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General Trends in Thermoelectrics

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Thermoelectrics as a direct energy conversion method between heat and electricity is mainly used for electrical power generation and cooling applications. It is based on Seebeck effect, stating that materials subjected to a temperature difference (ΔT), will develop a proportional internal electrical voltage (V). The proportion coefficient between V and ΔT is known as Seebeck coefficient, α, which strongly depends on Fermi energy and the electronic scattering parameter. One more growing application, utilizing the strong influence of electronic scattering centers on Seebeck coefficient, is for Non Destructive Evaluation (NDE) and monitoring of metallurgical states and atomic defects in metallic alloys.

The thermoelectric conversion efficiency depends not only on Seebeck coefficient but also on other parameters and increases with the dimensionless figure of merit, ZT= $\alpha^2\sigma T/\kappa$, where, Z, T, σ and κ are the figure of merit, absolute temperature, electrical conductivity and thermal conductivity, respectively. A large variety of materials, such as intermetallic compounds (*e.g.* half-Heuslers such as TiNiSn), silicides (*e.g.* Mg_2Si and $MnSi_{\sim 1.75}$) and chalcogenides (*e.g.* $(Bi,Sb)_2Te_3$, PbTe and GeTe) have been investigated as thermoelectric materials due to high ZT values at different temperature ranges. Among these material classes, although currently showing lower ZTs, silicides and intermetallic compounds possess additional advantages due to improved mechanical properties, the ability to operate at higher temperatures (>500^{o}C) and the potential for large scale commercialization, since they are composed of naturally abundant and less toxic elements.

Global trends for improving the thermoelectric efficiency via maximizing the ZT values include, electronic doping optimizations; generation of Functionally Graded Materials (FGMs) with an optimal maximal ZT envelope over a wide temperature range; and nanostructuring formation for reduction of the lattice thermal conductivity. Nanostructures generation can be achieved by nano-powdering using energetic ball-milling followed by a rapid consolidation method such as Spark Plasma Sintering (SPS). Yet, due to the demand for high stability characteristics, required for long operation periods at high temperatures, one approach for avoiding nano-features coarsening and thermoelectric properties degradation, is based on utilizing thermodynamically driven nanostructures, due to physical metallurgy based effects such as spinodal decomposition and nucleation and growth reactions.

All of the mentioned above general trends in thermoelectric will be discussed during the talk. A focus on the related activities in the department of Materials Engineering at BGU will be given.