Alumni's Diary

Never Give-up

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Hi,

This is Raghu Piska. I have finished my PhD in the year 2020 from the Civil Engineering department. I am currently working as an assistant professor at the BITS Pilani Hyderabad campus. I have also recently received the DST INSPIRE faculty fellowship from the Government of India.

What made me join IIT, Hyderabad?
IIT Hyderabad is known for its innovative curriculum, state-of-the-art infrastructure, laboratories, and highly qualified faculty. I especially enjoyed the course Finite Element Analysis given by Prof Amirtham Rajagopal. There is no course which I did not enjoy.

Activities you were involved in?
I was part of the mess monitoring committee during the year 2018-2019. I also participated in the Inter-IIT sports meet in the table tennis category held at IIT Bhubaneswar in the year 2019. I was also a core member of volunteers who organized the International Conference on Composite Structures during the year 2017 which attracted more than 600 participants all over the world

Specialized training have you had?
At IITH, I was fortunate to attend the GIAN course on Advanced Finite Element Analysis and a workshop on Nonlocal Mechanics given by Prof JN Reddy from Texas A&M University. I have acquired the required skillset at IITH to get a job in academics. The in-depth concepts taught in each subject, mathematical, programming skills, the competitive culture at IITH made me prepared for my current job.

Best moment from your's life @ IIT Hyderabad?
The day when my code worked!

The message you want to convey to the existing student folk @ IIT, Hyderabad?
Be prepared to face the challenges and never give up.

Best about IITH and suggestion for improvement
Well-qualified faculty is something that is the best at IITH. Improvement in sports facilities will be an area where IITH should work on.

Best way to contact you?
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Alumni's Diary

Thermoelectric Energy Harvesting: Concept, Challenges, and Technology

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Introduction
Electrical energy plays an essential part in modern human society. The energy is generated by consuming nonrenewable resources, which on the contradictory is also responsible for releasing greenhouse gasses into the atmosphere. Greenhouse gases can hamper the ecological balance by disrupting the ecosystem through global warming and climate change.

The imbalance in demand and supply of these limited energy resources also forecasts a global energy crisis for the future generation. The solution to the above problems lies in alternative energy resources and/or new technologies with higher efficiencies of energy conversion.

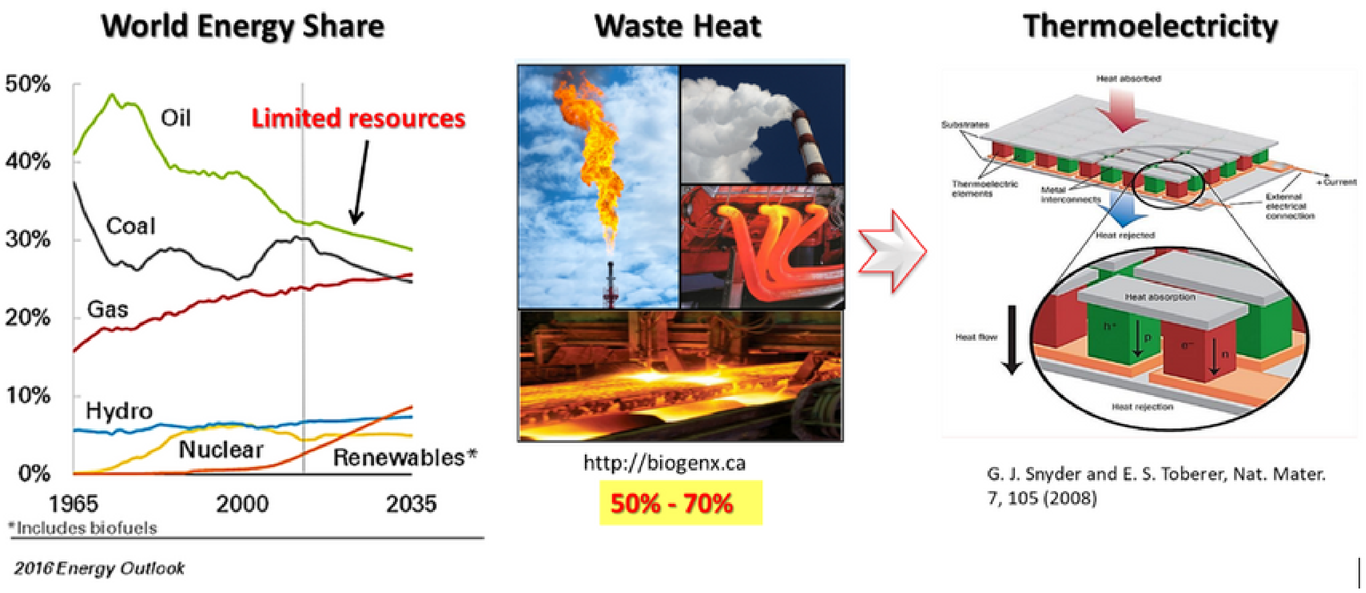

Fig. 31: Consumption of nonrenewable resources for global energy need, waste from of energy in heat, and TEG and energy harvesting technology. https://www.ogj.com/articles/2016/02/bp-fossil-fuels-remain-dominant-form-of-energy-through-2035.html

Concept

Thermoelectric generators (TEGs), solid-state devices that can convert waste heat into useful electrical energy and wise versa without any moving mechanical parts or fluids, are emphasized as one of the potential technologies to reduce the carbon footprint and utilize the energy resources more efficiently.

The concept is very simple when a temperature difference is applied to a substance that easily conducts electricity, such as a metal or a semiconductor, a voltage (thermal electromotive force) is generated across the substance. The thermoelectric effect is the mutual influence of this thermal energy and electrical energy, and one of them is a phenomenon called the "Seebeck effect" in which the temperature difference between two junctions is directly converted into a voltage.

The efficiency energy conversion in TEGs is an increasing function of the dimensionless figure-of-merit,

$$\eta = \frac{T_H - T_C}{T_H} \frac{\sqrt{1+ZT} - 1}{\sqrt{1+ZT} + \frac{T_C}{T_H}}$$

Here, TH and TC represent the temperature of the hot end and cold end, ZT=S^2 σTκ^(-1), where S, σ, T, and κ stand for the Seebeck coefficient, electrical conductivity, absolute temperature, and thermal conductivity of constituent thermoelectric materials, respectively. The efficiency of energy conversion in TEGs is directly proportional to electrical conductivity and Seebeck coefficient while inversely to thermal conductivity.

Challenges and strategies for High-Performance Materials

A high-performance thermoelectric material should possess a high power factor S2σ along with low lattice thermal conductivity. This means a material must be a good conductor of electricity and a poor conductor of heat. Theoretically, all the physical quantities are strongly coupled with each other, which makes it more challenging to obtain a high-performance thermoelectric material. Since the early 1900s, extensive research has been carried out for obtaining high-performance thermoelectric materials found out that semimetals could be used for practical applications by improving their thermoelectric properties through novel strategies.

Such as reducing lattice thermal conductivity through grain boundary scattering, nanostructuring, composite effect, quantum dot superlattices, amorphous structures, modulation doping, and nanoporous structures.

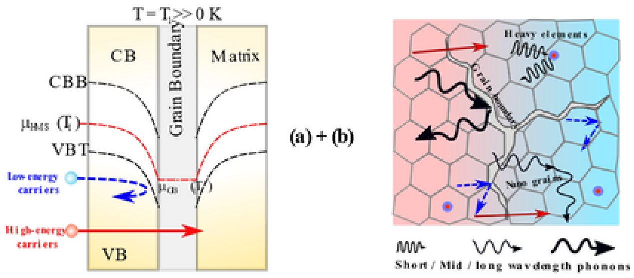

Fig. 32: Strategy of energy filtering and phonon scattering strategy for high-performance TEG [Ghodke et al. ACS Appl. Mater. Interfaces 2019, 11, 34, 31169–31175]

Numerous state-of-art thermoelectric materials have been reported with ZT more than unity in different temperature range; SnSe (ZT = 2.6), Pb-Te (ZT ~ 1.8), Bi-Sb-Te (ZT ~ 1.86), Zn-Sb (ZT ~ 1.3), Cu2Se (ZT > 2), Mg2Si (ZT ~ 1.3), TAGS (ZT ~ 1.5), MnSig (ZT ~ 1.15). Using these materials, the equivalent efficiency of energy conversion from waste heat to electrical energy in practical applications varies in the range of 5% to 15% depending on the applied temperature range.

Teg Applications: Mars Rovers to IoT Devices

TEGs became very famous when NASA in the 1970s utilized this technology in radioisotope thermoelectric generators for deep space missions and interplanetary explorations (Mars rovers). Along with technological advancements, TEG technology has been used for energy harvesting in automobiles, power plants, or industries.

In recent years with the growth of IoT devices and wireless technology, TEGs have come into use for day-to-day life applications in form of wearable battery-free devices. Here, the human body heat as a source is used to generate electric power for such devices as digital watches, health monitoring patches, etc. Autonomous power sources for sensors generally do not require large amounts of power and can be sustained from ambient sources with a stable power supply, solely on TEGs.

Fig. 34: An overview of wearable thermoelectric generator and applications. [Adv. Mater. 2021, 2102990]

ATEG_Tested concept by BMW corporation / www.bmw.com US Department of Energy/www.energy.gov

Fig. 33: TEG concept tested for efficient exhaust in automobile by BMW, and RTEG used by NASA for Mars Rover