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Development of oxide-based nanostructured thermoelectric materials

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Nano-structure control is the key for the realization of high-performance thermoelectric material. The effectiveness of nano-structure control was theoretically predicted by Dresselhaus (MIT) *et al*. in 1993[1]. After that, high *ZT* value (>2) has been reported one after another. There are two approaches of nano-structure control for the realization of high-performance thermoelectric materials. One is to enhance the thermopower by utilizing quantum electron confinement effect. Thermopower of quantum well (QW) structures increases drastically with a decrease in the thickness of QW when the thickness becomes less than the thermal de Broglie wavelength. The other one is to reduce the thermal conductivity based on "phonon-glass electron-crystal" concept (Slack, 1995).

The former scenario was demonstrated experimentally using an oxide thermoelectric material, $SrTiO_3$. High-density (~10^{21} cm^{-3}) two-dimensional electron layers in $SrTiO_3$ crystal exhibits giant thermopower when the layer thickness is as thin as a few nanometers[2–4]. Two-dimensional electron layer of $SrTiO_3$ can be fabricated in superlattices[2] composed of Nb-doped $SrTiO_3$/undoped $SrTiO_3$ and water-gated $SrTiO_3$-based field effect transistors[3,4]. In both cases, the thermopower is approximately five times larger than that of the bulk. Although superlattice is rather difficult to fabricate, electric field approach is simple and effectively verifies the performance of thermoelectric materials, it may accelerate the development of nanostructures for high performance thermoelectric materials.

In this presentation, thermopower enhancement utilizing nano-structure control induced carrier quantum confinement effect is explained based on the authors' results.

[1] L. D. Hicks and M. S. Dresselhaus, *Phys. Rev. B* 47, 12727 (1993), [2] H. Ohta *et al*., *Nature Mater*. **6**, 129 (2007), [3] H. Ohta *et al*., *Nature Commun.* **1**, 118 (2010), [4] H. Ohta *et al*., *Adv. Mater*. **24**, 740 (2012).

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