Pulsed Light enables faster and better sintering of nanoparticles on thermoelectric films

Overview

In a collaboration across six universities, researchers conducted a study on improving the efficiency of thermoelectric (TE) generators for waste heat recovery. They aimed to improve TE materials by creating nanostructured TE films using Bismuth Telluride-based nanoparticles. Using a photonic sintering process with a XENON Corp. Pulsed Light system, the researchers successfully sintered the nanoparticles into continuous TE films rapidly and at low cost. The photonic sintering process proved to be highly compatible with rapid roll-to-roll manufacturing and allowed the creation of TE films on both rigid glass and flexible polymer substrates.

The study highlights the potential of a method for low-cost and scalable production of high-efficiency thermoelectric devices. Results of the research indicate new possibilities for thermoelectric energy harvesting with improved manufacturing capabilities.

Markets/Applications

- Automotive: Thermoelectric energy harvesting can improve vehicle efficiency by converting waste heat from the engine into usable electrical power.
- Energy Generation: Recover waste heat and convert it into electricity, contributing to more sustainable and efficient energy production.
- Microelectronics & Wearable Devices: TE films can be integrated into wearable gadgets to harvest body heat or used in microelectronic devices to manage heat dissipation.
- Industrial Waste Heat Recovery: Advanced thermoelectric materials in high-temperature industrial settings could lead to significant waste heat recovery and potential cost savings.
- Aerospace: Thermoelectric power generation can convert excess heat into electrical energy, improving mission endurance and reducing dependence on traditional power sources.

Highlights

- Pulsed Light can be used to coalesce and sinter thermoelectric (TE) nanoparticles into continuous films rapidly and efficiently.
- TE films created through photonic sintering demonstrated electrical conductivity of about five to six orders of magnitude greater than compacted nanoparticles before sintering.
- Photonic sintering is highly compatible with rapid roll-to-roll manufacturing, offering a cost-effective and scalable production method for TE devices.
- Enables the printing and sintering of nanoparticle films at arbitrary locations under ambient conditions, eliminating the need for complex processes like vacuum deposition or sintering.

"This work opens-up an exciting possibility of extremely rapid fabrication of TE generators under ambient conditions on a variety of flexible and rigid substrates."

The information in this report was prepared by XENON and does not contain the complete research conducted by *Danaei* et al. A full version of the research paper is available at https://onlinelibrary.wiley.com/doi/abs/10.1002/adem.201800800

Summary of Research

Ultrafast Fabrication of Thermoelectric Films by Pulsed Light Sintering of Colloidal Nanoparticles on Flexible and Rigid Substrates

Original research by Roozbeh Danaei, Tony Varghese, Mostafa Ahmadzadeh, John McCloy, Courtney Hollar, Mohammad Sadeq Saleh, Jonghyun Park, Yanliang Zhang, and Rahul Panat

Objective: Assess the use of Pulsed Light sintering to create high-efficiency thermoelectric films from nanoparticles for energy harvesting applications.

Methodology: The study employed photonic sintering to create high-efficiency thermoelectric (TE) films from Bismuth Telluride-based nanoparticles. The researchers first synthesized nanoparticles using a microwave-stimulated wet-chemical method. These nanoparticles were mixed with ethylene glycol to create a nanoparticle ink dispersion. The nanoparticle ink was then dispensed onto the substrates using a micropipette, creating TE films with a thickness of approximately 12-15 µm.

The sintering process occurred under ambient conditions, and pulse durations ranged from 0.5 to 2 milliseconds. The TE films were exposed to the intense Pulsed Light from the lamp, causing the nanoparticles to coalesce and sinter rapidly. The process locally heated the nanoparticles, resulting in TE films with significantly increased electrical conductivity. To understand the physical processes occurring during photonic sintering, researchers used a thermo-plasmonic modeling approach with COMSOL software. The model considered individual nanoparticles and assumed a film with micrometer-scale length scales to estimate temperature rise, particle coalescence, and heat conduction during and after the pulse. The modeling predictions aligned with experimental observations. After sintering, the TE films were characterized by measuring their temperature-dependent electrical conductivity and Seebeck coefficient.

Results & Conclusions: The study successfully demonstrated the use of photonic sintering to create high-efficiency thermoelectric (TE) films from Bismuth Telluride-based nanoparticles. The TE films gained a sharp increase in electrical conductivity, up to 3200 S m^−1, which was about five to six orders of magnitude higher than compacted nanoparticles before sintering. The photonic sintering process proved compatible with rapid roll-to-roll manufacturing, offering a cost-effective and scalable method for producing TE devices on both rigid glass and flexible polymer substrates. The results show new possibilities for highly efficient thermoelectric energy harvesting devices with diverse applications.