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THE ENERGY HARVESTER: THERMOELECTRIC GENERATOR

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Abstract

Energy harvesting is the process of capturing the waste energy from any source or process e.g solar energy, wave motion, heat generated by human body and motion, industries, radio wave etc. This energy can further be used to operate many kinds of devices e.g. thermoelectric generators, piezoelectric generators, solar cell, photovoltaic cell etc. There are so many devices from alarm clock to computers used in security system which are controlled by microchips powered by energy harvesters. The thermoelectric generator is the device that converts heat energy directly into electricity. The heat generated by human body can be converted into electricity by using flexible thermoelectric materials and can be used in charging of mobile, wristwatch etc. Far from being a green technology, batteries generated a large amount of waste energy and also require non-renewable energy sources. Furthermore, the energy harvesters are cost-effective, eco-friendly and long lasting. For a temperature around 1273K and figure of merit 3-4 (figure of merit for monolayer AsP_3 SnP_3, and SbP_3 are 36, 3.46 and 3.5 respectively) the efficiency of thermoelectric generator is approximately 33-37%, which is comparable to heat engine efficiency.

Keywords: Thermoelectric material, semiconductor, nanomaterial

Introduction

Our dependency on fossil fuels e.g. coal, natural gas, oil had a very adverse impact on nature and hence leads to serious public health issues. Moreover, fossil fuels have limited resources. The solution for this problem is to find sustainable energy sources. These sources have no harmful effect on environment as well as coast effective. Energy harvesters take energy from sun light, heat, wind etc and convert it into electrical energy.

The thermoelectric generator is a solid state device that converts heat energy directly into electrical energy. It can harvest waste energy from sun light, industries; power plant etc. this can be used as automotive thermoelectric generator in automobiles to increase the fuel efficiency and as a radio-isotop thermoelectric generator in space craft. Moreover, this device can also use the waste heat generated by human body. Thermoelectric generators have no moving parts, hence no noise pollution or friction which makes it more reliable and durable electrical energy source. This device can be more popular in the cloudy region where solar cells do not meet the expectations and along with solar panel to generate the additional electricity.

Thermoelectric materials are those materials which convert temperature difference into electricity, this effect is called Seebeck effect and reverse is also possible called Peltier effect. The ability of a thermoelectric material to convert a temperature differences into potential difference is measured by Seebeck coefficient or thermopower. Efficiency of thermoelectric generator is measured by figure of merit (ZT). Higher value of ZT indicates higher efficiency. It is a dimensionless quantity. If dT temperature difference creates dV potential difference, then Seebeck coefficient (S) is given by

$$S= dV/dT \qquad (1)$$

and

$$ZT= S^2\sigma T/k \qquad (2)$$

Where S is Seebeck coefficient, σ is electrical conductivity, T is operating temperature and k is thermal conductivity. Generally, semiconductors are good thermoelectric material (as metals have higher value of thermal conductivity and

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thermal conductivity is inversely proportional to the figure of merit) and can further be modified by doping and nanotechnology.

Construction and working

As the heat flow from hotter to cooler end of a thermoelectric material, charge carriers also drift from hot to cold side of the generator and hence a potential difference would be created between the two ends. But this induced potential difference is very small and can further be balanced by voltage developed in the connecting wires. Therefore, to overcome is problem a thermoelectric generator consist two legs which are made from two type of thermoelectric material i.e. one is of p-type and other one is n-type semiconductor known as thermocouple. To further increase the output voltage a series of thermocouples is used to design a thermoelectric generator. The symbolic diagram of a thermoelectric generator or thermocouple is shown in fig. 1. A load resistance R is connected with n and p type semiconductors. When a temperature difference is provided, the majority charge carriers will drift from hotter to cooler end, thus creating a potential difference and current will start flowing through the load resistance.

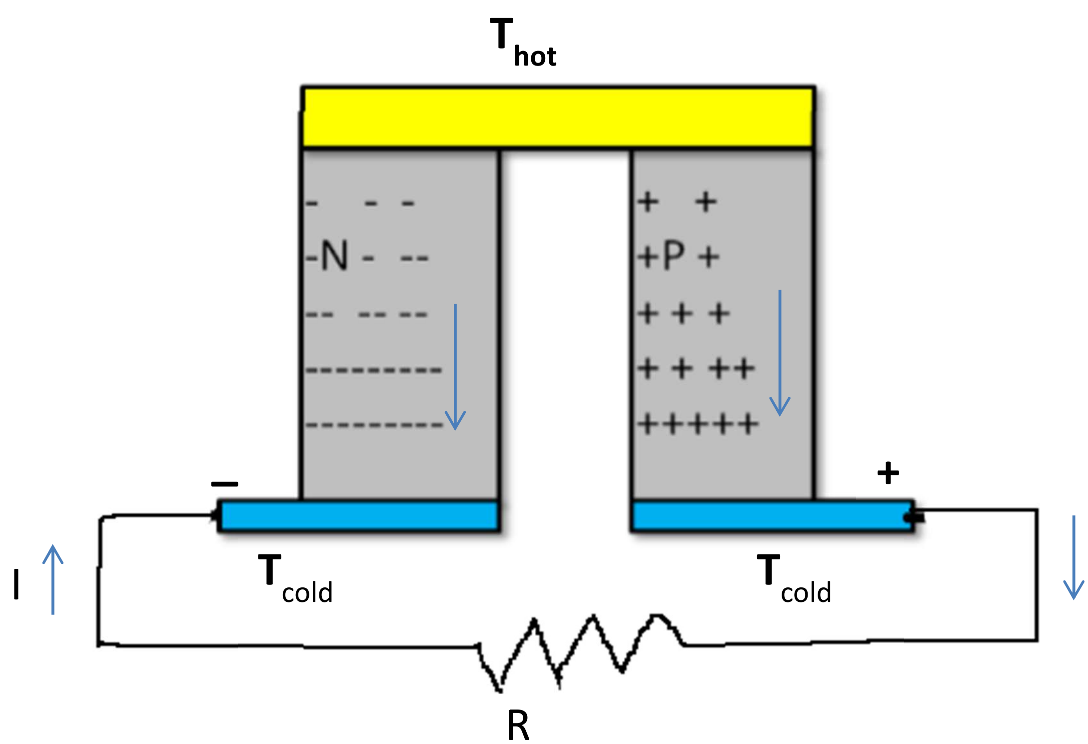

Fig. 1. thermocouple

Material of interest

Bismuth chalcogenides such as Bi_2Te_3 and Bi_2Se_3 are best room temperature thermoelectric material. To further enhance the thermoelectric properties nano-structuring play an important role. Layered superlattice structure of Bi_2Te_3 and Sb_2Te_3 exhibit a figure of merit approximate 2.4 at room temperature. Heremans et. al. reported thallium doped telluride with a ZT of 1.5 773K in 2008 and Synder et. al. in 2011 synthesized sodium doped led telluride showing a ZT of 1.4 at 750K. Darren Quick (2012) reported lead telluride with a figure of merit 2.2. Skutterudite thermoelectric exhibit ZT> 1 and can be used

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in multistage thermoelectric device. Oxide thermoelectric are promising thermoelectric material at high temperature due their high thermal stability. Layered $Ca_3Co_4O_9$ can reach ZT from 1.4 to 2.7 at 900K. other members of this family are $NaCo_2O_4$, ZnO, MnO_2, NbO_2 etc. Certain thermoelectric materials called flexible thermoelectric material can harvest the waste energy released by human body like PEDOT, Polyaniline, polythiophenes, polycarbazole, polyaceteline, PEDOT:PSS etc. and can be useful for small energy applications. Another promising thermoelectric materials are Ag_2Te, grapheme, silicon-germanium alloys, AsP_3, SnP_3, SbP_3 etc.

Efficiency

The efficiency of thermoelectric generator majorly depends on the temperature difference across the two ends and is given by

$$\eta = \frac{\Delta T}{T(hot)} \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T(cold)}{T(hot)}} \quad (3)$$

A good thermoelectric material is that who has high electrical conductivity and low thermal conductivity which is a very complex task. Nanotechnology is the key reduce thermal conductivity and simultaneously to increase the electrical conductivity. For a temperature around 1273K and figure of merit 3-4 (figure of merit for monolayer AsP_3, SnP_3, and SbP_3 are 3.6, 3.46 and 3.5 respectively) the efficiency of thermoelectric generator is approximately 33-37%, which is comparable to heat engine efficiency.

Uses

Thermoelectric generators can be used at room temperature to higher temperature range that's why can be used in variety of applications such as mountain tops, space and deep ocean. Thermoelectric devices have been used in aerospace and military since many years. Radio-isotop thermoelectric generator are used in space prob, satellite etc. This type of thermoelectric generator uses some radioactive element for heat generation. The first modular general purpose heat source thermoelectric generator on Galilio spacecraft was launched by NASA in 1989.

Wearable thermoelectric devices can be designed using flexible thermoelectric material. Heat generated by human body can be harvested by wearable thermoelectric devices and can be used in medical such as health monitoring, tracking system, sports and fittness; other uses are like charging of wrist watch, mobile charging etc.

Thermoelectric device can be used to harvest waste heat from industries, power plant, electronic devices e.g. computers, automobiles etc. Suski designed an apparatus to recover the waste heat from semiconductor electronic device using a thermoelectric device and was installed between the IC and heat sink.

Conclusion

This paper has review the basic introduction, working principal and some applications of thermoelectric generator. There is huge amount of waste heat in the environment. Researchers have been taken interest in developing or synthesizing new thermoelectric materials and applied many technologies to improve the figure of merit and hence the efficiency of a thermoelectric generator for few decades. Thermoelectric generators have no moving part and hence can be used without maintenance for many years. This can be a promising energy harvester.

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