NANO-STRUCTURED THERMOELECTRIC MATERIALS

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Thermoelectric (TE) device technology offers several advantages, such as solid-state reliability, CFC-free refrigeration and air-conditioning, noise-free operation, and ability to convert waste-heat to electricity These traits are highly desirable from an environmental standpoint. However, for the last 40 years, the performance of these devices has been limited by the so-called figure-of-merit (ZT) of the bulk materials. The materials' limitation stems from the fact that an ideal TE material has to be a good electrical conductor in order to minimize Joule heating during current flow, but also a bad thermal conductor in order to minimize parasitic heat flow between the hot side to cold side from where the heat is pumped. Such a requirement of properties, not easily found in nature, forced us to look at engineered nanomaterials several years ago. We have recently demonstrated a ZT of about 2.4 at room temperature in nano-structured Bi_2Te_3/Sb_2Te_3 superlattices compared to a typical ZT of 1 in bulk materials. In addition to the enhanced ZT for potentially higher efficiency in refrigeration or power conversion, the thin-film TE technology offers tremendous possibilities in the area of rapid cooling and heating as well as in very lightweight, compact portable systems. In addition, thin-film technology requires minimal active materials, about 1/40,000 of bulk approach, thereby potentially reducing concerns about materials availability and recycling for a vast array of applications. We will discuss the state of the technology development, our effort in prototype devices, and progress towards various applications, such as automotive waste-heat recovery, microscale heating and cooling for biotechnology applications, cooling high power density electronics, and powering wireless sensors.