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New material studied that would reduce 'waste heat' at power plants

by John Mark Shaver
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Ellena Gemmen and Cesar Octavio Romo de la Cruz, members of the WVU research group responsible for engineering an oxide ceramic that could decarbonize the thermoelectrics industry, test the material's conductivity.

West Virginia University researchers have created a new oxide ceramic material that will dramatically cut down waste heat at power plants, which some officials believe is one of the leading causes of global warming.

Professor Xueyan Song, George B. Berry Chair of Engineering at WVU's Benjamin M. Statler College of Engineering and Mineral Resources, has a led a team in developing the material in order to reduce the amount of "waste heat" generated by thermoelectric technology anywhere from NASA missions shot into space to heated seats in modern automobiles.

Song

"The very core of this thermoelectric technology is the thermoelectric materials," Song said. "Those currently being used in NASA and the automobile industry are usually composed of rare and toxic elements, such as lead, bismuth, tellurium, and arsenic, which makes them too expensive and too hazardous to be used in most circumstances.

"In our labs, we worked on oxide ceramics with thermal stability, natural abundance, lightweight, and non-toxicity. Through this project, we work on the most straightforward and classic sintering of the oxide powders to make bulk-scale oxide ceramics. We do not use specialized equipment to develop and make those oxide ceramics. Instead, we design the chemistry and subsequently control the atomic structure of those oxide ceramics."

Through the development of the new material, Song's team demonstrated the best oxide ceramics reported in the past 20 years, a record-breaking achievement that was previously thought impossible.

While oxide ceramics are similar to the ceramics used in pottery, cement and silicon, one key difference is that oxide ceramics are infused with metallic elements that make them very resistant to heat and corrosion. And thanks to the research team's work, setbacks previously thought to hold the material back have been neutralized.

"The thermoelectric oxide ceramics developed in our lab could function in the air directly, without using expensive and sophisticated vacuum technology, and the thermoelectric materials could effectively take the heat from the hot surface to over 900C into the electricity directly," Song said. "Direct heat electrification or direct conversion of thermal energy into electricity using thermoelectric technology could be the most promising and versatile technology to integrate into various power generation, including natural gas power plants and concentrated solar plants, and improve their efficiency."

Song said that an estimated 20% to 50% industrial energy input is lost as waste heat, taking forms such as exhaust, cooling water and heat loss from hot equipment. Recovering this waste heat, she said, not only reduces overall costs and improves productivity, but reduces the environmental impact that the industrial process has.

"The invisible waste heat is an overlooked renewable resource," Song said. "By the law of thermodynamics, every time that engine runs, it loses about 70% of energy as heat that is usually unproductivity released into the atmosphere. Nowadays, between 20 to 50% of industrial energy input of all energy produced by humankind is lost as waste heat. Heat and waste heat are ubiquitous and are one of the largest energy sources and renewable resources on the planet."

Song said although she and her team have developed this new material, the work is far from over. The most immediate next step will be understanding the new material structure on a more in-depth level to potentially develop an even better material in the future.

Song said the team also plans to work on integrating the developed thermoelectric materials into different power generation systems in order to produce cleaner electricity.

The ordinary waste heat recovery and combined heat and power system usually consist of a prime mover, a generator, a heat recovery system, and electrical interconnection equipment configured into an integrated system," Song said. "Those systems possess large footprints, involving moving parts that could be operation and maintenance intense. ...

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WVU researchers Sergio Andres Paredes Navia, Cesar Octavio Romo de la Cruz, Liang Liang and Ellena Gemmen use an electron microscope to study the nanostructure of a new oxide ceramic material with the potential to make thermoelectric generators efficient enough to capture a significant portion of the waste heat that industrial systems like power plants emit.

"By contrast, thermoelectric power generators directly convert temperature gradients into electricity, and thermoelectric devices have no moving parts, are silent, and with maintenance-free operation. TE devices could enable a wide range of applications, from solid-state cooling to high-temperature power generation, and could integrate into and dramatically increase the overall effectiveness of concentrated solar power generation."

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