New breakthrough in thermoelectric materials

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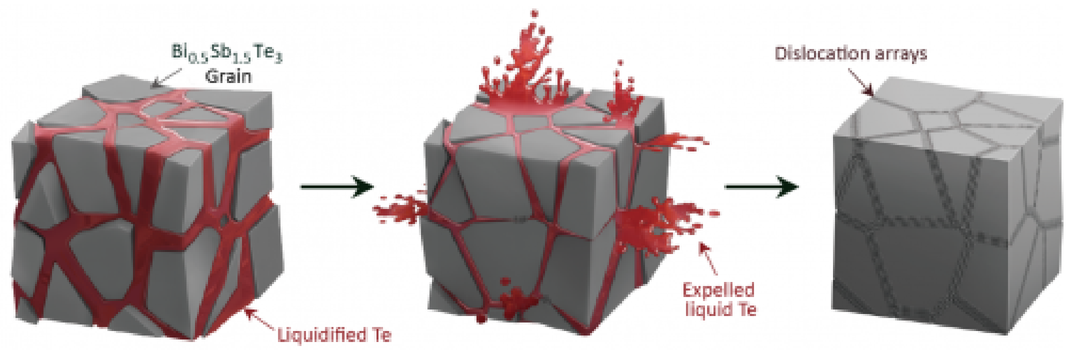

Generation of dislocation arrays during the liquid-phase compaction process. The Te liquid (red) between theBi0.5Sb1.5Te3 grains flows out during the compacting process and facilitates theformation of dislocation arrays embedded in low-energy grain boundaries. Credit: Institute for Basic Science

A joint South Korean and American research group has developed a scalable production method for a state of the art alloy for the use in solid state thermoelectric devices. This new alloy is nearly twice as efficient as existing materials and may lead to a new host of applications. Uses include refrigeration, consumer electronics, transportation as well as novel devices which have not been produced yet do to the inefficiencies of existing materials.

French physicist Jean Charles Athanase Peltier discovered a key concept necessary for thermoelectric (TE) temperature control in 1834. His findings were so significant, TE devices are now commonly referred to Peltier devices. Since his work, there have been steady advancements in materials and design. Despite the technological sophistication Peltier devices, they are still less energy efficient than traditional compressor/evaporation cooling.

In the 1960's, Peltier devices were primarily made from Bismuth-Telluride (Bi_2Te_3) or Antimony-Telluride (Sb_2Te_3) alloys and had a peak efficiency (zT) of 1.1, meaning the electricity going in was only slightly less than the heat coming out. Since the 1960's there have been incremental advancements in alloy technology used in Peltier devices.

In 2014, researchers in South Korea at IBS Center for Integrated Nanostructure Physics along with Samsung Advanced Institute of Technology, the Department of Nano Applied Engineering at Kangwon National University, the Department of Energy Science at Sungkyunkwan University, and Materials Science department at California Institute of Technology California, USA have formulated a new method for creating a novel and much more efficient TE alloy.

TE alloys are special because the metals have an incredibly high melting point. Instead of melting the metals to fuse them, they are combined through a process called sintering which uses heat and/or pressure to join the small, metallic granules. The joint team, including IBS researchers, used a process called liquid-flow assisted sintering which combined all three antimony, bismuth and telluride granules into one alloy ($Bi_{0.5}Sb_{1.5}Te_3$). Additional melted tellurium was used as the liquid between the $Bi_{0.5}Sb_{1.5}Te_3$ granules to help fuse them into a solid alloy, and excess Te is expelled in the process.

By creating the alloy this way, the joints between the fused grains, also known as the grain boundaries, took on a special property. Traditionally sintered Bi0.5Sb1.5Te3 have thick, coarse joints which have led to a decrease in both thermal and electrical conductivity. The new liquid-phase sintering creates grain boundaries which are organized and aligned in seams called dislocation arrays. These dislocation arrays greatly reduce their thermal conduction, leading to an enhancement of their thermoelectric conversion efficiency.

In tests, the efficiency (zT) reached 2.01 at 320 K within the range of 1.86 ±0.15 at 320 K (46.85° C) for 30 samples, nearly doubling the industry standard. When the melt spun $Bi_{0.5}Sb_{1.5}Te_3$ alloy is used in a Peltier cooler, the results are also significant. The new material was able achieve a temperature change of 81 K at 300 K (26.85° C).

The applications for such a material are abundant. As new fabrication techniques are developed, Peltier cooling devices may be used in place of traditional compression refrigeration systems. More importantly, as electrical vehicles and personal electronic devices become more ubiquitous in our daily lives, it is becoming increasingly necessary to have more efficient systems for localized electrical power generation and effective cooling mechanisms. This new thermoelectric alloy paves the way for the future of modern TE devices.

More information: Sang Il Kim, Kyu Hyoung Lee, Hyeon A. Mun, Hyun Sik Kim, Sung Woo Hwang, Jong Wook Roh, Dae Jin Yang, Weon Ho Shin, Xiang Shu Li, Young Hee Lee, G. Jeffrey Snyder, Sung Wng Kim (2015). Dense dislocation arrays embedded in grain boundaries for high-performance bulk thermoelectric. *Science*. www.sciencemag.org/lookup/doi/ … 1126/science.aaa4166

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