Thermoelectric Refrigeration

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The Refrigeration Problem

A reliable source of fresh and healthy food impacts the health, safety, and the economy, to all communities. The lack of fresh food most greatly impacts low-income communities (Andrew Dowdy, 2019), there needs to be significant advances in refrigeration technology to give everyone access to proper food. Currently one-third of the food produced globally is spoiled and not eaten (Aste et al., 2017). For people in developing countries, food is often spoiled before reaching the consumers because of financial and refrigeration technology barriers. There may be as many as 2 billion people worldwide without access to reliable refrigeration(*Chill Challenge—Engineers Without Borders USA*, n.d.). Since people have noticed that this is an issue, many are researching and making advances in developing better refrigeration technologies.

There are two critical problems with typical refrigeration methods: amount of power used, and the harmful chemicals used. The typical refrigeration method consumes a lot of power which does not work for communities that get their power from off-grid energy systems. The pumping refrigeration systems, that most people are familiar with, accomplishes heat transfer through liquid refrigerant cooling which is able to lower the temperature of the surrounding air. Not only is this power intensive, it also often uses hazardous chemicals unsafe for humans. This system does not support communities without reliable access to the power grid. This paper will discuss thermoelectric cooling, another method of heat transfer, and how it is being used to benefit developing countries.

How Thermoelectrics Work

Thermoelectrics are devices that are able to generate electricity from a difference in temperature. This process can be reversed so given power, a thermoelectric module can produce a temperature difference. The cooling and heating produces is from the Peltier effect: electrical current flowing through the junction of two different conducting metals will release or absorb heat due to the imbalance in the properties of the metals (Terasaki, 2016), as seen in Figure 1. Electricity flows through metal 1 from the bottom to the top, and then run flows from the top to bottom through metal 2 to produce a temperature difference.

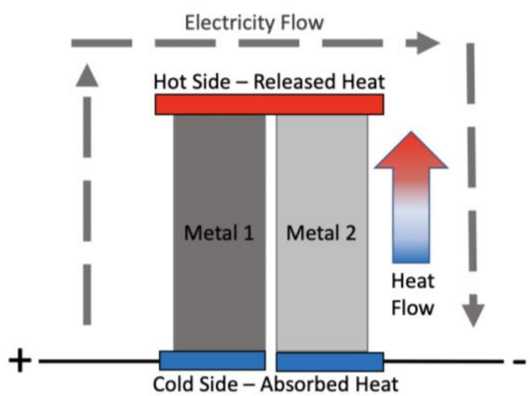

Figure 1. The Basics of Thermoelectrics

Typical metals that are used for thermeoelctrics are semiconducting metals. Semiconductors have the conductivity between fullying conducting materials, like copper, and nonconducting materials, like ceramics. Semiconductors have many applications, and there were many differet kind of semiconductors depending on the properties that wanted. For thermoeoecltric modules, typical materials will have electrical conductivity and limited thermal conductivity. Low thermal conductivity allows the heat to flow from one end to the other creating a temperature difference. Some typical materials used in thermoelectric moducles include Bismuth telluride (Bi2Te3) and Lead(II) Telluride (PdTe) (Rademann et al., 2016).

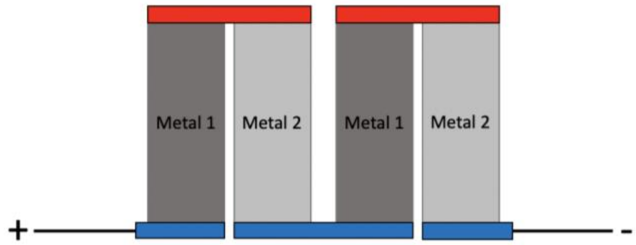

Figure 2: Multiple Junction Points

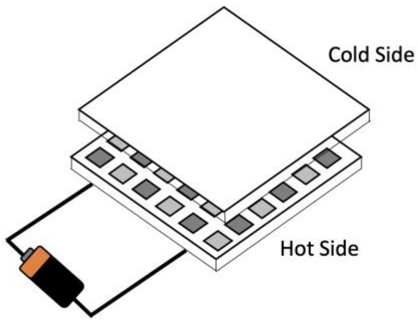

Figure 3: Thermoelecrtric Module

By placing multiple junction points together, more heat can be absorbed, as seen in Figure 2. In a common thermoelectric device, there are around 254 junctions sandwiched between two ceramic plates (*The Most Frequenctly Asked Questions About Thermoelectric Cooling*, n.d.). This allows for thermoelectric modules that are able to get down into the fridge and freezer range making it a safer alternative to liquid refrigerant. The overall size of these modules ranges from the size of a computer chip to is 40 x 40 x 3.9 mm, like the one being used in our senior design project.

Uses Today

There is a lot of potential for thermoelectric coolers. A few examples are computer chip cooling and medication transportation. Maintaining the proper temperature of computer chips is important as excessive heat can cause damage to the chips. Thermoelectric modules are available in sizes that allow them to be placed on computer chips to help remove excessive, so they are not damaged. There are also many medical applications for thermoelectric coolers. Teca developed a thermoelectric cold plate built into a Pelican™ box that can be used for medicine storage (Rademann et al., 2016). Many essential medications need to be maintained at a proper temperature. This box can be used to help transport medication that needs to be at temperatures, and because thermoelectrics allow for precise temperature control, it is versatile in the different vaccines and medications it can transport. Thermoelectric coolers can also be used in other medical portable applications such as transportation collected samples back to the lab.

Relating to our senior design project, we intend to develop a solar-powered thermoelectric mini fridge and freezer unit. A "collapsible, portable, photovoltaic/thermoelectric refrigerator" was designed years ago (Field, 1980). One major reason this refrigerator did not become widely used in 1980 was because it was expensive. The total cost was $8,500 in 1980 which is equivalent to $26,000 today in 2020. The price of the thermoelectric and solar panels has greatly reduced since then. In addition, the efficiencies of batteries, solar panels, and thermoelectrics has increased since 1980 making it more accessible for refrigerators.

Since then, other experiments have been done to investigate thermoelectric refrigerators driven by solar cells. In 2003, an experiment demonstrated that a prototype could maintain refrigerator temperatures at 5-10˚C. This further shows the feasibility of solar powered thermoelectric coolers are feasible and can be used for storing vaccines, food, and drink in off-grid areas (Dai et al., 2003). This is promising and helpful in understanding that thermoelectric coolers can be powered by solar.

While solar powered thermoelectric coolers have been researched, in our senior design project, we hope to create a more complete prototype with a fridge and freezer component. The top challenges we expect to face are understanding the power consumption for heat transfer and determining an efficient control system. Heat transfer requires a lot of power, and we need to understand the total power requirements to determine the proper solar cell system to use. For our cooling system to be efficient, our team will also need to develop a suitable control system. Today, off the shelf control systems do not exist for thermoelectrics, therefore we will need to investigate required hardware like switches to turn the thermoelectrics on and off and make sure heat is not entering the cooler when the thermoelectrics are off.

Why Use Thermoelectrics

Many researchers, individuals, and companies have found that thermoelectric cooling is a good solution for portable applications. It is robust and there are no hazardous refrigerants, it makes it safer and more reliable to use. There is also a low initial cost, a reduced operational cost, and reduced development time. Because of the precise temperature control and ease of mounting in any orientation, thermoelectric provide many options for customization. (*Thermoelectric cooler solutions for medical applications*, 2019).

There are already many ready-to-use commercial components that can be used to accomplish thermoelectric refrigeration (Aste et al., 2017). With few other parts, and simple leads to power thermoelectric, they are simple enough that someone without a technical background could fix a problem.

These benefits make thermoelectrics a good fit for many applications as already described, like portable refrigeration for vaccines to solar powered thermoelectric coolers in developing countries. Our senior design project is focused on using thermoelectric cooling for people no-power situations due to natural disasters. For example, this may include people who have lost power due to a rain or snowstorm, or individuals who have planned power shutoffs due to wildfires like in California this past year. However, while our project is focused on no-power situations due to natural disasters, it is important to understand that this can be applied to other applications like people in developing countries.

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