio wave (30 kHz - 3 MHz) is triggered at the ore body by seismic wave. Semiconductor minerals are divided into n- or p-type and form p-n junctions. Rectifying property of the junction would particularly affect the geoelectric phenomena. Natural ore body contains a lot of micro p-n junctions which connect in parallel or in series and they can be equivalent to a single p-n junction at large scale. Therefore clarifying the electric property of micro p-n junction leads to the understanding of semiconductor property of natural ore body. However, due to the defect and trace elements, the composition and electric properties of natural semiconductor minerals are heterogeneous. For this reason, a quantitative understanding of electric properties of semiconductor minerals is not clear yet.

In this research, we measure the electrical properties of the pyrite to discuss the relation between geoelectric phenomena and semiconductor minerals. In order to understand heterogeneity of the mineral surface we apply the electrolytic etching method. We also use the indentation method to reveal electric characteristics of a given small region. Natural pyrites from Waga-Sennin ore were used. Its area of cross section is 1.4 cm^2 and thickness of 0.38 cm.

In the electrolytic etching method, pyrite is reduced. As a result, pyrite surface shows macro-etching patterns attributed to the difference in solubility and some macro-etching patterns show zonal structures. The variation in solubility is due to the difference in conduction mechanism. P-type regions have a higher solubility than n-type regions. In the zonal structure, the properties of p- or n-type alternately change at narrow range (several dozen to several hundred millimeters). Electrical conductivity of the p-type region is greater than of the n-type region, so electric current preferentially flows into n-type region about ten times larger than p-type region. At the p-n junction region, rectifying property is observed. By eliminating to the effect of internal resistances in the sample, we can get semiconductor properties, such as forward and reverse break down voltages of p-n junction.

The reverse breakdown voltage of the p-n junction is close to the maximum voltage for the generation of radio waves when voltages were applied to the ore body in the laboratory experiment (Maibuk, 2006). It is considered that the radio wave is generated by discharge at p-n junction which is triggered by electric pulses. Our result supports this trigger mechanism. Further, it suggests that the electric pulses generated by elastic waves during earthquake can be triggered to radio waves radiation. Negative self-potential anomaly is observed above the ore body, due to the geothermal gradient or redox potentials difference in groundwater. It makes galvanization system: top and bottom ore body act as a cathode and anode respectively, and ground water behave as an electrolyte. If the ore body is regard as a single large p-n junction, the breakdown forward voltage of the p-n junction of the ore body corresponds to the electromotive force generated by galvanization process. Therefore the amplitude of the self-potential anomaly in an ore body could be estimated by investigating the properties of various semiconductor minerals.

In conclusions, it became clear that semiconductor minerals play an important role in geoelectric phenomena and we need further research on electric properties of semiconductor minerals.

Keywords: semiconductor minerals, rectification, geoelectric phenomena, pyrite