Investigation of Thermoelectric Behaviour of Nano Particulate Zinc Antimonide Semiconductor For Refrigeration

K.Aravinth[1], N.Arun vishnu[2], J.Bhirajeeth[3], L.Dhinesh[4], Y.Ebin Godwin[5]
[1, 2, 3, 4, 5] Dept of Mechanical Engineering
[1, 2, 3, 4, 5] Amrita College of Engineering and Technology,Nagercoil.

Abstract- *Solar energy can be converted into electric energy by means of solar panel. This energy can be stored in a rechargeable battery. The electric energy can be then created into any desired energy. In this project the electric energy is converted in to cool energy using peltier effect. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa via a thermocouple. When a voltage is passed through a thermocouple one end of the thermocouple is heated, the other end gets cooled and. The heated air from the one end of the Pettier element is passed to the exhaust fan. The cool air from the other end of the Pettier element is passed to the blower fan. So as time increases, the cooling will be increased.*

Keywords- peltier effect,solar energy

I. INTRODUCTION

The refrigeration process means removing heat from a specific surrounded space to make its temperature lower than the surrounding temperature. The aim is to provide cooling by using thermoelectric effects rather than using vapour compression cycle or the vapour absorption cycle. The aim is to provide a device that can do the same function without polluting the environment and to reduce the production of the CO_2, SO_2 because it affects our environment. This study was a part of the advanced intelligence technology (AIT) that utilizes the solar energy. Also, it designs and develops a prototype unit that was illustrating the usefulness and economic sustainability of solar energy for the planned purposes

The main objective is to improve the COP of the system. Recent research provides three possible paths that may lead to significant progress in thermoelectric cooling

1. To improve thermoelectric cooling system's thermal design and optimization
2. To improve the intrinsic efficiencies of thermoelectric materials
3. To improve the intensity of the sunlight received through the panel

Already in this paper the design and optimization technique is utilized to improve the COP now for future work the COP of the system can be improved through another two ways

II. METHODOLOGY

The main application of the Peltier effect is cooling. However, the Peltier effect can also be used for heating. In every case, a DC voltage is required. Thus, aim of the project is to utilize cooling effect of a peltier module efficiently. Peltier module can convert thermal energy into electricity. When dc voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface (cold side). The main energy resource that is being used in this prototype is solar energy. PV cells transform solar energy into electrical energy which is used to power the TE system. This system actively uses solar energy to maintain a temperature gradient across a material surface. The heating/cooling power is dependent on the input current direction to each element. Heating power increases with an increasing incoming current, whereas the cooling power has an optimum for a specific current. A regulator can make sure that the incoming current and voltage does not exceed the maximum for each module. The prototype has been designed to manage the maximum output from the solar panel. A battery could also be installed to collect the excess power produced by the PV panel and keep the system running as the sun sets, climate change etc. The electricity produced by the PV cells can be used to run a circulation fan. Air is filtered and blown into the chamber by the fan. The incoming air stream is cooled down by Peltier elements.

A. Peltier module

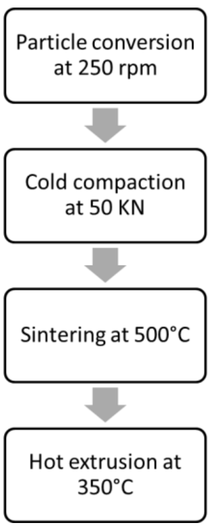
The peltier module contain peltier element which can be prepared by nano technology as follows

B. Powder Metallurgy

Powder metallurgy is the science of producing metal powders and making finished/semifinished objects from mixed or alloyed powders with or without the addition of nonmetallic constituents.

C. Steps in powder metallurgy

Powder production, Compaction, Sintering, &Secondary operations. The size of reinforcement had to be reduced to nano to avoid formation of air gaps or commonly known as porosity. This particle size conversion was carried out in planetary mill at constant speed for calculated time. A ball mill consists of a hollow cylindrical shell rotating about its axis. The axis of the shell may be either horizontal or at a small angle to the horizontal. It is partially filled with balls. The grinding media is the balls, which may be made of steel (chrome steel), stainless steel, ceramic, or rubber. The inner surface of the cylindrical shell is usually lined with an abrasion-resistant material such as manganese steel or rubber. Less wear takes place in rubber lined mills. The length of the mill is approximately equal to its diameter.



D. Powder production

Raw materials - Powder; Powders can be pure elements, pre-alloyed powders Methods for making powders – Atomization: Produces powders of both ferrous and non-ferrous powders like stainless steel, super alloys, Ti alloy powders.

E. Particle size conversion

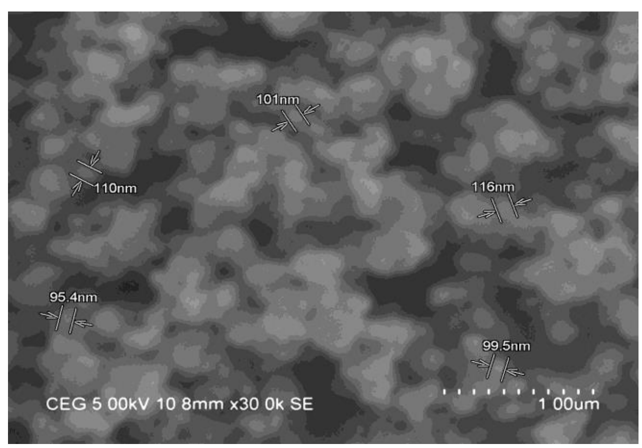
The size of reinforcement had to be reduced to nano to avoid formation of air gaps or commonly known as porosity. This particle size conversion was carried out in planetary mill at constant speed for calculated time. The reinforcement is filled in the jar along with steel balls and placed in the planetary mill. A ball mill is a type of grinder used to grind and blend materials for use in mineral dressing processes, paints, pyrotechnics, ceramics and selective laser sintering. It works on the principle impact and size reduction is done by impact as the balls drop from near the top of the shell.

A ball mill consists of a hollow cylindrical shell rotating about its axis. The axis of the shell may be either horizontal or at a small angle to the horizontal. It is partially filled with balls. The grinding media is the balls, which may be made of steel (chrome steel), stainless steel, ceramic, or rubber. The inner surface of the cylindrical shell is usually lined with an abrasion-resistant material such as manganese steel or rubber. Less wear takes place in rubber lined mills. The length of the mill is approximately equal to its diameter.
The mill provides as axial rotation which creates striking contact between steel ball and reinforcement inside jar. This contact reduces the size of reinforcement after specified time.

F. Testing for nano particle conversion

The powder produced by planetary milling is tested using SEM from college of engineering, Guindy(CEG).

They provide the result that the particle size is of about 90-100µm this is the range of nano particle so we successfully convert that zinc and antimony into nanoparticle



F. Elemental mixture

The nano sized reinforcement had to be added to the base metal for further processing. This step was carried out using the planetary mill that was used for size conversion. Both the powders were weighed according to the composition and then poured into the jar and mixed in mill by axial rotation for specified time. The material requirement for this stage is similar to previous stage. The ball mill is used for the homogeneous mixing of powders or different wet components with differing specific weights and particle sizes. The product is mixed in a removable container preventing cross-contamination between batches and dusting when mixing powders.

G. Compaction

It is the process of converting loose powder into a green compact of accurate shape and size. It is done in steel dies and punches. The die is manufactured for the required dimension of specimen. The most commonly used material for die is die steel, EN 24, EN 18 etc. Compaction is usually performed at room temperature. The compaction pressure ranges from 138MPa to 827MPa, or more.

The powder is filled in the die and load is applied using a punch designed for the specimen's dimension. The maximum load that the base metal can withstand is identified and it is used for compaction of the elemental mixture. This compaction process is carried out in universal testing machine or it can be also done in hydraulic press. The compaction die was fabricated and heat treated for 50RC to make sure it can withstand the load applied by universal testing machine.

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures. It can not only be used for testing their strength but also can be used for compaction process. The dial gauge in UTM as shown in above diagram can be used to determine the acting load. Generally, once load is reached the punch will be released in hot compaction. But in cold compaction the load is held for specified time after it is being reached in the meter. This is to ensure equal load split all over the volume of specimen will be released in hot compaction. But in cold compaction the load is held for specified time after it is being reached in the meter. This is to ensure equal load split all over the volume of specimen.

H. Sintering

Sintering is a heat treatment applied to a powder compact in order to impart strength and integrity. The temperature used for sintering is below the melting point of the major constituent of the Powder Metallurgy material.

After compaction, neighboring powder particles are held together by cold welds, which give the compact sufficient "green strength" to be handled. At sintering temperature, diffusion processes cause necks to form and grow at these contact points.

These steps and the sintering process itself are generally achieved in a single, continuous furnace by judicious choice and zoning of the furnace atmosphere and by using an appropriate temperature profile throughout the furnace. But for certain specimen the heat treatment process cannot be done in open atmosphere when might lead to either oxidation or damage of specimen in case of flammable metal usages. At this situation generally instead of normal furnace inert gas atmosphere furnace is used. Heat treatment here is done in an electronic muffle furnace in nitrogen atmosphere. Heat treatment process is carried out to increase hardness of the specimen as a cold compacted specimen is not much stronger than an ice cube. This heat treatment process not only increases hardness but also improves machinability and toughness.

I. Hot extrusion

Extrusion is a process used to create objects of a fixed cross- sectional profile. A material is pushed through a die of the desired cross-section. The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections, and to work materials that are brittle, because the material only encounters compressive and shear stresses. It also forms parts with an excellent surface finish.

Extrusion is done to reduce porosity and improve the grain structure of the specimen. Not only can that but extrusion also improves the mechanical properties such as hardness, compressive strength, tensile strength etc.

To perform extrusion a tapered die and punch has to be fabricated in die steel or EN 24 or EN 18 or any other metal suitable for fabricating a die. The specimen is separately heated while die is heated for extrusion. This is done to avoid air reaction of specimen while heating. The specimen is heated in muffle furnace while die is pre heated using a bandwidth heater designed for the dimensions of the die. This extrusion process is carried out in 100-ton hydraulic press.

Hot extrusion is a hot working process, which means it is done above the material's recrystallization temperature to keep the material from work hardening and to make it easier to push the material through the die. Most hot extrusions are done on horizontal hydraulic presses that range from 230 to

11,000 metric tons (250 to 12,130 short tons). Pressures range from 30 to 700 MPa (4,400 to 101,500 psi), therefore lubrication is required, which can be oil or graphite for lower temperature extrusions, or glass powder for higher temperature extrusions.

J. Final specimen

Thus after all these process we can get the specimen

Fig .3.7 photographic view of three stages

III.EXPERIMENTAL SET UP

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when a DC electric current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.

Construction

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

Some benefits of using a TEC are:

- No moving parts so maintenance is required less frequently
- No chlorofluorocarbons (CFC)
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration
- Long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Controllable via changing the input voltage/current

Experimental setup

The effect of Peltier is a crucial concept in this study. The thermoelectric effect is a direct exchange of temperature differences to electric voltage and vice-versa

Thermoelectric coolers operate by Peltier effect which also goes by general name thermoelectric effect. However, the device has two sides when a DC electric current passes over the Peltier; it generates heat from each side which one side gets cooler while the other hotter

The hot side is attached to the heat sink which remains at atmospheric temperature. On the other hand, the cold runs below the room temperature

Fig.1 photographic view of experimental set up

Fig.2 photographic view of peltier module

IV. RESULTS

A. Heat rejection vs current

The variation of heat rejection with respect to current shows that the it is directly proportional when the current increases the heat rejection rate also increasing because when current flow increases the working of exhaust fan also increases and hence the heat rejection rate increases this can be obtain using the formula Q= mc_p dt

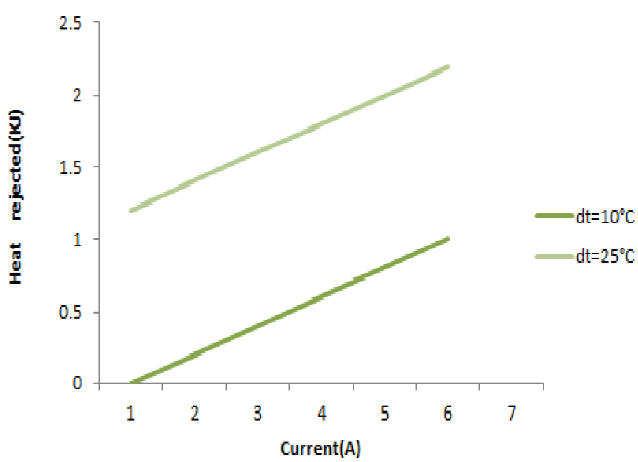


Fig.3 Heat rejected Vs current

B. *Coefficient of performance vs current*

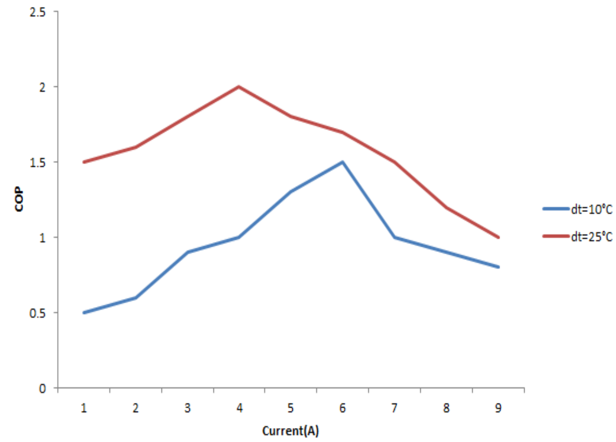


Fig.4 coefficient of performance vs current

The figure shows the variation of COP with respect to current and it shows that COP is increases up to a point when the current increases and it decreases due to heat produced in the peltier module it gets overheated due to the increase in current flow and from the graph it is obtained that the maximum COP reached is 2 above this it decreases

C. Temperature vs current

The Figure shows that the variation of temperature with respect to current and it shows that current is increases when the temperature increases because when the temperature increases the rate of photon that hits the surface of the solar panel will increase and hence the rate of flow of current will increase

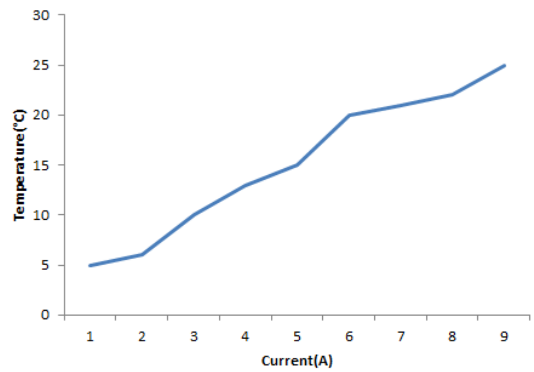


Fig.5 temperature VS current

D. Efficiency vs temperature

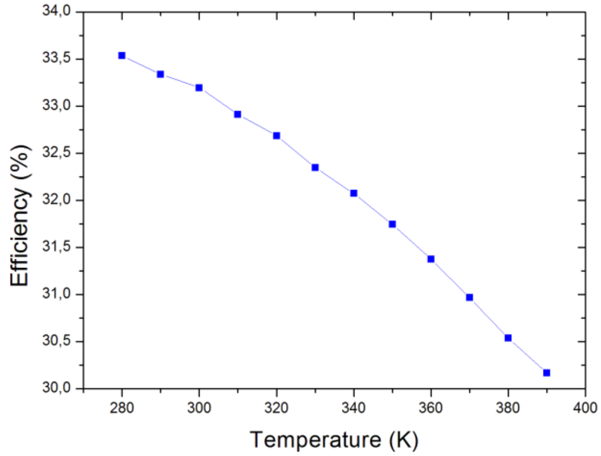


Fig.6 Efficiency vs temperature

The variation of temperature with respect efficiency shows in the figure 5.4 it is obtained that efficiency decreases as the temperature increases this what obtain in the P-V characteristics of the solar panel where we that the panel will reach the optimum point at 25°C at the same time from the above graph that it will produce maximum efficiency at 300K (i.e.27°C)

So from the above observation the panel will produce maximum power at atmospheric temperature (32°C) if the temperature rises above it the efficiency will decreases

E. Time vs temperature

The variation of time with respect to time in summer and winter shows that the voltage and temperature will maximum at noon time because of the position of the sun directly above the head so that it reaches maximum intensity

So that by using tracking system can improve the solar irradiation and hence the intensity can be tracked by it so that maximum intensity which will utilized in the future work

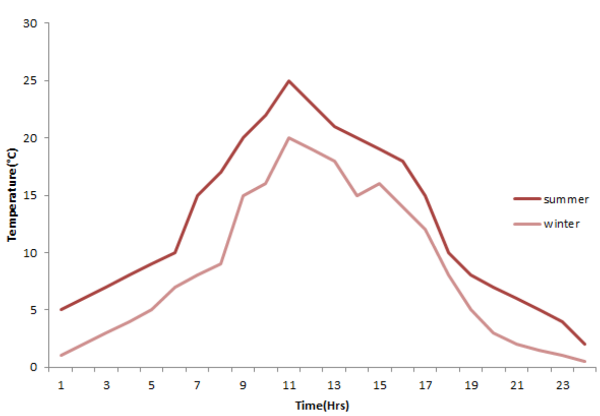


Fig.7 temperature Vs time

V. ACKNOWLEDGMENT

First and foremost, I would like to invoke the grace of the Almighty Lord without whom no fruitful events occur in the world.

I would also like to thank all the other faculties and technical Assistants of our Department who helped us in their own way with regards to our project.

Last but not least I acknowledge a million thanks to our family for their consistent support for backing us without which I would not have successfully accomplished our project.

REFERENCES

[1] Anliang Wang, Wei Zhu, Yuan Deng, Yao Wang, (2013), “Finite element analysis of miniature thermoelectric coolers with high cooling performance and short response time”, Microelectron, Vol.44, pp.860-868.

[2] Chin Hsiang Cheng, Shu-Yu Huang, Tsung Chieh Cheng, (2010), “A three-dimensional theoretical model for predicting transient thermal behaviour of thermoelectric coolers”, International Journal of. Heat and Mass Transfer, Vol.53, pp.2001-2011.

[3] Daniel Mitrani, Jordi Salazar., Antoni Turo, Miguel J. Garcia, Juan A. ChaveDz,(2018), “One-dimensional modeling of TE devices considering temperature dependent parameters using SPICE”, Microelectron,Vol.40,pp.1398-1405.

[4] Diago et al, (2013), “Cooling, heating, generating power, and recovering waste heat with thermoelectric systems”, Science, Vol.321, pp.1457-1461.

[5] Han Li, (2009), “High performance $In_xCe_yCo_4Sb_{12}$ thermoelectric materials with in situ forming nanostructured InSb phase”, Applied Physics Letters, Vol.94, pp.102-114.

[6] Hilaal Alam, Seeram Ramakrishna, (2013), “A review on the enhancement of figure of merit from bulk to nano-thermoelectric materials”, Nano Energy, Vol.2, pp.190-212.

[7] Hongxia Xi, Lingai Luo, Gilles Fraisse, (2017) “Development and applications of solar based thermoelectric technologies”, Renewable and Sustainable energy, Vol.11, pp.923-936.

[8] Hosung Lee, (2013), “The Thomson effect and the ideal equation on thermoelectric coolers”, Energy, Vol.56, pp.61-69.

[9] Huili Liu, (2012), “Copper ion liquid like thermoelectrics”, Nature Materials, Vol.11, pp.422-425.

[10] Jeffrey Snyder .G, Toberer.S,(2018),"Complex thermoelectric materials", Natural Material, Vol.7,pp.105-114.

[11] Jing-Hui Meng, Xiao-Dong Wang, Xi Xin Zhang, (2013), "Transient modeling and dynamic characteristics of thermoelectric cooler", Applied Energy,Vol.108 ,pp.340-348.

[12] Jong Soo Rhyee, et al., (2009) ,"Peierls distortion as a route to high thermoelectric performance in $In_4Se_{3—}d$ crystals", Nature of materials459Vol.5,pp.965-968.

[13] Kanishka Biswas, et al., (2011), "Strained endotaxial nanostructures with high thermoelectric figure of merit", Nature of Chemistry, vol.2, pp.160-166.

[14] Kuei Fang Hsueal.,(2018), "Cubic $AgPb_mSbTe_{2\ m}$: bulk thermoelectric materials with high figure of merit", Science, vol.3,pp.303-818

[15] Mei Jiau Huang, Ruey-Hor Yen, An-Bang Wang,(2015),"The influence of the Thomson effect on the performance of a thermoelectric cooler", International Journal of Heat and Mass Transfer",vol.48,pp.413-418

[16] Pierre F.P., Poudeu, et al., (2010), "High figure of merit in nanostructured n-type $KPb_mSbTe_{mþ2}$ thermoelectric materials", Chemistry of Materials. Vol.22, pp.1046-1053.

[17] Riffat S.B, Xiaoli Ma, (2019), "Thermoelectric: a review of present and potential applications", Applied Thermal Engineering, Vol.23, pp.913-935.

[18] Simon Lineykin, Shmuel Ben-Yaakov, (2007), "Modelling and analysis of thermoelectric modules" IEEE Trans, Vol.43.

[19] Sootsman.J.R, (2015), "New and old concepts in thermoelectric materials, Angew", Chemical International Editions, Vol.48, pp.8616-8639.

[20] Terry M. Tritt, "Thermoelectric phenomena, materials, and applications", Annual Reviews of Material Research. Vol.41, pp.433-448.

[21] Weishu Liu, Xiao Yan, Gang Chen, Zhifeng Ren, (2016), "Recent advances in thermoelectric Nano composites", Nano Energy, Vol.1, pp.42-56.

[22] Wei-Shin Chen, Chen-Yen Liao, Chen-I. Hung, (2012), "A numerical study on the performance of miniature thermoelectric cooler affected by Thomson effect", Applied Energy, Vol.89, pp.2464-473.

[23] Wei Zhu, Yuan Deng, Yao Wang, Anliang Wang,(2013), "Finite element analysis of miniature thermoelectric coolers with high cooling performance and short response time", Micro electron, Vol.44, pp.860-868

[24] Xiao-Dong Wang, et al.,(2012), "A three numerical modelling of thermoelectric device with consideration of coupling of temperature field and electric potential field", Energy,Vol.47, pp.488-497.

[25] Yuanyuan Zhou, Jianlin Yu, (2012),"Design optimization of thermoelectric cooling systems for applications in electronic devices", international Journal of Refrigeration.Vol.35,pp.1139-1141.

[26] Zhi-Gang Chen, Guang Han, Lei Yang, Lina Cheng, Jin Zou, (2012), "Nanostructured thermoelectric materials: current research and future challenge", Progress in Natural Science: Materials International, Vol.22, pp.535-549.

[27] Zhang Y.C., Mui, Tarin.m, (2010), "Analysis of thermoelectric cooler performance for high power electronic packages", Applied Thermal Engineering.Vol.30, pp.561-568