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HVAC (Heat Ventilation and Air Conditioning System) Using TEC (Thermoelectric Couple)

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ABSTRACT: *A column-type micro thermoelectric cooler is being made using p-type Sb2Te3 and n-type Bi2Te3 films (approximately 4 μm thick). The films are grown by thermal co-evaporation and patterned on Cr/Au/Ti/Pt. (hot) connectors, which are deposited onto a silicon dioxide coated wafer. The column height is limited by control of the Te deposition rate. Our aim is to introduce the new HVAC system using thermoelectric couple which shall overcome all the disadvantages of existing HVAC system. If this system comes in present HVAC system, then revolution will occur in the automotive as well as domestic HVAC system. So, our group has been trying to overcome these demerits by replacing the existing HVAC system by newly emerging thermoelectric couple or cooler which works on peltier and seebeck effect.*

I. INTRODUCTION

Telluride compounds are the thermoelectric materials used in the fabrication of the micro thermoelectric cooler, since they currently have the highest cooling performance at room temperature. The techniques used for fabrication of these compounds are dependent, among other factors, on the desired film thickness deposited thin films (700 nm) of *n*-type Bi2Te3 and *p*-type Sb2Te3 by vapor deposition, which had a room temperature dimensionless figure of merit approximately equal to 0.3. The Seebeck coefficient and electrical resistivity were -200 μV/K and 1.29x10-5 Ω-m for the n-type, and 171 μV/K and 3.12x10-5 Ω-m for the *p*-type material. Min and Rowe have proposed a micro thermoelectric cooler where the thermoelectric thin films are grown on a very thin, low thermal conductivity SiC membrane (PECVD) to minimize the heat leakage effect. The electrical current and heat flow parallel to the film plane. Lim et al. deposited thick films (20 μm) of telluride compounds using electroplating for fabrication of thermoelectric coolers where the current and heat flow perpendicular to the film plane (column-type design). They built a thermoelectric micro device that presented a maximum cooling effect of 2 K, and a dimensionless figure of merit of 0.011. The *n*-type Bi2Te3 films exhibited in plane Seebeck coefficients ranging from -30 to 60 μV/K and in plane electrical resistivity of 1x10-5 Ω-m. The properties of *p*-type Bi2-xSbxTe3 films were not fully characterized due to poor reproducibility. Due to parasitic conduction heat transfer between the hot and cold junctions, and the thermal and electrical contact resistances, thin films (less than 1 μm) have not been used in conventional column-type thermoelectric coolers. These problems can be minimized if thicker films (2 to 10 μm) are used. Here, the column-type design of a micro thermoelectric cooler is considered for a wireless vapor sensor application, as shown in annexure-8. The thermoelectric films (Bi2Te3 and Sb2Te3), grown based on the deposition technique of Zouetal are about 4 μm thick. The goal for the cooler is to lower the temperature of the sensor 10 K below ambient in less than 30 seconds, while using minimal power with a 3 V battery. The device design is based on predictions from a thermoelectric cooler model. Initial results of the device fabrication are presented. The deposition and characterization of the thermoelectric films and the device fabrication steps are describe.

II. PRINCIPLE OF REFRIGERATION

When one hears the term air conditioning, usually the first thing that comes to mind is cold air. The mechanical refrigeration system demonstrates three basic laws of refrigeration which are the basic of all natural and mechanical refrigeration systems.

Law 1: Refrigerate is to remove heat. The absence of heat is cold. Heat is ever present. Law 1 is illustrated by the refrigeration system of automobile. Heat removed from the passenger compartment of the vehicle. In so doing, the temperature is lower. The absence of heat is cold. If it is now asked, “What is cold?” it appears that the answer is that cold is the absence of all heat. If it is true, at what point is all the heat removed from matter? Ice, at 32F (0C), is said to be cold. But solid carbon dioxide (co2), or dry ice, is even colder at its normal temperature of -109.3F (-165.8C). Dry ice is so cold that if it is touched, one has the sensation of being burned. However, it cannot be said that dry ice is cold either because it still contains a large amount of heat as measured in Btu. Complete absence of heat does not occur until the temperature of -459.67f (-273.16c) is reached. All temperature above this value contains heat. For example -459F still contain 0.67F of heat; -273C still contain 0.16C of heat. In summary then, cold is the absence of heat energy. According to current scientific theory, absolute zero is the point at which all molecular movement stops. Since molecular movement causes heat energy, it follows that if there is no movement there is no heat.

Law 2: Heat is ready to flow or pass to anything that has less heat. Nothing can stop the flow of heat; it can only be slowed down. Law 2 is demonstrated by the special refrigerant in the evaporator. In this instance, heat is ready to flow to anything that contains less heat.

Law 3: If a change of state is to take place there must be a transfer of heat. If a liquid is to change to gas, it must take on heat. The heat is carried off in vapor. If a vapor is to change into a liquid it must give up heat. Law 3 is shown by the liquid refrigerant in the evaporator. That is, as the refrigerant takes on heat, it changes to vapor. The heat is carried off to be expelled outside the car.

Conventional Air Conditioning System

Usually what the air conditioning first brings to mind is cold air. Actually, an air-conditioning system automatically controls the temperature, humidity, purity, and circulation of air. In mobile vehicle air-conditioning system, air conditioning is a system that cools, dehumidifies, and circulation the air the air inside the driver and passenger compartment of a vehicle.

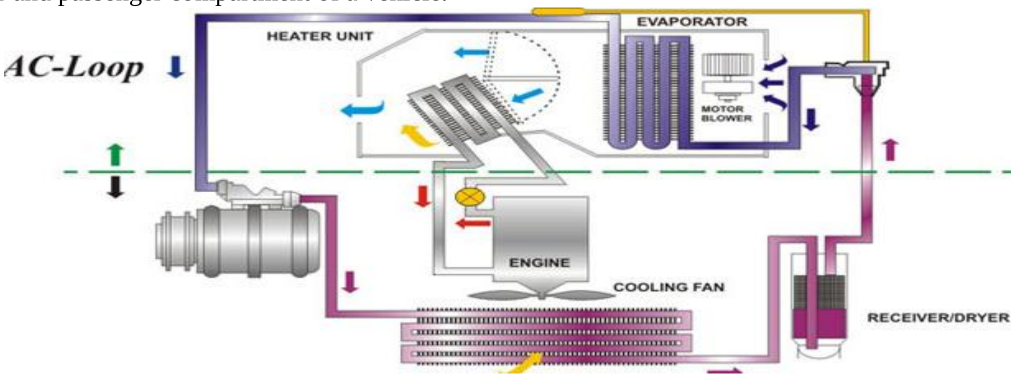

Figure 1: HVAC system used in today's vehicle.

3.1 Disadvantage of conventional HVAC system

Power loss: Compressor is driven by the crankshaft of the engine. It consumes 5 to 10% of engine power.
Fuel loss: Present HVAC System reduces the mileage of the vehicle.
Pick up decreases: An air conditioning system can consumes about 8 h.p. with a unit capacity of 3 tones or 9072 kcal/hr. approximately. SO, due to these the pickup of vehicle decreases.
Electric loss: Battery provides 12V current to the blowers and electromagnetic clutch of compressor for engaging the compressor.
Cost: Cost of present HVAC System is very high.
Hazardous refrigerant: HFC is quit hazardous for human body & ozone layer which leads to global warming.
Repairing cost: Repairing cost of HVAC System is very high.
Maintenance: Proper maintenance is very necessary because this system can affect human body & Environment.
Size: Present HVAC system required very large space in the engine compartment and dashboard.
Delicate system: If any component fails to perform well then the whole HVAC system will either not function properly or not function at all.

Introduction of Thermoelectric Module/Cooler

A thermoelectric (TE) cooler, sometimes called a thermoelectric module or Peltier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. It is important to note that this phenomenon may be reversed whereby a change in the polarity (plus and minus) of the applied DC voltage will cause heat to be moved in the opposite direction. Consequently, a thermoelectric module may be used for both heating and cooling thereby making it highly suitable for precise temperature control applications.

To provide the new user with a general idea of a thermoelectric cooler's capabilities, it might be helpful to offer this example. If a typical single-stage thermoelectric module was placed on a heat sink that was maintained at room temperature and the module was then connected to a suitable battery or other DC power source, the "cold" side of the module would cool down to approximately -40°C. At this point, the module would be pumping almost no heat and would have reached its maximum rated "Delta T (DT)." If heat was gradually added to the module's cold side, the cold side temperature would increase progressively until it eventually equaled the heat sink temperature. At this point the TE cooler would have attained its maximum rated "heat pumping capacity" (Q_{max}). The Seebeck, Peltier, and Thomson Effects, together with several other phenomena, form the basis of functional thermoelectric modules. Without going into too much detail, we will examine some of these fundamental thermoelectric effects. [1]

4.1 Seebeck Effect

In 1821 Thomas Johann Seebeck found that a circuit made from two dissimilar metals, with junctions at different temperatures would deflect a compass magnet. Seebeck initially believed this was due to magnetism induced by the temperature difference. However, it was quickly realized that it was an electrical current that is induced, which by Ampere's law deflects the magnet. More specifically, the temperature difference produces an electric potential (voltage) which can drive an electric current in a closed circuit. Today, this is known as the Seebeck effect. The voltage produced is proportional to the temperature difference between the two junctions. The proportionality constant ( ) is known as the Seebeck coefficient, and often referred to as the thermoelectric power or thermo power. The Seebeck voltage does not depend on the distribution of temperature along the metals between the junctions. This is the physical basis for a thermocouple, which is used often for temperature measurement. [8]

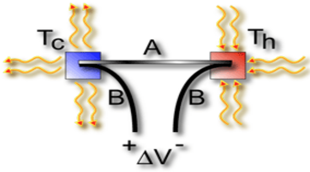

Figure 2: Seebeck effect

V = (Th– Tc)   (1)

The voltage difference, V, produced across the terminals of an open circuit made from a pair of dissimilar metals, A and B, whose two junctions are held at different temperatures, is directly proportional to the difference between the hot and cold junction temperatures, Th - Tc. To illustrate the Seebeck Effect let us look at a simple thermocouple circuit as shown in fig. The thermocouple conductors are two dissimilar metals denoted as Material x and Material y. In a typical temperature measurement application, thermocouple A is used as a "reference" and is maintained at a relatively cool temperature of Tc. Thermocouple B is used to measure the temperature of interest (Th) which, in this ex. , is higher than temperature Tc. With heat applied to thermocouple B, a voltage will appear across terminals Tl and T2. This voltage (Vo), known as the Seebeck emf, can be expressed as:

Vo = axy x (Th - Tc)   (2)

Where, V_O is the output voltage in volts axy is the differential Seebeck coefficient between the two materials, x and y, in volts/^oK Th and Tc are the hot and cold thermocouple temperatures, respectively, in ^oK. [8]

4.2 Peltier Effect

In 1834, a French watchmaker and part time physicist, Jean Charles Athanase Peltier found that an electrical current would produce heating or cooling at the junction of two dissimilar metals. In 1838 Lenz showed that depending on the direction of current flow, heat could be either removed from a junction to freeze water into ice, or by reversing the current, heat can be generated to melt ice. The heat absorbed or created at the junction is proportional to the electrical current. The proportionality constant is known as the Peltier coefficient. If we modify our thermocouple circuit to obtain the configuration shown in fig, it will be possible to observe an opposite.

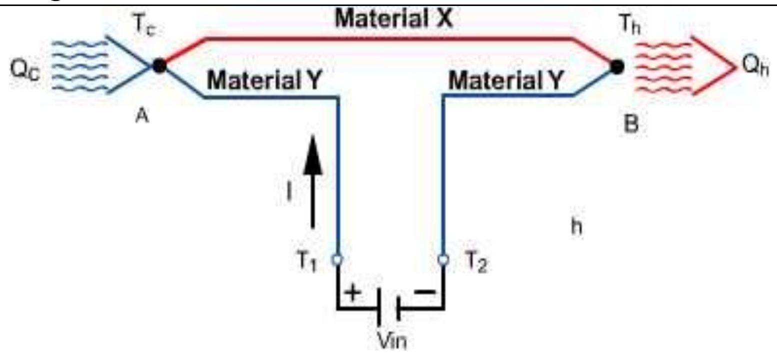

Figure 3: Peltier Effect.

If a voltage (V_{in}) is applied to terminals Tl and T2 an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (Q_c) will occur at thermocouple junction A where heat is absorbed and a heating effect (Qh) will occur at junction B where heat is expelled. Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow. The Peltier effect can be expressed mathematically as:

Q_c or Q_h= pxy x I (3)

Where, pxy is the differential Peltier coefficient between the two materials, x and y, in volts I is the electric current flow in amperes Qc, Qh is the rate of cooling and heating, respectively, in watts Joule heating, having a magnitude of I x R (where R is the electrical resistance), also occurs in the conductors as a result of current flow. This Joule heating effect acts in opposition to the Peltier effect and causes a net reduction of the available cooling. [7]

4.3 Thomson Effect

Twenty years later, William Thomson (later Lord Kelvin) issued a comprehensive explanation of the Seebeck and Peltier Effects and described their interrelationship. The Seebeck and Peltier coefficients are related through thermodynamics. The Peltier coefficient is simply the Seebeck coefficient time's absolute temperature. This thermodynamic derivation leads Thomson to predict a third thermoelectric effect, now known as the Thomson effect. In the Thomson effect, heat is absorbed or produced when current flows in a material with a temperature gradient. The heat is proportional to both the electric current and the temperature gradient. The proportionality constant, known as the Thomson coefficient is related by thermodynamics to the Seebeck coefficient. [5]

When an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends upon the direction of both the electric current and temperature gradient. This phenomenon, known as the Thomson Effect, is of interest in respect to the principals involved but plays a negligible role in the operation of practical thermoelectric modules. For this reason, it is ignored.

Thermoelectric Materials

The thermoelectric semiconductor material most often used in today's TE coolers is an alloy of Bismuth Telluride that has been suitably doped to provide individual blocks or elements having distinct "N" and "P" characteristics. Thermoelectric materials most often are fabricated by either directional crystallization from a melt or pressed powder metallurgy. Each manufacturing method has its own particular advantage, but directionally grown materials are most common. In addition to Bismuth Telluride (Bi_2Te_3), there are other thermoelectric materials including Lead Telluride (PbTe), Silicon Germanium (SiGe), and Bismuth-Antimony (Bi-Sb) alloys that may be used in specific situations.

Characterization of Bi2te3 And Sb2te3 Films

A glass substrate was attached to the patterned wafer, so that a sample of the deposited film could be obtained for Seebeck coefficient, resistivity and thickness measurements, as well for x-ray diffraction analysis. A silicon substrate with a thin layer of platinum was also included to allow for stoichiometry analysis of the film cross-section. Energy dispersive x-ray analysis (EDX) was used to identify the elements present in the films, and their relative concentrations. The atomic ratio between T_e and Bi (or Sb) varied up to ±10% along the film thickness. Note that these are qualitative values, i.e., they must be considered only for comparison. The precision (which depends on the x-ray counts in the peaks of interest) and the accuracy (which depends on a reference, i.e., a standard material of known composition to compare to the unknown), were not investigated. The silicon wafer used for the device fabrication is also the micro cooler heat sink. To provide electrical insulation for the device, a 850 nm silicon dioxide layer is grown on the Si wafer. PR is spun cast defining a lift-off pattern for the hot (bottom) connectors and electrical connectors (pads). These connectors are Cr/Au/Ti/Pt layers grown by E-Beam evaporation. The Au and Pt layers are 200 nm and 20 nm thick, respectively. The Cr and Ti are 20 nm thick seed layers. The Pt, which has an electrical resistivity about 5 times larger and a thermal conductivity about 5 times smaller than Au, is used for its good adhesion to the columns, while preventing the diffusion of Au. Each column of the thermoelectric element is patterned consecutively before evaporation using an AZ9245 PR mold, which is where the *n*-type (or *p*-type) thermoelectric element will be formed. [8]

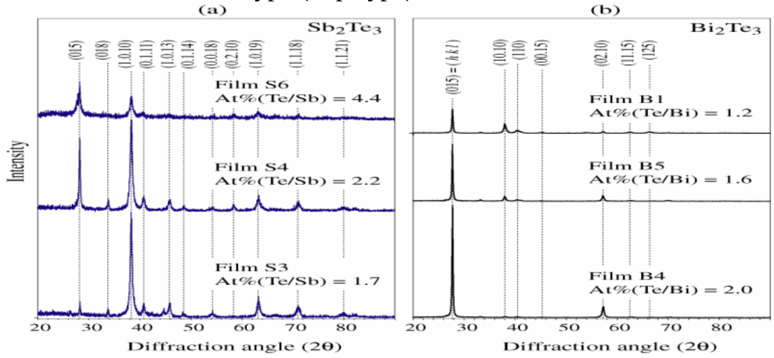

Figure 4:X-ray diffraction pattern of co-evaporated (a) Sb2Te3 and (b) Bi2Te3 films. The measured peaks agree with the Powder Diffraction File [5].

The Sb2Te3 and Bi2Te3 thermoelectric elements deposited on the hot connector pattern are shown in annexure-9. Micro thermoelectric coolers with up to 300 pairs of columns with cross-sectional areas equal to or larger than 7 μm x 7 μm are being fabricated. Current yield limitations are due to the deformation of the PR patterns (which define the thermoelectric elements) during the long exposure time of the PR to temperatures ranging from 70^{o}C to 106^{o}C. In some cases, mainly in devices with large column cross-sectional area (e.g., 30 μm x 30 μm), a shifted column can reach the bottom connector next to it, or even the other column of the pair, leading to the device failure. Also, over hard baked PR is left at the borders of the columns, affecting the subsequent PR patterning. The use of a high temperature PR and an alternative method for patterning the columns (such as shadow mask) are being explored.

III. FABRICATION OF DEMO MODEL OF HVAC USING TEC

We are replacing the whole existing HVAC system (Compressor, Electromagnetic clutch, Condenser, Receiver/drier, Metering devices, Evaporator, Refrigerants, Hoses and blower) by the TEC System, two blowers and some electric equipment.

The electric source provided to the TEC system by the battery as per the specification of TEC plate. The TEC system consists of a cooling coil surrounded by the TEC plates on four surfaces of coil.

The construction and working of cooling coil is just like an intercooler or radiator. The Four heat sinks are attached to the surface of TEC plate.

A blower circulates the air from passenger compartment to the TEC system and again the cool air is circulating from TEC system to passenger compartment.

Another blower circulates the atmospheric air from all heat sinks and controls the temperature of heat sink.

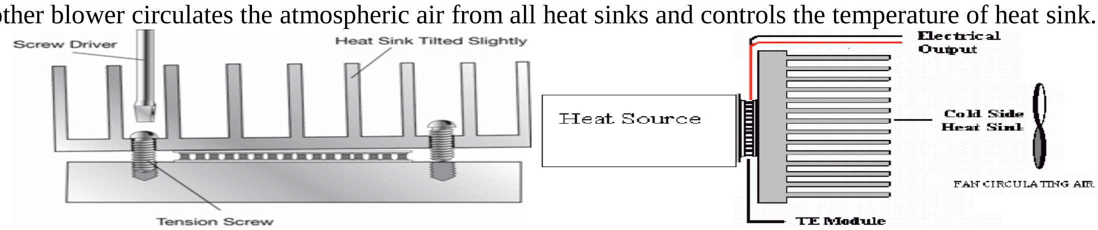

Figure 5: Demo model of HVAC using TEC.

8.1. Parts
Thermoelectric plate- 1plate
Specification-
Part no. - ISA-T1-D-18-L

Length-40mm
Width-40mm
Voltage (V_{max}) - 15.4 v
Ampere (I_{max}) - 3.9A
Temperature difference (ΔT) = 68^o
Aluminum heat sink- 2 pieces
Transformer (12V, 3A)
Blower (12V) - 2 pieces

Advantages of Thermoelectric Cooler

Ability to Cool below Ambient: Unlike a conventional heat sink whose temperature necessarily must rise above ambient, a TE cooler attached to that same heat sink has the ability to reduce the temperature below the ambient value.

Ability to Heat and Cool with the same module: Thermoelectric coolers will either heat or cool depending upon the polarity of the applied DC power. This feature eliminates the necessity of providing separate heating and cooling functions within a given system.

Precise Temperature Control: With an appropriate closed-loop temperature control circuit, TE coolers can control temperatures to better than +/- 0.1°C.

High Reliability: Thermoelectric modules exhibit very high reliability due to their solid state construction. Although reliability is somewhat application dependent, the life of typical TE coolers is greater than 200,000 hours.

Electrically "Quiet" Operation: Unlike a mechanical refrigeration system, TE modules generate virtually no electrical noise and can be used in conjunction with sensitive electronic sensors. They are also acoustically silent.

Operation in any Orientation: TEs can be used in any orientation and in zero gravity environments. Thus they are popular in many aerospace applications.

Convenient Power Supply: TE modules operate directly from a DC power source. Modules having a wide range of input voltages and currents are available. Pulse Width Modulation (PWM) may be used in many applications

Spot Cooling: With a TE cooler it is possible to cool one specific component or area only, thereby often making it unnecessary to cool an entire package or enclosure.

Ability to Generate Electrical Power: When used "in reverse" by applying a temperature differential across the faces of a TE cooler, it is possible to generate a small amount of DC power.

Environmentally Friendly: Conventional refrigeration systems cannot be fabricated without using chlorofluorocarbons or other chemicals that may be harmful to the environment. Thermoelectric devices do not use or generate gases of any kind.

IV. CONCLUSION

Bi2Te3 and Sb2Te3 films have been deposited by co evaporation of the elements, and the Seebeck coefficient and electrical resistivity were measured. The thermoelectric films with the highest electrical power factor, αS 2/ρ*e*, have αS and ρ*e* equal to -84 μV/K and 2.4x10-5 Ω-m (*n*-type film deposited with a maximum substrate temperature of 94 ^{o}C), and 120 μV/K and 1.9x10-5 Ω-m (*p*-type film deposited with a maximum substrate temperature of 90 ^{o}C). By using this plate we fabricated the demo model of HVAC (Heat Ventilation and Air Conditioning System) Using TEC (Thermoelectric Couple).

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