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Editorial

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Nanostructured Thermoelectric Materials with Improved Performance for Energy Conversion

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Introduction

Thermoelectric materials are the materials that convert thermal energy to electrical energy or vice versa. The effects of thermoelectrics can be applied for both power generation and electronic refrigeration. The devices built from thermoelectric materials exhibit high reliability but no noise or vibration as there is none mechanical moving part involved. They have portable size and are light in weight [1]. Nowadays, thermoelectric material technology and performance are under dynamic development for device applications covering the fields of energy generators and converters, thermoelectric coolers, heat pumps and thermal sensors [1,2]. However, compared to that of conventional mechanical device, the efficiency or the coefficient of performance of thermoelectrics is still low [3].

The dimensionless figure of merit ZT is the most important parameter for evaluating the performance of the thermoelectric materials. ZT is defined as $ZT=(S^2\sigma/\kappa)T$, where S is the Seebeck coefficient (also known as thermopower), σ the electrical conductivity, κ the thermal conductivity and T the absolute temperature. An excellent thermoelectric material should possess large Seebeck coefficient to generate high voltage, high electrical conductivity to minimize the internal resistance of a device thus reducing loss of electrical energy and low thermal conductivity to decrease thermal conduction between the hot and cold sides in the application. Enhancement of figure of merit would lead to an increase of power conversion efficiency and coefficient of performance of thermoelectric cooling and lead to an improvement on responsivity of thermal sensors. The thermoelectric community is widely targeting $ZT \geq 3$ to make these solid-state systems competitive with traditional mechanical energy conversion systems [4].

There is no easy way to increase ZT due to the inter-related parameters S, σ and κ. However, nanostructured thermoelectric materials offer a probability of considerably enhancing ZT. Two effects are allowing for exceeding the limits of thermoelectric performance by nano preparation. On one hand, the low-dimensional quantum confinement deforms the density of states of the charge carriers in a beneficial manner leading to an increasing thermoelectric power factor ($S^2\sigma$). On the other hand, nanostructures in scales between 10 and 100 nanometres may drastically reduce the thermal conductivity due to phonon scattering but leaving the electrical conductivity less affected, thus considerably improving the thermoelectric figure of merit [2].

According to the dimensionality of the materials, there are 4 nanostructures in the thermoelectrics with improved figure of merit: 0D nanodots, 1D nanowires, 2D quantum wells and super lattices and 3D nanomaterials and nanocomposites [4]. Compared to those of 0-2 dimensional materials, 3D bulk thermoelectric materials have easier fabrication processes and more practical applications. Many of the recent advances in enhancing the thermoelectric figure of merit of bulk materials are linked to both in nanoscale samples themselves, like Bi_2Te_3 [5] and in the samples containing nanoscale constituents, like SiC in Bi_2Te_3 [6], oxides in $CoSb_3$ [7] and ZrO_2 in $CoSb_3$ [8,9].

Thermoelectric conversion technology is receiving increasing attention due to the worldwide energy and environment problems, and great progress has been made in the development of high-performance thermoelectric materials [10]. Nanostructuring is definitely one of the effective approaches to improving thermoelectric figure of merit. It is hopeful and optimistic that the progress already made in thermoelectric research will lead to a large leap in the performance of the thermoelectricity.

References

1. Riffat SB, Ma X (2003) Thermoelectrics: A review of present and potential applications. Appl Therm Eng 23: 913-935.
2. Dresselhaus MS, Chen G, Tang MY, Yang R, Lee H, et al. (2007) New directions for low-dimensional thermoelectric materials. Adv Mater 19: 1043-1053.
3. Boukai AI, Bunimovich Y, Tahir-Kheli J, Yu JK, Goddard III WA, et al. (2008) Silicon nanowires as efficient thermoelectric materials. Nature 451: 168-171.
4. Vineis CJ, Shakouri A, Majumdar A, Kanatzidis MG (2010) Nanostructured thermoelectrics: Big efficiency gains from small features. Adv Mater 22: 3970-3980.
5. Zhao XB, Ji XH, Zhang YH, Zhu TJ, Tu JP, et al. (2005) Bismuth telluride nanotubes and the effects on the thermoelectric properties of nanotube-containing nanocomposites. Appl Phys Lett 86: 062111.
6. Li JF, Liu J (2006) Effect of nano-SiC dispersion on thermoelectric properties of Bi_2Te_3 polycrystals. Physica Status Solidi a 203: 3768-3773.
7. Mourea A, Rull-Bravob M, Abadb B, Del Campoa A, Muñoz-Rojo M, et al. (2017) Thermoelectric skutterudite/oxide nanocomposites: Effective decoupling of electrical and thermal conductivity by functional interfaces. Nano Energy 31: 393-402.
8. He Z, Stiewe C, Platzek D, Karpinski G, Müller E, et al. (2007) Effect of ceramic dispersion on thermoelectric properties of nano-ZrO2/CoSb3 composites. J Appl Phys 101: 043707.
9. He Z, Stiewe C, Platzek D, Karpinski G, Müller E, et al. (2007) Nano ZrO_2/$CoSb_3$ composites with improved thermoelectric figure of merit. Nanotechnology 18: 235602.
10. Li JF, Liu WS, Zhao LD, Zhou M (2010) High-performance nanostructured thermoelectric materials. NPG Asia Mater 2: 152-158.