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THERMOELECTRIC REFRIGERATION: RECENT DEVELOPMENTS, RESEARCHES A REVIEW

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Abstract

***In the recent years, there is a fast growing awareness in the field of environmental degradation due to release of ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs). Thermoelectric refrigeration serves as one of the best alternative in the field of refrigeration because of their innovative advantages. This paper briefs various researches which had been carried out by different researchers in the field of thermoelectric Refrigeration. A detailed performance analysis has been thoroughly reviewed in this paper*.**

I. INTRODUCTION

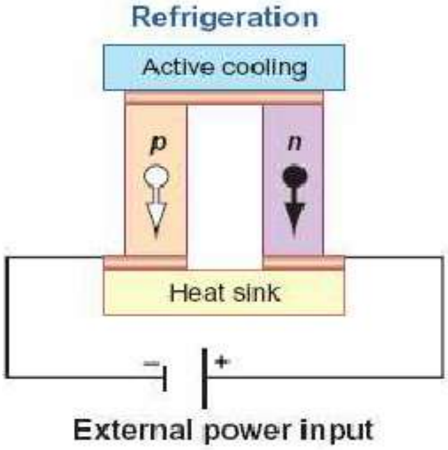
Refrigeration is a process of extracting heat from a reservoir which is kept at low temperature and transferring it to a reservoir which is kept at high temperature. It can also be defined as the process of cooling of systems to temperatures lower than those available in the surrounding. Thermoelectric refrigeration comes under the non conventional refrigeration methods. The main principle of Thermoelectric Refrigeration is Peltier Effect. Apart from Peltier Effect there are two more effects in thermoelectric category which are known as the Seebeck Effect and Thomson Effect where these two affects act on a single conductor & Peltier Effect is a junction phenomenon. A wide variety of products uses thermoelectric coolers, including Double CCD focused cameras, Central processing units, microprocessors, DNA analyzers and water coolers etc. Thermoelectric Refrigeration also serves one of the best alternatives for food preservation as well as cooling of pharmaceutical products.

In 1821, Thomas Seebeck discovered that a continuously flowing current is created when two wires of different materials are joined together and heated at one end. This idea is known as the Seebeck Effect. The Seebeck effect has two main applications including temperature measurement and power generation. Thirteen years later Jean Charles Athanase reversed the flow of electrons in Seebeck.s circuit to create refrigeration. This effect is known as the Peltier Effect. This idea forms the basis for the thermoelectric refrigerator. Scottish scientist William Thomson (later Lord Kelvin) discovered in 1854 that if a temperature difference exists between any two points of a current carrying conductor, heat is either evolved or absorbed depending upon the material.6 If such a circuit absorbs heat, then heat may be evolved if the direction of the current or of the temperature gradient is reversed. The coefficient of performance (COP) of compression refrigerators decreases with the decrease in its capacity. Therefore, when it is necessary to design a low capacity refrigerator, TER is always preferable. Also, better control over the space temperature is the major advantage of the TER. Hence, TER is good option for food preservation applications & cooling of pharmaceutical products. [3]

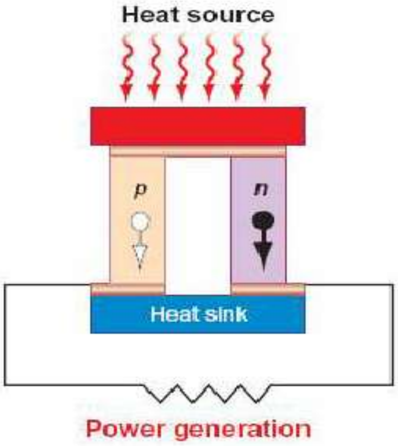
II. PRINCIPLE

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials.
Thermoelectric heating uses the Seeback effect to create a temperature difference between the junctions of two different types of materials.

Peltier Effect : According to Peltier, when electric current is maintained in a circuit of material which consists of two different conductors, one junction becomes hot and the another junction becomes cold.



Seeback effect : It states that when temperature difference is maintained between two dissimilar conductors, Electric voltage difference is produced between the two junctions.



III. MATERIAL REVIEW

The most commonly used thermoelectric material in today's TER chillers is an alloy of Bismuth Telluride (Bi2Te3) which is having different N and P characteristics also it has been properly doped to provide saperate elements. Apart from Bismuth Telluride, some other useful thermoelectric materials are Lead Telluride (PbTe), Silicon Germanium (SiGe), and Bismuth-Antimony (Bi-Sb) alloys, which may be used in specific situations; however, Bismuth Telluride is the best material in most computer cooling scenarios.

Thus Commonly used thermoelectric materials are Bismuth Telluride (Bi2Te3), Lead Telluride (PbTe),Silicon Germanium (SiGe) and Cobalt Antimony (CoSb3), among which Bi2Te3 is the most commonlyused one. These materials usually process a ZT value (figure of merit at temperature) less than one. From 1960s to 1990s, developments in materials in the view of increasing ZT value were modest, but after the mid-1990s, by using nano structural engineering thermoelectric material efficiency is greatly improved. Thermoelectric materials such as skutterudites, clathrates and half-Heusler alloys, which are principally produced through doping method are developed but not exploited for commercial use Dongliang et al

According to the primary criterion of figure of merit ($Z = \alpha 2\ RK$), a good thermoelectric material should have high Seebeck coefficient, high electrical conductivity, and low thermal conductivity. Commonly used thermoelectric materials are Bismuth Telluride (Bi2Te3), Lead Telluride (PbTe), Silicon Germanium (SiGe) and Cobalt Antimony (CoSb3), among which Bi2Te3 is the most commonly used one. These materials usually process a ZT value (figure of merit at temperature) less than one. Thermoelectric materials such as skutterudites, clathrates and half-Heusler alloys, which are principally produced through doping method are developed but not exploited for commercial use Dongliang et al.From 1960s to 1990s, developments in materials in the view of increasing ZT value was modest, but after the mid-1990s, by using nano structural engineering thermoelectric material efficiency is greatly improved. Thermoelectric materials such as primary bulk thermoelectric materials like skutterudites, clathrates and half-Heusler alloys, which are principally produced through doping method are developed but not exploited for commercial use. [4] The best commercial thermoelectric materials currently have ZT values around 1.0. The highest ZT value in research is about 3. Other best reported thermoelectric materials have figure-of-merit values of 1.2-2.2 at temperature range of 320-5200C. It is estimated that thermoelectric coolers with ZT value of 1.0 operate at only 10% of Carnot efficiency. Some 30% of Carnot efficiency could be reached by a device with a ZT value of 4. However, increasing ZT to 4 has remained a formidable challenge. Bell also mentioned that if the average ZT reaches 2, domestic and commercial solid-state heating, ventilating and air-cooling systems using thermoelectric material would become practical.[4]

IV. REVIEW OF VARIOUS RECENT RESEARCHES AND WORKS

1. **Min et al.** developed a prototype of thermoelectric refrigerators with different heat exchanger combinationwas .They calculated the COP, heat pumping capacity, cooling down rate and temperature stability. The COP of a thermoelectric refrigerator which they have calculated is found as 0.3-0.5 for a typical operating temperature of 5^{o}C with ambient at 25^{o}C.They also investigated the potential improvement in the cooling performance of a thermoelectric

refrigerator employing a realistic model, with experimental data obtained from this work. The results show that an increase in its COP is possible through improvements in module contact resistances, thermal interfaces and the effectiveness of heat exchangers.

2. **Dai et al.** developed the thermoelectric refrigeration system powered by solar cells generated DC voltage.Experimental investigation and analysis has also carried out by them. A prototype which was developed by them, consists of a thermoelectric module, array of solar cell, controller, storage battery and rectifier. The refrigerator which they have studied, can maintain the temperature in refrigerated space at 5–10oC, and having a COP of about 0.3 under given conditions.

3. **Putra et al.** have worked in thermoelectric module and heat pipe.They had designed, manufactured and tested a portable vaccine carrier box employing thermoelectric module and heat pipe. The position of heat pipe as a heat sink on the hot side of the TEM enhanced the cooling performance. The minimum temperature in the vaccine carrier cabin reached -10oC, which shows that vaccine carrier can store the vaccine at desired temperature.

4. **Vian et al.** had shown the development of a thermo-siphon with phase change (TSF) which enhances the thermal resistance of the heat exchanger of the hot side of the Peltier pellet by 36%, which ultimately produces an increase in the COP of thermoelectric refrigerator of 26% at an ambient temperature of200 C, and 36.5% at 300 C.

5. **Adeyanju et al.** worked in the field of thermoelectric module .They carried out a numerical and experimental analysis of a thermoelectric beverage chiller. They had alsoCompared thermoelectric beverage chiller's cooling time with cooling times obtained from the freezer space and cold space of a household refrigerator. The result shows that for the refrigerator freezer space, the temperature of the water decreased linearly with increasing time and for thermoelectric beverage chiller the temperature of the water decreased exponentially with increasing time.

6. **Riffat et al.** have worked in the thermo-siphon system; they incorporated the thermo-siphon system in a thermoelectric heat pump system that works as cooling and heating mode.

7. **Lertsatitthanakorn et al.** worked in the mathematical formulation of the TEC.They calculated the cooling performance and thermal comfort of a thermoelectric ceiling cooling panel (TE-CCP) system composed of 36 TEM. The cold side of the TEM was fixed to an aluminum ceiling panel to cool a test chamber of 4.5 m3 volume, while a copper heat exchanger with circulating cooling water at the hot side of the TE modules was used for heat release.They also performed Thermal acceptability assessment to find out whether the indoor environment met the ASHRAE Standard-55's 80% acceptability criteria. The standard was met with the TE-CCP system operating at 1 A of current flow with a corresponding cooling capacity of 201.6 W, which gives the COP of 0.82 with an average indoor temperature of 27oC and 0.8 m/s indoor air velocity.

8. **Gillott et al.** cworked in the experimental investigation of TEC.They conducted an experimental investigation of thermoelectric cooling devices for small-scale space conditioning applications in buildings. They prepared a theoretical study to find the optimum operating conditions, which were then applied in the laboratory testing work. A TEC unit was assembled and tested under laboratory conditions. Eight pieces of Ultra TEC were shown to generate up to 220W of cooling effect with a COP of 0.46 under the input current of 4.8A for each module.

9. **Bansal et al.** have done a detailed study on conducted on energy efficiency and cost-effectiveness for vapour compression, thermoelectric and absorption refrigeration of similar capacity (about 50 litre). The result from their investigation shows that vapour compression refrigerator was the most energy efficient (with a COP of 2.59) followed by thermoelectric (COP of 0.69) and absorption refrigerator (COP of 0.47). The results which they obtained from Cost analysis shows that the total purchasing and operating costs over the life of the systems was the lowest for the vapour-compression unit at NZ$506, followed by the thermoelectric ($1381.2) and the absorption refrigerator ($1387.4). They finally concluded that the VC refrigerator was the most energy efficient and cheaper unit followed by the thermoelectric and the absorption refrigeration.

10. **D. Zhao and G. Tan** have reviewed thermoelectric cooling, its Materials, modeling & applications also they have sorted the the thermoelectric materials in accordance to their performances in the Thermoelectric coolers.

11. **Edward S. Kolesar et.al** has reviewed thermoelectric cooling and also they have categorically listed the applications of Thermoelectric refrigeration.

V. APPLICATIONS

1. Thermoelectric refrigeration
2. Electronic equipment cooling
3. Automobile parts cooling
4. AC appliances cooling
5. solar still cooling
6. PCM space cooling
7. Solar space power system
8. Water chiller application

VI. THERMOELECTRIC Refrigeration V/s TRADITIONAL REFRIGERATION

1. Zero moving parts
2. Chip design
3. Free from Hazardous gases
4. Noice free operation
5. Compact and lightweight
6. Sizes to match your component footprint
7. No bulky compressor units

VII. CONCLUSION

TEC modules offers several benefits including: zero moving components, low profile and compact elements, no maintenance, vibration free ,Acoustically silent and electrically quiet straight forward temperature regulation, extremely precise temperature management (to inside zero.1°C), Operation in any orientation, no gravity and free from Environmentally degradation, Sub-ambient cooling. The paper has categorically reviewed all the major recent developments which had been done in the field of thermoelectric refrigeration.

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