§ 8. A Proposal of Nernst-Seebeck Element for High Energy Conversion

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In order to improve the energy efficiency of the thermoelectric conversion, the research has been done for long time. However, the conversion efficiency is not high and thermoelectric conversion is not a common technology. The principle of the energy conversion depends on the Seebeck effect, and the efficiency only depends on the characteristics of the materials, and in this meaning the major study is the material research.

Here, we propose the other way to improve the conversion efficiency, and the principle of the proposal depends on the magnetic field effects. The magnetic field effects were also studied for a long time[1], and there are two types of the magnetic field effects. One is called "magneto-Seebeck effect", and the effect of the magnetic field was positive for the bismuth-antimony alloys. When the magnetic field was applied, the electrical resistivity is increased, the thermal conductivity was decreased and the Seebeck coefficient was peaked. Therefore, the figure of merit was improved twice at the optimum magnetic field. The other magnetic field effect was "Nernst effect", and the induced electric field is perpendicular to the direction of the magnetic field and the temperature gradient. Once, this effect was studied as Ettingshausen cooling device[2] like a Peltier cooling element, and the temperature difference exceeded 100 degree. Since the direction of the Seebeck electric field is parallel to the temperature gradient, these electric fields are perpendicular to each other.

We can propose a new element as shown in the figure 1.

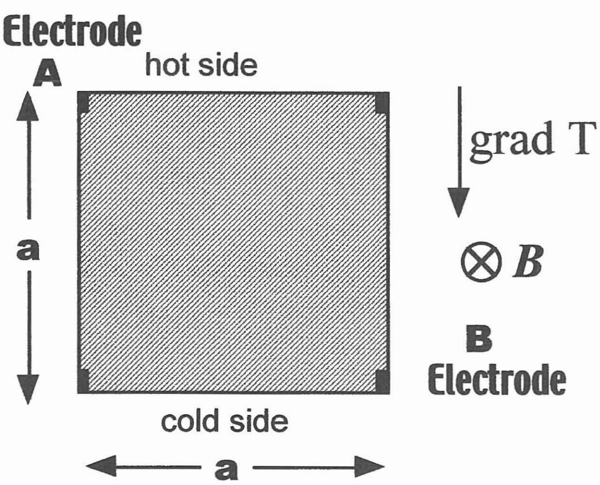

Fig. 1. A proposed the shape of the element, its magnetic field and temperature difference.

The upper side of the element is the hot side and the lower side is the cold side, the magnetic field is applied to the perpendicular to the sheet. Therefore, we can expect the direction of the Seebeck voltage is the vertical direction, and the Nernst voltage is the horizontal direction. The electrodes are connected to the each ends of the square, and therefore we can expect that the voltage between the electrodes of A and B is the sum of the Seebeck and Nernst voltages in the figure 1.

This kind of the configuration is only available for the electric generation element, and not for the cooling element because the current of the cooling element is several times larger than that of the electric generation element. Therefore, the size of the electrode should be bigger for the cooling elements, and the electrode is contacted to all surfaces of the hot and cold sides individually for the cooling element.

The figure 2 shows the thermoelectric powers from Seebeck and Nernst effects. The material is the poly-crystal bismuth.

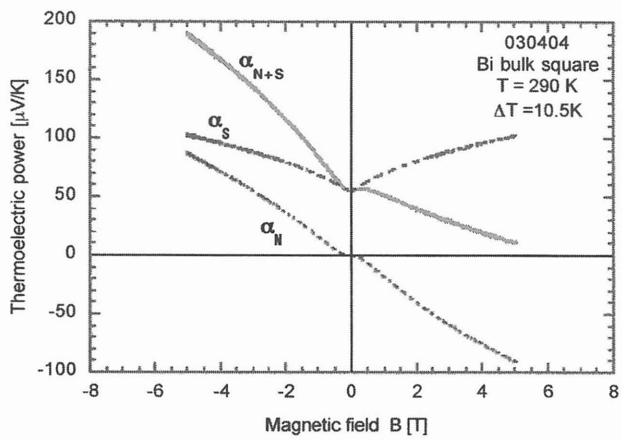

Fig. 2. Thermoelectric powers of Seebeck and Nernst effects under magnetic field, normalized for the zero magnetic field.

α_{N+S} shows the sum of the Nernst and Seebeck thermoelectric powers, and α_S and α_N show the Seebeck and the Nersnt thermoelectric powers, respectively. Even at the temperature of 290 K, the thermoelectric power is enhanced by 3.4 times at the magnetic field of -5T, and the magnetic field effect is strong in low temperature. Actually, the ratio of the thermoelectric power is 8 times at the temperature of 100 K and the magnetic field of -1.5 T for this new proposal element. The experiment also shows that the figure of merit is enhanced by 4 times below room temperature. Moreover, the heat process by the Seebeck effect is different from that of the Nersnt effect, and if the figure of merit is same, the conversion efficiency of the Nernst effect is higher than that of the Seebeck effect[3]. Therefore, this is one of the ways to improve the efficiency in thermoelectric conversion.

References

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