New materials offer solutions to energy production challenges

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Credit: Maarit Karppinen and Anni Hanén

New materials will have a central role in many of the energy applications of the future. For instance, inexpensive and environmentally friendly thermoelectric materials will be capable of converting waste heat into electricity in both homes and factories in the future.

Nearly all of the new inorganic materials being developed at the Aalto University School of Chemical Technology involve energy - its production, transfer, or storage - in one way or another. New superconductors, as well as materials used in lithium ion batteries, solid oxide fuel cells, and oxygen storage, among other things, are being developed at the laboratory of Academy Professor Maarit Karppinen.

Other interesting projects are the thermoelectric materials being developed at the laboratory, which are capable of extracting electrical energy from waste heat originating from various sources. In future visions these materials will be producing energy in places such as the walls of homes, solar panels, car exhaust pipes and the heat exchangers of power plants. They can also be used as sources of electricity in mobile devices or in cardiac pacemakers, for instance.

'Thermoelectric materials can be used in both small consumer applications as well as large industrial institutions in the production of electricity from waste heat', Karppinen says.

Common to all of the materials developed in the laboratory is that they are based on oxides, which do not damage the environment. Also, they contain inexpensive and easily-available materials, such as zinc, titanium, and iron, instead of costly precious metals.

Hard work and pure coincidence

Karppinen's laboratory engages in pioneering basic research in which the goal is the development of completely new materials. The application point of view is always in the background, but it is not necessarily the primary consideration.

'We try to find compounds and entire families of materials that nobody else in the world has managed to produce yet', she says.

She says that in addition to persistent research , coincidence has had an important role in the work.

'A new material that has been developed into a superconductor has sometimes proven to be a good thermoelectric material, and vice versa. A new kind of cobalt oxide which was supposed to be a promising thermoelectric material proved to be uniquely suitable for the storage of oxygen.'

This is possible because the materials being researched are typically mixed oxide materials which can be used for a number of different applications. 'The materials that I have studied have remained similar over the years, but the variety of their applications has kept growing', Karppinen says.

She studied oxide superconductors already for her doctoral dissertation, which was completed in 1993. After that, she went to Japan, to the Tokyo Institute of Technology, where she spent a total of ten years. In the last five years of this period she served as an assistant professor.

'We continue to cooperate closely. Japan is one of the main players in the development of oxide materials.'

An open-minded approach produces results

The application of different methods of synthesis is a key part of the practical work of a laboratory.

'To find something completely new, it is necessary to have the courage to experiment with production methods that nobody else has ever tried before', Karppinen explains.

For instance, her laboratory has produced oxide materials under ultra-high pressure - in the same kinds of conditions that turn graphite into diamonds. Another important method is atomic layer deposition, or ALD, in which materials are produced as thin films, one atom at a time.

'Some materials will only become stable when they are made in thin film form', she says.

Half of the approximately 20 researchers in Karppinen's laboratory produce materials in the form of thin films, and the other half produce them as powders. Researchers have also used ALD technology to produce new types of hybrid materials combining organic and inorganic layers of atoms.

However, it will be a long time before the materials will have commercial applications.

'Closest to it are thermoelectric materials. They have a very wide range of potential applications', she observes.

Karppinen's role model is Professor John Goodenough of the University of Texas at Austin. At the age of 90, he is still continuing his long career as one of the most important researchers in his field. In the late 1970s he and his small research group developed a lithium ion battery which was taken into commercial production by Sony in 1991.

Karppinen says that this is typical of the time frame from the discovery of a new functional material to its commercialisation.

'Significant discoveries do not necessarily emerge in big laboratories alone. We also have possibilities for practically anything', she says.

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