Development of promising nanostructured thermoelectric materials and their hybrids through sustainable chemical routes

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Thermoelectric (TE) materials are capable of converting waste-heat to electrical energy. They can have a big impact on sustainable transition, if its large-area applications can be realized. This is limited due to the inherent limitations of materials stability, or the cost of materials and their production.

Nanostructured TEs, are normally fabricated using a bulk process rather than a nano-fabrication process, which has the important advantage of producing in large quantities and in a form that is compatible with commercially available TE devices.

We developed and demonstrated colloidal fabrication of some well-known TE materials as $FeSb_2$, Bi_2Te_3, Sb_2Te_3, Bi_{2-x} Sb_xTe_3, and $Cu_{2-x}Se$ as nanostructures. in a matter of minutes using MW-assisted heating. We repeatedly demonstrated improvements in the TE performance of various materials, by designing high-throughput, scalable, energy effective synthetic methodologies resulting in well-defined nanostructured building blocks. The focus was first on the Bi-Sb-Te materials (n- and p-type), which was then applied to p-type and earth abundant compositions including Cu_2Se, Cu_2S, $CuFeS_2$.

Our research shows the significance of the preparation route on the resultant material's morphology, particle size, microstructure and transport properties. Our preliminary studies showed a successful intercalation of synthesized Sb-telluride and Bi-telluride nanoparticles into a PMMA matrix, during which we identified some key process parameters and interface modifiers (or performance boosters), causing strong influence on the charge transport between the two phases, reaching impressive power factor.

References

1. M. Y. Tafti et al., "Promising bulk nanostructured Cu2Se thermoelectrics: Via high throughput and rapid chemical synthesis," RSC Adv., vol. 6, no. 112, 2016.
2. B. Hamawandi et al., "Minute-Made, High-Efficiency Nanostructured Bi2Te3 via High-Throughput Green Solution Chemical Synthesis," Nanomaterials, vol. 11, no. 8, p. 2053, Aug. 2021.
3. B. Hamawandi et al., "Composition tuning of nanostructured binary copper selenides through rapid chemical synthesis and their thermoelectric property evaluation," Nanomaterials, vol. 10, no. 5, 2020.
4. B. Hamawandi et al., "A Comparative Study on the Thermoelectric Properties of Bismuth Chalcogenide Alloys Synthesized through Mechanochemical Alloying and Microwave-Assisted Solution Synthesis Routes," Front. Mater., vol. 7, Sep. 2020.
5. J. F. Serrano-Claumarchirant et al., "Thermoelectric Inks and Power Factor Tunability in Hybrid Films through All Solution Process," ACS Appl. Mater. Interfaces, vol. 14, pp. 19295–19303, Apr. 2022.