

Traditional thermoelectric materials and challenges

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7.1 Traditional thermoelectric materials

In general, the materials used to synthesize thermoelectric (TE) devices are semiconducting [1]. It is well known that the intrinsic figure of merit ($zT = \frac{S^2\sigma T}{k}$) is the central parameter in designing TE materials. The intrinsic zT is calculated from various transport parameters such as Seebeck coefficient (S), electrical conductivity (σ), and total thermal conductivity (k) (due to electrons, κ_{el} and phonons, κ_l). The essential requirement to acquire high value of zT corresponding to a particular material is that the material should simultaneously exhibit high power factor (i.e., $S^2\sigma$) and low lattice thermal conductivity. In earlier days, metals were used for TE applications due to their good electrical conductivity, but the corresponding zT values were very low since metals also exhibit large thermal conductivity (especially due to electrons). On the other hand, insulators reveal a large Seebeck coefficient but have very low electrical conductivity. Hence, a third type of material, semiconductors, in which electrical conductivity and Seebeck coefficient lie between conductors/metals and insulators, are utilized for TE applications. A comparison among the average values of transport coefficients (i.e., S , σ , κ , and Z) of metals, semiconductors, and insulators are shown in Table 7.1.

From Table 7.1, it is obvious that, in semiconductors, the transport coefficient, particularly $S(\sigma)$, is higher (lower) than metals and lower (higher) than insulators. However, the average value of Z is much higher than both the metals and insulators. Therefore, in general, semiconducting materials are used for TE purposes.

Although recent progress shows significant development toward high temperature TE material, finding promising candidates is still a difficult task, especially at room temperature. High temperature TE materials are used for power generation devices utilized in the automobile industry, power plants, industrial processes, etc. As we know, traditional TE materials are mostly based upon bismuth telluride and lead chalcogenides, but the presence of toxic elements limits their commercial use. In general, the nontoxic alternatives in their pure and defect-induced states are the best substitutes