

Electromagnetic emissions from fracture of semiconductor pyrite

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Introduction

When elastic waves propagate in orebodies composed of semiconductor minerals, electromagnetic (EM) radiation with radio frequency occurs. Its frequencies were 10-100 times higher than those of the elastic waves. They were observed by geophysical exploration surveys and laboratory experiments. These previous studies suggested that generation of radio waves is closely related to the rectifying property of orebodies which is attributed to semiconductor minerals. Semiconductor minerals are divided into p- or n-type conductivity by its charge carrier. When p- and n-type are joined, the resulting junction (p-n junction) has the rectifying property. Because many p-n junctions of semiconductor minerals exist as which connect in parallel and in series in the orebody, they also show rectifying property. Previous research measured only large scale rectifying property of orebody to understand the generation mechanism of radio wave. However, due to the lack of the measurement of rectifying properties of each micro p-n junction in semiconductor minerals, quantities evaluation was difficult.

Composition of semiconductor minerals is heterogeneous due to the presence of impurities and lattice defects. Because rectifying property depends crucially on the composition, clarifying the composition at each micro region is needed. In this research, we measured the composition and rectifying property of semiconductor pyrite to discuss the possibility of EM emission from the ore bodies.

Methods

Semiconductor pyrite sample was obtained from Waga-Sennin mine, Akita prefecture, Japan. It was cut into slabs with a thickness of about 0.38 cm and an area of 1.4 cm².

We obtained composition of the sample surface by electroetching method and SEM-EDS. Thermal probing method allowed us to discriminate between p- and n-type conductivity. By electrical probing, we quantified the rectifying properties.

Results

After the electrolytic etching, heterogeneity of composition in the sample surface was emerged as the difference in solubility. The difference of solubility caused etching figure and zonal structures. Thermal probe method revealed that the differences of p-n type regions corresponded to the difference in solubility of each region. P-types regions showed a higher solubility than n-type regions. According to the SEM-EDS analysis, about 1.0 wt.% of Pb inclusions were precipitated parallel to crystallographic planes in the p-type regions.

In the electrical probing method, rectifying effects were observed at p-n junctions. We obtained the current and voltage characteristic of p-n junction. The reverse and forward breakdown voltages were estimated to be 1.5 V and 0.3 V, respectively.

Discussion and conclusion

When two types of rocks make contact, electrons move between the surfaces of rocks, producing the potential difference between them. This electrification becomes a possible source of EM radiations during separating rocks. If we regard p- and n-type semiconductor minerals as the two types of rocks, the contact potential is given by the forward breakdown voltage of p-n junction. When the junction is split into two pieces, separated surface can be regarded as capacitance plates. If the surface charge density of plates reaches the Paschen's minimum charge density of breakdown (e.g. air 5.0×10^{-5} C/m²), corona discharge occurs. We estimated the charge density of separated plates at p-n junction to be 2.7×10^{-4} C/m². Given the effect of charge relaxation, we must take into account separation velocity of plates. In this case the critical separation velocity to cause corona discharge is estimated to be 2.0 km/s. Therefore, it is expected that the pyrite fractured by propagation speed higher than 2.0 km/s can cause corona discharge.

In conclusion, the fracturing of pyrite becomes a possible source of EM radiations. Further investigation is needed to clarify the properties (e.g. frequency) of EM radiations from the orebodies.

Keywords: Seismic electromagnetic signals, Semiconductor minerals, Radio wave, P-n junction