Electricity from waste heat with more efficient materials

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Thermoelectric materials can convert waste heat directly into electricity. Tommi Tynell, M.Sc., who is a doctoral candidate at the Aalto University School of Chemical Technology, has developed hybrid thermoelectric materials which combine useful properties from different types of materials.

He found that by adding organic layers between layers of zinc it is possible to improve the performance of thermoelectric materials. The organic layers are also believed to have a major effect in reducing thermal conductivity, which would be very useful in thermoelectric materials.

"Developing more efficient thermoelectric materials is a major challenge, because the physical properties that affect the performance of the materials are not independent of each other. The optimization of a material is very difficult, because as you improve one feature, other properties may deteriorate at the same time," says Tynell.

The biggest obstacle to the broad utilisation of thermoelectric generators is the low efficiency of currently known thermoelectric materials. In addition, the best existing compounds do not withstand the high temperatures required and often contain rare and harmful elements.

Eco-friendly materials

In his doctoral research, Tynell added layer upon layer of nanoscale structures, examining their formation using X-ray and infrared devices. In the research, thin films of zinc oxide were used, because zinc oxide is one of the most promising thermoelectric oxide materials. Oxide materials are environmentally friendly and in turn their availability is not a problem. It is believed that they will play an important role in the future development of sustainable energy technologies.

Tynell combined atomic layer deposition and molecular layer deposition and thus succeeded in manufacturing a hybrid superlattice composed of organic and inorganic compounds. Atomic layer deposition is an extremely accurately controlled nanofabrication process. The process was used to produce layered hundred-nanometre-thick nanostructures, with extremely thin organic layers alternating with thicker inorganic layers. Three different source materials were used for the organic substance: hydroquinone, 4-aminophenol and 4,4'-oxydianiline. All of the organic molecules tested were found to influence the thermoelectric properties of the thin zinc oxide film.

"Although the structures of the starting materials were quite similar, the size of the effect was quite variable depending on the source material. Hydroquinone was the most applicable of the three, because it formed the desired structures most easily."

Unique research

Tommi Tynell did his doctoral thesis in Academy Professor Maarit Karppinen's research group. Karppinen and her team have studied thermoelectric materials for a dozen years. The research of the group is unique in that it is rare to use hybrid materials in thermoelectric research. Only a few research groups in the world are currently focused on investigating the properties of hybrid materials. By utilising thermoelectric energy harvesting it will be possible to reduce our dependence on traditional energy sources. Untapped waste heat is available everywhere. For example, it is produced in industrial processes and households, and car exhausts also produce wasted heat. Tommi Tynell's research is a step towards being able to take advantage of heat that is currently disappearing into thin air.

More information: Master of Science (Technology) Tommi Tynell's dissertation 'Atomic Layer Deposition of Thermoelectric ZnO Thin Films' will be examined at the Aalto University School of Chemical Technology on 13 December 2013 at 12 noon.

Provided by Aalto University

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