Abstracts

Session 2 – Applied Thermoelectric Generator R&D

PROSPECTS FOR A BROADENED USE OF THERMOELECTRICS IN VEHICLES

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Very large strides have been made recently in the performance of solid-state thermoelectric (TE) systems, due directly to substantial efficiency gains at the system level and through the development of hetrostructure materials. Combined, these result in at least a factor-of-two improvement in system performance with the prospect of significant additional gains in the near future. The prospect is that such systems will have advantage over today's devices within the next several years. As a result, TE's are projected to become serious contenders for cooling, heating, temperature control, and waste power recovery applications in vehicles. The characteristics and performance requirements to meet present and projected usage for specific applications are discussed. Requirements for achieving these targets are analyzed.

Present and near-term vehicle applications include small, on-board refrigerators and Amerigon's seat cooling and heating systems. Amerigon's product is given as an example of a TE product that has exhibited very good consumer acceptance, through a direct increase in personal comfort. Manufacturers have adopted the technology since it increases consumers' perceived performance of current heating, cooling, and air-conditioning (HVAC) systems and reduces vehicle energy consumption by decreasing HVAC power demand.

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.

QUANTUM MATERIALS DEVELOPMENT AND SCALE-UP

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and
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Si/SiGe and B_4C/B_9C quantum well materials have been under development at Hi-Z for more than 5 years, and very favorable thermoelectric properties have been achieved. An efficiency of 14 percent has been measured at a DT of 190°C, and efficiencies of greater than 25 percent are expected with thicker films.

Pacific Northwest National Laboratory will describe their recent progress in depositing superlattice films by magnetron sputtering and efforts to scale up the sputtering deposition process to deposit larger area films with much lower costs. Initial results on deposition of p-type Si/SiGe superlattices and release layers will also be described.

QUANTUM DOT SUPERLATTICE THERMOELECTRIC MATERIALS AND DEVICES

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PbSeTe-based quantum dot superlattice structures grown by molecular beam epitaxy have been investigated for applications in thermoelectrics. We have demonstrated improved values relative to the conventional bulk $(Bi,Sb)_2(Se,Te)_3$ thermoelectric materials using an n-type film in a one-leg thermoelectric device test setup. The typical device consists of a substrate-free, bulk-like (typically 0.1 mm in thickness, 10 mm in width, and 5 mm in length) slab of nanostructured PbSeTe/PbTe as the n-type leg and a metal wire as the p-type leg. This paper also describes the growth and characteristics of n-type and p-type quantum dot superlattice materials. Projections of future thermoelectric performance expectations for PbSeTe-based quantum dot superlattice materials will be presented.

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