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IMPORTANCE OF THERMOELECTRIC GENERATORS

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Abstract

In this article, waste-heat recovery with thermoelectric power generators can improve energy efficiency and provide distributed electricity generation. New thermoelectric materials and material performance improvements motivate development of thermoelectric generators for numerous applications with excess exhaust and process heat.

Keywords: thermoelectric generator, waste heat recovery, thermoelectric system

Introduction.

Everyone know, thermoelectric devices offer an essential power generation solution because they convert thermal energy into electricity without requiring moving components. Thermoelectric generators have been propose for waste-heat recovery applications, and advancements in thermoelectric materials development have highlighted the technology's energy efficiency and commercial potential. To realize this potential and improve thermoelectric power generation feasibility, the gap between thermoelectric materials development and generator systems engineering must be close. The thermoelectric generator materials characteristics are particularly important because it is a solid-state energy conversion device. Electron and thermal transport through multiple materials in the device is paramount and affects overall system performance. This review provides a systems-level perspective of thermoelectric generator development. It underscores the relationships between thermoelectric materials development goals and generator system requirements [1-2]. Considerations for system components beyond the thermoelectric materials discussed along with manufacturing and cost issues. A thermoelectric (TE) module consists of units, or legs, of semiconducting materials connected electrically in series and thermally in parallel. The figure of merit ZT describes material performance. It depends on the thermoelectric material properties Seebeck coefficient S, electrical conductivity σ, and thermal conductivity k, and $ZT = S^2\sigma T / k$ where T is the temperature of the material. A TE couple is one pair of n- and p-type legs, and a module generally has several couples. These couples and their electrical interconnects are enclosed by an electrical insulator, typically a ceramic.

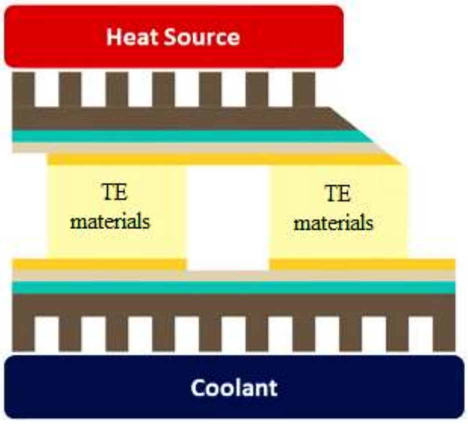

Figure 1. Scheme of TE materials processing.

Key advantages of TEGs for waste-heat recovery are their simplicity, minimal maintenance requirements, and reliability since there is no rotating machinery in the system. Disadvantages include low efficiencies, high costs, and systems integration barriers [3-6]. The assessment for TEG waste-heat recovery potential often focuses on the heat source temperature where high-temperature processes are favorable. Government-initiated studies and funding for TEGs reflect the interest in these promising, high-temperature industrial process applications.

Method. All thermoelectric materials typically classified by material structure and composition. Some of the main classifications are chalcogenide, clathrate, skutterudite, half-heusler, silicide, and oxide. Excellent reviews of thermoelectric materials have provided descriptions of both the material classifications and the relationship between material structure and thermoelectric properties so comprehensive descriptions not provided here. Chalcogenide materials have a long history of demonstrated thermoelectric use with bismuth telluride and lead telluride being the most prominent. Commercial, off-the-shelf thermoelectric modules for low temperature use primarily made with bismuth telluride and its solid solutions with antimony or selenium. Lead telluride has better thermoelectric properties at higher temperatures [7-9, 10-16].

While the materials development progress is promising, the increasing breadth of materials and the reports of ever-increasing ZT mask the underlying challenges of employing the materials in devices. Material properties are highly temperature-dependent, posing multiple challenges for application-specific materials selection. Few applications have heat sources at one single temperature, so matching an application temperature with the point of peak ZT in a thermoelectric material is unrealistic. Instead, most applications have some degree of thermal fluctuation or cycling. If the heat source is a fluid stream, the temperature of the fluid varies along the flow direction. The temperature decreases along the length of each thermoelectric leg, as well.

Material stability over the full operating temperature range is relevant to device engineering. Thermoelectric materials must be stable within the filler medium. If the thermoelectric material exposed to air, the material must not oxidize within the operating temperature range. Devices can packaged in an inert gas to mediate this problem. In low temperature devices, a solid filler is sometimes used, but solid filler media for high temperature applications – if they currently exist – must also be sufficiently stable and inactive with the TE material. For example, some materials undergo sublimation within the operating temperature range of high temperature applications.

Conclusion. The abundance of waste-heat sources and increasing energy efficiency goals make waste-heat recovery with thermoelectric power generation a promising technology. The realization of commercial thermoelectric generators hinges on solving the intimately coupled challenges with materials development and systems engineering. Measuring system performance with thermoelectric material ZT alone is insufficient for determining generator performance, and other thermo-mechanical/chemical material properties and components strongly impact product development. Major issues to resolve for TEG commercialization are material selection based on average (not peak) ZT, material thermal and chemical stability.

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