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Air Conditioning Using Thermoelectric Based Peltier Modules

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Abstract—*Today most of the cooling in air conditioning system is achieved by using refrigerants such as sulfur dioxide, ammonia, Freon and hydrocarbons such as propane. Though these refrigerants produce maximum output but the disadvantage is the production of harmful green house gases which in turn result in global warming. Such harmful effects can be avoided by using thermoelectric modules based on peltier effect and their by providing a helping hand in the protection of environment. This paper discusses the various modules of Thermoelectric air conditioners. There are various advantages of using thermoelectric air conditioners such as no moving parts, small in size, light weight and no working fluid.*

Keywords*: Thermoelectric air conditioner and peltier module.*

1. INTRODUCTION

Cooling is the process of heat-removal from a space in order to bring it to a lower temperature than surrounding temperature. There are various methods of cooling but in thermoelectric materials, electrical energy can be directly converted into thermal energy and thermal energy into electrical energy. Direct conversion from electrical to thermal energy is possible because of two important thermoelectric effects: the Seebeck effect and the Peltier effect. The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar metals or semiconductors produces a voltage difference between the two substances[1]. The peltier effect is opposite of seebeck effect which states that heat is given out or absorbed when an electric current passes across a junction between two dissimilar metals or semiconductors[1].

Thermoelectric cooling, commonly known as cooling technology using thermoelectric coolers (TECs), has advantages of high reliability, no mechanical moving parts, small in size and light in weight, and no working fluid. In addition, it possesses advantage that it can be powered by direct current (DC) electric sources, When a voltage or DC current is applied to two dissimilar metals or semiconductors, a circuit can be created that allows for continuous heat transfer between the conductors' junctions this is the principle of thermoelectric air-condition. Cooling is a process of removing heat from a room or other applications. Many methods to produce a cooling effect are vapour compression and vapour absorption air condition. These air methods are producing cooling effect by using refrigerants like Freon, hydrocarbons and ammonia etc. It gives maximum output but, one of the disadvantages is producing harmful green house gases to the atmosphere. The harmful gases are chlorofluorocarbons (CFC's) and some other gases are present. These gases are harmful for the environment as it causes global warming and also results in the depletion of ozone layer. Due to the depletion of ozone layer people on earth come in contact with harmful UV radiations which causes diseases such as cataracts, damage to human tissue, skin cancer etc.

A simple cooling system contains three basic parts - the evaporator, compressor and condenser. The evaporator or cold section is the part where the pressurized refrigerant like Freon and ammonia is allowed to expand, boil and evaporate. During this process of change of state from liquid to gas, energy (heat) is absorbed. The compressor acts as the refrigerant pump and again compresses the gas to a liquid. The condenser removes the heat absorbed in the evaporator plus the heat produced during compression, into the environment. A thermoelectric has similar parts. At the cold junction, energy (heat) is absorbed by the electrons as they pass from a low energy level in the p-type semiconductor, to a higher energy level in the n-type semiconductor. The electric power supply gives the energy to move the electrons through the system. At the hot junction, energy is released to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type).

2. TRANSPORT PROPERTIES

The thermoelectric phenomena is reversible in the sense that they themselves do not give rise to thermodynamic losses. However, it is always, in practice, accompanied by the irreversible effects of electrical resistance and thermal conduction. It turns out that the performance of any thermocouple as an energy convertor can be expressed in terms of the differential Seebeck coefficient and thermal and electrical resistances of the two branches. These resistances depend on the thermal and electrical resistivity and the ratios of length to cross-sectional area of the material.

The electrical resistivity ρ is the reciprocal of the electrical conductivity , which is defined by the relation below,

$$I = \frac{\sigma V A}{L} \quad (1)$$

Where, 'I' is the electric current through a specimen having cross-sectional area A and length L when a voltage V is applied across its terminal. Likewise, the thermal conductivity, K is defined by the below equation,

$$q = \frac{-KA\Delta T}{L} \quad (2)$$

Where, q is the rate of flow of heat through a similar specimen that has a temperature difference of T between its two terminals. We shall refer to the thermoelectric coefficients and the electrical and thermal conductivities of a given material used for thermoelectric effect as its transport properties. All these properties will be temperature-dependent.

3. WORKING OF PELTIER COOLER

The Peltier effect is observed whenever electrical current flows through two **dissimilar conductors**; depending on the direction of flow of current, the junction of the two conductors will either absorb or release heat. In the thermoelectric technology, **semiconductors** (usually Bismuth Telluride) are mostly used for producing the Peltier effect because they can be more easily optimized for pumping heat as per the requirement. By using this type of material, a Peltier device (i.e., thermoelectric module) can be fabricated in its simplest form around a single semiconductor "pellet" which is soldered to electrically-conductive material on each end (usually thin plates of copper). In this configuration, the second dissimilar material used for the Peltier effect, is actually the copper connection paths to the power supply[2].

It is important to note that the heat will be moved in the direction of movement of charge carrier throughout the circuit (actually, it is the charge carriers that transfer the heat).

4. PELTIER COOLING WITH N-TYPE SEMICONDUCTOR

In Figure 2, fabrication of the pellet using "N-type" semiconductor material is shown so that electrons (with a **negative** charge) will be the charge carrier employed to create the bulk of the Peltier effect.

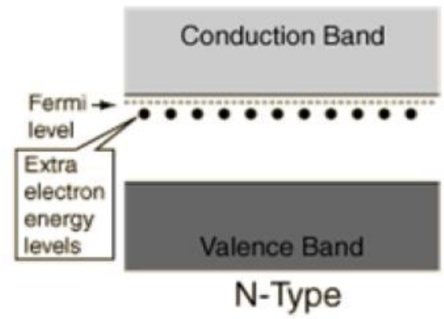

Figure 1: N-type semiconductor Energy band diagram [3].

With a **DC voltage source** connected as shown in figure, electrons will be repelled away by the negative pole and attracted towards the positive pole of the supply; due to this attractive force, electrons from Fermi level move towards positive terminal by releasing heat energy and creating the holes in the Fermi level. Now, due to continuous supply of current, electrons move to Fermi level from valance band (lower energy band) by absorbing energy from the junction. With the electrons flowing through the N-type material from bottom to top, heat is absorbed at the bottom junction and transferred to the top junction. [2].

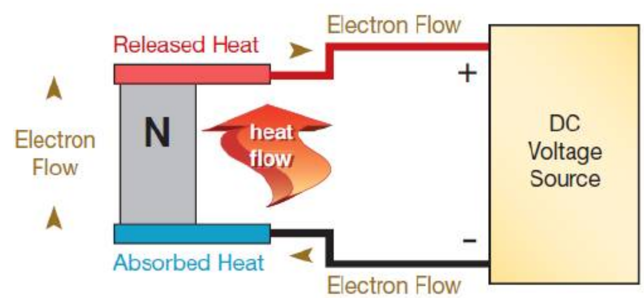

Figure 2: Peltier cooling with N-type semiconductor [2].

So, in Peltier cooler using N-type of semiconductor, heat is absorbed at the junction at negative terminal and heat is rejected at the junction near positive terminal.

5. PELTIER COOLING WITH P-TYPE SEMICONDUCTOR

Fabrication of the pellet using, "P-type" semiconductor are also employed. The energy band diagram of P-type semiconductor is shown in figure 3. In P-type semiconductors, holes are at the Fermi level (higher energy level).

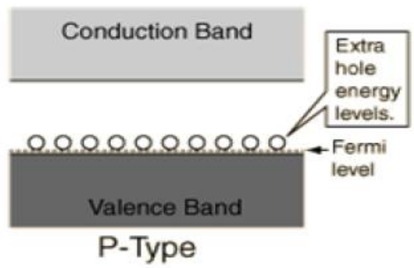

Figure 3: P-type semiconductor Energy band diagram [3].

Now, when DC current is applied through the circuit as shown below in Figure 4; holes get attracted towards negative terminal of voltage source. Due to attraction, holes move towards negative terminal by releasing heat energy. Due to continuous supply of current, holes moves to Fermi level from conduction band by absorbing heat energy from the junction.

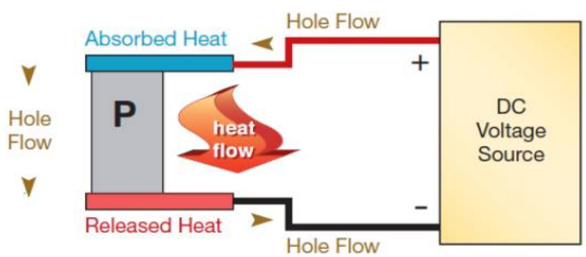

Figure 4: Peltier cooling with P-type semiconductor [2]

So, in Peltier cooler using P-type of semiconductor, heat is absorbed at the junction near positive terminal and heat is rejected at the junction near negative terminal

6. PELTIER COOLING WITH P & N TYPE OF SEMICONDUCTORS.

Through proper arrangement of N and P-type pellets in a "couple" (see Figure 5) and forming a junction between them with a plated copper tab, a series circuit can be formed which can keep all of the heat moving in the same direction. As shown in the figure, with the bottom end of the P-type pellet connected to the positive voltage potential and the bottom end of the N-type pellet connected to the negative side of the voltage.

As we have seen for N-type of semiconductor, heat is absorbed from the junction near to the negative terminal and heat is releases at the junction near to the positive terminal. Similarly for P-type of semiconductor, heat is absorbed at the junction near to positive terminal and released at the junction near to negative terminal.

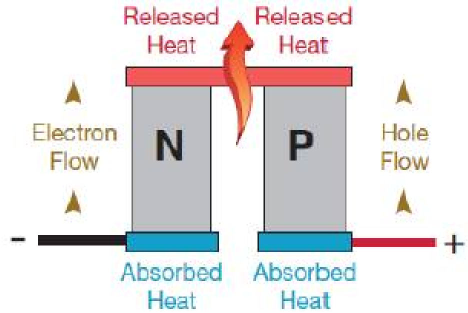

Figure 5: Peltier cooling by couple of N&P semiconductors[2].

By proper arrangement of similar circuits like in Figure 5, it is possible to release heat to the one side and absorb from another side. Using these special properties of the Thermoelectric "couple", it is possible to team many pellets together in rectangular arrays to create practical thermoelectric modules with higher efficiency as in Figure 6.

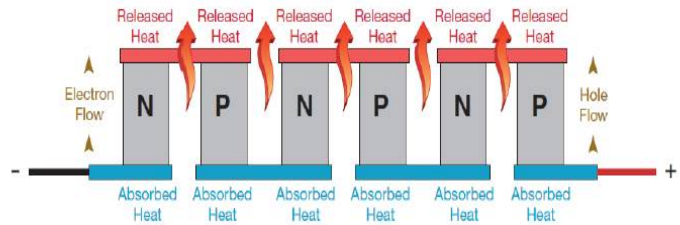

Figure 6. Peltier cooling by multiple pallets [2].

7. FABRICATION OF PELTIER COOLER

As we have seen above, for producing thermoelectric effect couples of P and N type semiconductors are connected in series by metal plates to increase the overall efficiency of thermoelectric cooler. By doing this it absorbs the heat from one end and releases it to another end.

So, when solid state P-N materials are connected electrically in series through metal plates and thermally in parallel it makes one thermoelectric unit as shown in Figure 7.

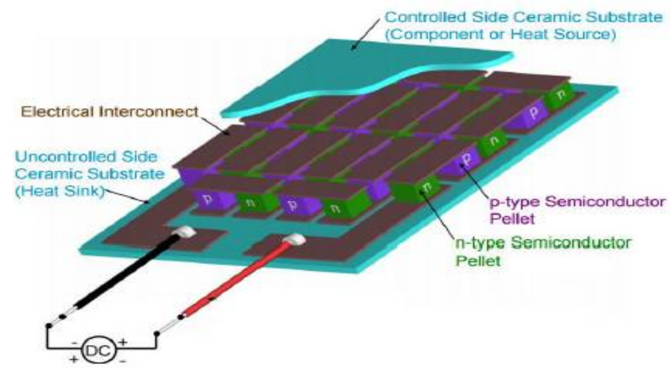

Figure 7: Fabrication of Peltier module [4]

A practical Thermoelectric cooler module comprises of two highly thermally conductive material (A12O3, AlN, BeO) that act as Hot/Cold plates. A series of p-type and n-type semiconductor (Bi2Te3, Sb2Te3, Bi2Se3, PbTe, Si-Ge) pellets are connected electrically and sandwiched between the substrates. The device is generally attached to the cold side of the TEC module, and a heat sink which is required for increasing the efficiency by increasing the rate of heat dissipation is attached to the hot side. Soldering is normally done to connect the TEC elements onto the conducting pads of the substrates. The working of a single stage thermoelectric module is shown in Figure 7. [4]

Considering a typical thermoelectric system designed to cool air in a closed volume. The main aim is to "collect" heat from the inside of the box, pump it to a heat exchanger on the outside of the box, and release the collected heat into the ambient surrounding. Usually, it is done by using two heat sink/fan combinations in combination with one or more Peltier devices. One of the heat sinks is used inside of the closed volume; cooled to a temperature less that of the air in the box, the sink collects heat as the air circulates between the fins. The Peltier device is placed between this "cold side" and a "hot side". As dc current passes through the thermoelectric device, it pumps heat from the cold side to the one on the hot side. The fan on the hot side then circulates surrounding air between the sink's fins to absorb some of the collected heat. The heat dissipated on the hot side not only includes what is pumped from the box, but also the heat produced in the Peltier device itself. [2]

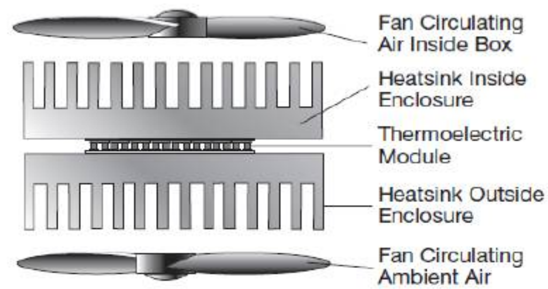

Figure 8: Assembly of air-to-air thermoelectric cooler [2].

REFERENCES

[1] S. Riffat, X. ma, Improving the coefficient of performance of thermoelectric cooling systems, international journal of energy research Int. J. Energy Res. 2004; 28:753–768

[2] Thermoelectric cooling FAQ, Tellurex Corporation

[3] www.hyperphysics.phy-astr.gsu.edu/

[4] Marc H., *Thermoelectric Modules: Principles and Research*, Inter PACK july 6-8, 2011, Portland

[5] Goldsmith, H.J. , *Introduction to thermoelectricity*, Springer-Verlag Berlin Heidelberg 2010