MERIT internship report

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Theme	Thermoelectric materials and modules

Backgrounds

Thermoelectric materials are functional materials that can convert heat into electricity directly. In recent years, thermoelectric materials have received a great amount of attention because they can contribute to the global energy demand by waste-heat energy harvesting. However, thermoelectric materials are inferior to other renewable energy devices because of their low conversion efficiency and durability. In order to spread the thermoelectric material as an electric generator of next decade, it is essential to improve efficiency and durability. I worked on improving thermoelectric materials in terms of durability in this internship.

Motivations

Most of state-of-the-art thermoelectric materials are composed of toxic and/or expensive elements such as lead, tellurium, and germanium. I research on the novel thermoelectric materials with harmless and low-cost elements at the university because if high-performance thermoelectric materials with environmentally benign and low-cost elements are realized, it will accelerate the market expansion of thermoelectric materials. However, as I mentioned above, durability of thermoelectric materials also plays an important role as well. I have never studied the durability of thermoelectric materials and therefore I was interested in this internship.

Research activities

Thermoelectric modules are composed of many thermoelectric couples consisting of n-type and p-type (see Fig. 1). Since the upper side of thermoelectric modules is heated at 300 ℃–500 ℃ for automotive applications, it is required that electric contact should be maintained but atomic

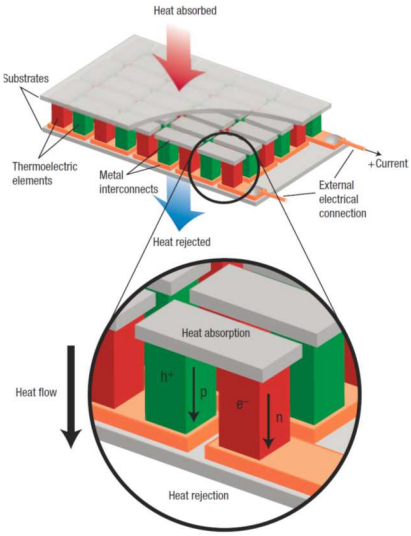

Fig.1 thermoelectric modules[1].

interdiffusion between thermoelectric materials and electrodes should be restricted. Thermoelectric materials and electrodes are bonded together with solder (melting point, T_M: ~200 ℃), silver paste (T_M: ~650 °C), or copper paste (T_M: ~1000 °C). However, tellurium, which most of state-of-the-art thermoelectric materials contain, forms eutectic melt with silver or copper at about 350 °C. The eutectic reaction enhances atomic diffusion between the interfaces and causes a decrease of the efficiency and durability of thermoelectric modules. For protecting the interfaces against interdiffusion at high temperature, the diffusion barrier layer must be galvanized or deposited between the interfaces.

In this internship, I prepared samples which were the thermoelectric materials with thin diffusion barrier layers. The samples were annealed and I evaluated the interdiffusion reaction between the barrier layer and thermoelectric material by scanning electron microprobe and X-ray diffraction. The coated elements were assembled to modules and I-V and P-I properties were measured.

1) Snyder, G. Jeffrey, and Eric S. Toberer. Nature Materials 7.2 (2008): 105.

Feedbacks

In the field of thermoelectric materials, it is a fact that most researchers are focusing on the physical properties. At this year's International Conference on Thermoelectrics, only 20% of oral presentations were about researches related to modules (i.e. barrier layers, solder, and applications) and the rest were on the physical properties. Actually, I focused only on the physical properties before this internship, too. However, after completing this internship program, I found the deep depth of the research related to modules and there still remain some problems to be resolved before the market expansion of thermoelectric materials. Although a lot of new thermoelectric materials with excellent physical properties were recently found, most of them seem to have some problems (i.e. sublimation, degradation, interdiffusion and so on) in terms of assembling modules. I felt that researchers interested in the physical properties should also study about modules related technology, then more thermoelectric materials suitable for modules will be found and leading to the market expansion.

Acknowledgements

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