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Nanotech Milling Produces Dramatic Increase in Thermoelectric Performance of Bulk Semiconductor

Researchers from Boston College, MIT, Clemson University and the University of Virginia have used nanotechnology to achieve a 60-90 percent increase in the thermoelectric figure of merit of p-type half-Heusler, a common bulk semiconductor compound, the team reported in the journal Nano Letters.

The dramatic increase in the figure of merit, used to measure a material's relative thermoelectric performance, could pave the way for a new generation of products -- from car exhaust systems and power plants to solar power technology -- that that runs cleaner, according to co-author Yan Xiao, a researcher in the Department of Physics at Boston College.

The team registered improvement in half-Heusler, which has been under study for its thermal stability, mechanical sturdiness, non-toxicity and low cost. However, the application of half-Heusler has been limited because of its poor thermoelectric performance: it previously registered a peak figure of merit of approximately 0.5 at 700 °C for bulk ingots.

Xiao, working with BC Professor of Physics Zhifeng Ren and MIT's Soderberg Professor of Power Engineering Gang Chen, have increased the figure of merit value of p-type half-Heusler to 0.8 at 700 °C. Moreover, the groups' material preparation methods proved to save time and expense compared with conventional methods.

"This method is low cost and can be scaled for mass production," Ren said. "This represents an exciting opportunity to improve the performance of thermoelectric materials in a cost-effective manner."

The researchers obtained their results by first forming alloyed ingots using arc melting technique and then creating nanoscale powders by ball milling the ingots and finally obtaining dense bulk by hot pressing. Transport property measurements together with microstructure studies on the nanostructured samples, in comparison with that of bulk ingots, showed that the thermoelectric performance improves largely because of low thermal conductivity produced by enhanced phonon scattering at grain boundaries and defects in the material. The material was also found to have a high Seebeck coefficient, a measure of thermoelectric power.

Researchers in the BC and MIT labs are still trying to prevent grain growth during press, which accounts for the still large thermal conductivity of half-Heusler.

"Even lower thermal conductivity and improved thermoelectric performance can be expected when average grain sizes are made smaller than 100 nm," said Ren, who was joined on the team by fellow Boston College researchers Giri Joshi, Weishu Liu, Yucheng Lan and Hui Wang, MIT's Sangyeop Lee, Virginia's Rogers Professor of Physics Joe Poons and J.W. Simonson and Clemson Professor of Physics Terry M. Tritt.

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