Optically active thermoelectric materials

Ichiro Terasaki
Department of Physics, Nagoya University

Renewable energy is one of the most important and challenging issues for the sustainable society of the human beings, especially for this country. Since the horrible disaster on the 11th March 2011, new energy resources other than nuclear power have been highly desired, searched, or even demanded. Thermoelectrics and photovoltaics are prime candidates, both of which are waiting for epoch-making break-through to improve their efficiencies. We have been struggling to find a way to combine these two energy conversion techniques in order to overcome the technological limitation of the efficiency. The project name is "optically active thermoelectric materials."

One direction is a search for the photo-Seebeck effect. The photo Seebeck effect is that a finite voltage is induced by photo-excited carriers in the presence of a temperature difference across the sample. We have found that the Seebeck coefficient of a high-purity ZnO single crystal changes from 2-3 mV/K down to 100-200 μV/K with increasing ultraviolet light intensity [1]. Based on a simple two-layer model, we evaluate the carrier density by photo doping to be 0.1 % per unit cell (10^{19} cm^{-3}), which is in principle enough to achieve an optimum carrier concentration for the maximum ZT. This technology can be easily mounted on a solar cell, and can help to increase the efficiency using ultraviolet light that is not used by the solar cell. We have proposed that a thermoelectric power generator with a large Seebeck coefficient is useful in oxide thermoelectrics [2]. The photo-doping is also applicable to such generators, because it can control a carrier concentration less than 0.1% per unit cell that is difficult to be achieved using conventional chemical doping.

The second direction is to fabricate a trial product of thermoelectric power generator using black body radiation as a heat source. As is widely accepted, heat is difficult to control; it cannot be confined, transported, and stored well. In contrast, light is easy to control; it can be transmitted, reflected, focused, and converted into other forms of energy. Thus we aim at establishing a technology to control black body radiation -- light from heat. To do this, we have prepared a thermoelectric uni-couple consisting only of oxide single crystals, and have set up a characterization system using a focused halogen light [3]. A large temperature difference of 500 K is generated across a 1-cm-long sample, whose efficiency is evaluated to be 2% at maximum.

This project is supported by the Advanced Low-Carbon Technology Research and Development Program (ALCA), Japan Science and Technology Agency. The author appreciate Ryuji Okazaki, Yukio Yasui, Ayaka Horikawa and Yu-Chin Hsieh for collaboration.

References

[1] R. Okazaki et al., submitted to J. Phys. Soc. Jpn.
[2] I. Terasaki, J. Appl. Phys. **110**, 053705 (2011).
[3] Y-C Hsieh et al., International Conference on Thermoelectrics 2012.